Positional pelvic organ prolapse (POP) evaluation using open, weight-bearing magnetic resonance imaging (MRI)

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Abstract

Introduction: Magnetic resonance imaging (MRI) of patients with pelvic organ prolapse (POP) is completed in the supine position. Open magnetic resonance imaging (MRO) uses vertical magnets, allowing imaging in a variety of upright postures. This pilot study used MRO to evaluate the change of prolapse in different positions compared to non-prolapsed images.
Methods: In total, 11 women (6 POP, 5 controls) aged 24 to 65 years had 12 MRO images (midline sagittal pelvic line) consecutively when supine, sitting and standing with a full and empty bladder. Lengths between the lowest point of the bladder to the pubococcygeal (PC) and pubopromontoreal (PP) lines in each image were compared, and the ratio of bladder area under the PC and PP lines to the total bladder area.
Results: Significant elongation between the PC line and lowest point of the bladder was evident in subjects with POP comparing supine and standing images ($p = 0.03$), but not controls ($p = 0.07$). Similarly, this axis was significantly longer in cystocele subjects versus controls only in the standing position. Bladder area under the PC line was significantly increased between supine and standing positions only among subjects with cystocele ($p < 0.01$), and significantly larger among the study group in the standing position ($p < 0.005$), less significant in the supine position ($p = 0.015$), and not significant in the sitting position ($p = 0.3$).
Conclusions: MRO imaging allows us to investigate the effects of upright position and weight bearing on the staging of POP. Imaging patients when sitting and standing identified that significant changes occur in the maximal descent of the bladder.

Introduction

Accurate staging of pelvic organ prolapse (POP) is critical to treatment assignment, including decisions regarding the type and extent of surgical correction. The POP-Q staging system is commonly employed and recognized as the gold standard for clinical staging. However, this is completed in the supine position, and hence, can result in under-staging of POP, which is a recognized limitation of the POP-Q.[1]

In POP, imaging modalities are employed to further understand the pathophysiology of the interplay between the pelvic organs and their structural supports. Magnetic resonance imaging (MRI) helps us understand the descent of the pelvic organs in both the diagnosis and the management of POP.[2] MRI has recognized benefits when compared to other techniques of visual positioning, such as video-urodynamics or contrast bowel imaging. These include imaging which is non-invasive and uses non-ionizing radiation.

Open magnetic resonance imaging (MRO) adds the additional benefit of vertical magnets, which allow imaging in a variety of positions, including standing. Given the recognized impact of upright posture on the pelvic organs, MRO is potentially advantageous for the diagnosis and evaluation of POP.

The objectives of this pilot study were: (1) to construct a feasible MRO protocol for performing POP assessments in 3 positions (supine, seated, standing) and (2) to evaluate the change of bladder position using MRO and reference lines for subjects with and without bladder prolapse in supine, seated and weight-bearing standing positions. We report the evaluation of POP using MRO imaging with a midline 3-position, 2-volume protocol.

Methods

After we received ethics board approval from the University of British Columbia, we recruited adult women with prolapse from a subspecialty practice urogynecologist/urologist. All women had Baden Walker grade 2 cystocele and were surgically naive. Controls were volunteer women with no known history of POP.

All subjects completed validated questionnaires, including the Urogenital Distress Inventory Score,[3] The Colorectal Anal Distress Inventory Score[4] and the Pelvic Organ Prolapse

Distress Inventory Score.[5] The POP-Q staging system was recorded in the standard supine position prior to imaging of the prolapse.

A Paramed Medical Systems 0.5T upright MRO scanner was used to obtain images of the female pelvis in the supine, seated, and standing weight bearing positions. The transverse field of this scanner enabled us to use phased array multichannel coils. Six 5-minute individual sequences consisting of 12 MR images of the sagittal midline were obtained with a full bladder and following voiding in all subjects. Four subjects (2 with POP and 2 controls) completed a full pelvic MRI in the supine, seated, and standing upright position with a full bladder during the protocol development phase.

The length from the lowest point of the bladder to the pubococcygeal (PC) line, the length between the lowest part of the bladder and the pubopromontoreal (PP) line, and the ratio of the bladder area under the PC and PP lines to the total bladder area were compared between images for each subject in all 3 positions and between those with POP and controls (Fig. 1, Fig. 2).

Results

In total, 11 were part of this study and they were between 24 and 65 years old (6 had POP and 5 acted as controls). We compared the percent area under the PP line and PC line by imaging position (Table 1). The length relationships between the PC line and PP line by the presence or absence of POP relative to imaging position i2222 shown in Table 2.

A significant elongation between the PC line and the lowest point of the bladder was noted in subjects with cystocele comparing supine and standing images ($p = 0.03$), which was not significant in controls ($p = 0.07$). This axis was significantly longer in subjects with cystocele compared to controls only in the standing position. The relative bladder area under PC line was significantly increased between supine and standing positions only among subjects with cystocele ($p < 0.01$) and not among controls ($p > 0.09$). While comparing the study and the control groups, this area was significantly larger among the study group in the standing position ($p < 0.005$), less significant in the supine position ($p = 0.015$), and not significant in the sitting position ($p = 0.3$).

By using the length between the PP line and the bladder lowest point, there was significant elongation between supine-standing and sitting-standing images in both the subject and the control groups. This length was significantly longer among patients compared to controls only when supine, and was not observed in the standing position. The relative area of the bladder inferior to the PP line was not significantly increased comparing supine and standing positions among subjects or controls. A sample image demonstrating area beneath the PC line in a control subject versus a cystocele subject is shown in Figure 3.

Discussion

This study reports the exploration of MRO as an imaging modality for POP, and successful use of a midline 3-position, 2-volume protocol.

Dynamic MRI, an advanced technique completed in the supine position, allows the effects of increased abdominal pressure on the pelvic organs and their mobility to be evaluated.[6] Comparing findings before and after surgery for POP, Broker and colleagues found that dynamic MRI could characterize reduced mobility of the pelvic organs following surgical mesh repairs.[7] Standardization of dynamic MRI using reference lines has been a subject of interest to extend the concept of pre- and post-treatment aspects of the pelvic organs.[8,9] Supine MRI, with or without dynamic components, has helped us to understand both the anatomic relationships of the pelvic organs affected by prolapse and complications related to mesh insertion for treatment. However, limitations of evaluation of the pelvic organs in the supine position are recognized.

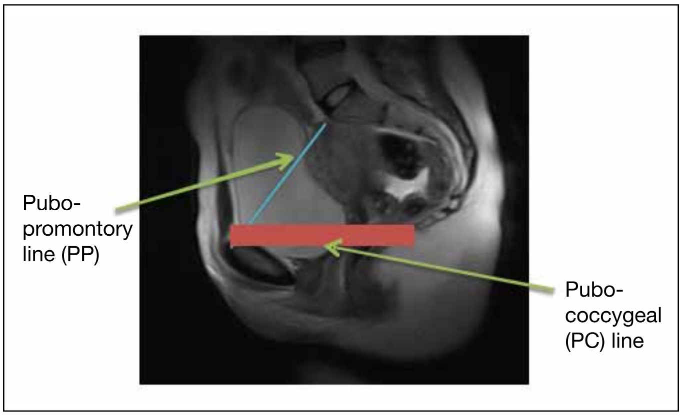

Fig. 1. Standing (weight bearing) open magnetic resonance image depicting positioning of the pubopromontoreal (PP) line, pubococcygeal (PC) line.

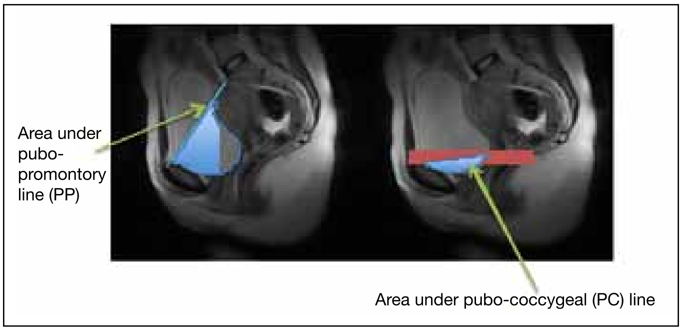

Fig. 2. Standing (weight bearing) open magnetic resonance image depicting bladder area under the pubopromontoreal (PP) line, pubococcygeal (PC) line.

Table 1. Comparison of percent area under the pubopromontoreal (PP) line and pubococcygeal (PC) line by imaging position

	Controls (n=5)	POP (n=6)	*p* value*
Area under PP line, %			
Supine	70%	72%	0.4
Sitting	59%	46%	0.08
Standing	77%	81%	0.36
Area under the PC line, %			
Supine	6%	14%	0.01
Sitting	5%	7%	0.32
Standing	12%	38%	0.003

POP: pelvic organ prolapse. *Student's T test.

Table 2. Comparison of length of the PP and PC lines in different imaging positions

	Controls	Patients	*p* value
Average length of PP line (mm)			
Supine	25.8	42.8	0.02
Standing	47.3	72.8	
Average length of PC line (mm)			
Supine	4.8	7.9	0.02
Standing	7.3	20.4	

PC: pubococcygeal; PP: pubopromontoreal.

With MRO vertical magnets make it possible for patients to be studied supine, seated, upright, and standing with full weight bearing. The ability of MRO to assess patients when weight bearing has led to many studies in orthopaedics. Many joint and ligament relationships have been studied including, but not limited to, the lumbar spine,[10] the hip joint,[11] the knee joint,[12] and the ankle.[13]

Since no existing pelvic POP staging protocol using MRO was available from the literature, a multi-iterative design process was undertaken to construct a feasible protocol. It was determined that full imaging, pelvic side-wall to side-wall in the coronal and sagittal plains was too lengthy to complete if supine, seated and standing views were to be included. Also midline views offered the ability to measure the bladder relative to bony structure reference lines. Moreover, the seated MRO images were best obtained with the patient slightly inclined to minimize movement. The protocol adopted therefore combined a 'focus to the midline' approach with the ability to complete 3 positions of observation (supine, seated and standing) with both a full and empty bladder in a reasonable period of time, with the ability to measure the bladder relative to bony structure reference lines described by other authors. The pubococcygeal line has been used in this way in reference to staging of POP.[14] Betschart and colleagues have furthered the idea of MRI reference lines in the pelvis by integrating their use into a system of measurement called the pelvic inclination correction system.[9] In our MRO protocol, 2 lines of reference and the relative area of the bladder beneath these were chosen as an initial examination of seating and standing positions on a full and empty bladder. The final protocol required 24 minutes for all 6 sequences.

A number of observations were apparent comparing controls to patients with known POP. The most significant difference in bladder prolapse were observed in prolapse patients comparing the supine to the weight-bearing standing position.

An important aspect of this pilot study was the exploration of pelvic anatomy in the seated position. Seated imaging is important in patients for whom this is their most upright position, such as women who have suffered a spinal cord injury. Little is known about the anatomic relationships of the bladder in the setting of prolapse in the seated position, as imaging of the bladder in this position is currently difficult, even with video-urodynamics. A limitation of video images is that they do not show the relationships of the other anatomic supports relative to the bladder; they also expose the patient to ionizing radiation and provide no information when the bladder is empty. MRO therefore offers an imaging modality with the potential to further the understanding of prolapse in this subset of patients.

While imaging of female pelvic anatomy in the standing position is important relative to POP, the location of the bladder and extent to which it extends into the abdomen above the symphysis pubis is important in the development of other technologies. Near-infrared spectroscopy (NIRS) for example has been used to study changes in oxygenation and hemodynamics in the bladder using optical signals generated both within the vagina[15] and transcutaneously from a suprapubic location.[16,17] The suprapubic position (2 cm superior to the symphysis pubis) relies on NIR light reaching the anterior wall of the bladder transcutaneously through the anterior abdominal wall to interrogate the detrusor muscle in the anterior wall of the bladder. In

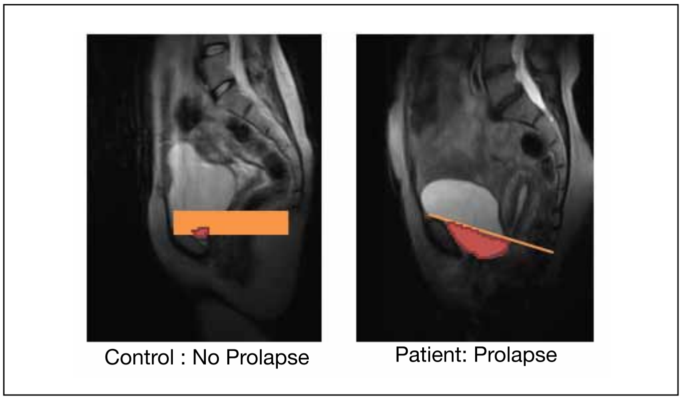

Fig. 3. Comparison image taken in the weight bearing, standing position, of a control versus prolapse patient using open magnetic resonance image (MRO) demonstrating area beneath the pubococcygeal (PC) line.

this context, observations of bladder height related to the symphysis were obtained through seated and standing ultrasound to determine bladder position relative to the symphysis with varying bladder volumes.[18] The MRO data in this study corroborated key findings obtained by ultrasound and indicated that in all subjects with a full bladder, even those with grade 2 or 3 POP, the bladder extended >2 cm above the symphysis in the seated and standing positions. Future development of photonic technologies to assess hemodynamics within the detrusor could therefore be combined with MRO to understand the pathophysiologic effects of POP within the detrusor, such as how the bladder responds to outlet obstruction.[19]

The limitations of this pilot study include the small sample size, which restricts comment on uterine and/or bowel prolapse. Also, bony anatomic reference points were selected and limited to the PP and PC lines; however, a larger study could explore alternative anatomic reference points of potential importance. Images of a full bladder were obtained when patients had volume in their bladder for which they would normally seek the bathroom. No attempt was made to try to equalize the volume in the bladder between subjects, given that this was a pilot study and a fully non-invasive test was sought. As the study used only midline references, no information is available about more lateral pelvic supports. However, it was felt that obtaining information in 3 positions was a higher priority for an exploratory study rather than doing fewer positions and a wider pelvic spectrum given that time is a consideration when obtaining images with a full bladder.

Future directions with MRO should include a larger scale study of subjects with POP to determine the full scope of frequency and severity of understaging. Additionally, the protocol we describe could be used to assess surgical recurrence and surgically naïve patients. Valsalva maneuvers could be added to examine more dynamic components of movement within the pelvis.

Conclusion

A midline sagittal sequence of 12 images with 3-positions and 2-volumes is a MRO protocol that is feasible in women with and without POP. Significant anatomic differences were observed among subjects with cystocele between supine, seated, and standing weight bearing positions, which were not observed in the control group. This supports standing MRO as an advantageous imaging modality for POP.

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This paper has been peer-reviewed.

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