MRI and MRI 3-D reconstruction of anatomic characteristics of the cardinal and uterosacral ligaments in uterine prolapsed women

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Summary

Objective: This study aimed to evaluate the anatomical alterations of the cardinal ligaments (CL) and uterosacral ligaments (USL) in women with uterine prolapse by magnetic resonance imaging (MRI) and MRI three-dimensional reconstruction (3DR). *Materials and Methods:* Forty patients with uterine prolapse and 40 volunteers with normal support underwent thin layer scan MRI. The 3D models were reconstructed with MRI data and 3D software. Origin, inserted end, geometric shape features of the CL and USL, were compared between the two groups, and the correlation in study group between the MRI and surgical dissection were reported. *Results:* In the study group, trauma was found in the USL in the insertion or origin. The dorsal USL attached to the sacrum in four (10%) patients was quite different from 12 (30%) patients of the control group. There was no significant difference in the inserted end of the USL between the two groups, nor in the origin and inserted end of the CL. In the study group, MRI and MRI 3DR better evaluated the anatomical characteristics of the USL compared to intraoperative detection via laparoscopy. *Discussion:* The approach using MRI and MRI 3DR can non-invasively detect the anatomic abnormality associated with the USL in uterine prolapsed women and can be a useful preoperative planning tool.

Key words: Cardinal ligament; Uterosacral ligament; Pelvic floor dysfunction; Uterine prolapse; MRI three-dimensional reconstruction.

Introduction

Uterine prolapse is a distressing disease which greatly affects women's daily activities and quality of life [1, 2]. The uterosacral ligaments (USL) and cardinal ligaments (CL) flexibility weakened and anatomic displacement may lead the uterus to descend into the vaginal cavity [3]. It is vital for reconstructive surgery to demonstrate how key anatomical damage of the CL and USL results in uterine prolapse.

USL and CL anatomical damage has been studied in cadavers and during surgery, however the syntopy differs from the living state due to the alterations and the borders of the ligament are difficult to establish on surgical dissection [4].

Magnetic resonance imaging (MRI) as main image research technique of pelvic floor dysfunction (PFD), that allows excellent soft tissue resolution and non-invasive depiction and with little distortion. MRI three-dimensional (3D) models can visualize complete shape and continuous changes of the pelvic support structure in living women. However most studies focused on the levator ani muscle (LA) [5-11]. The studies on USL and CL were limited to normal support in women [4, 12-16], hence still insufficient in understanding uterine prolapse.

Therefore, the purpose of this study, was to use thin-layer MRI and MRI 3D technique, to explore main anatomical features of the USL and CL in uterine prolapsed women, in order to supply the objective bases for the surgery related rehabilitation of uterine prolapse.

Materials and Methods

This prospective study was carried at the department of Gynecology and Obstetrics, Southwest Hospital, the Third Military Medical University of Chongqing, China. From October 2010 and December 2011, 40 patients with uterine prolapse in at least Stage 2 were included in the study group, who desired corrective surgery of uterine prolapsed, 40 normal women without symptoms of PFD and previous surgeries in control group. Basic demographic data was collected including age, parity, BMI, menopausal status. All women underwent clinic examination including the Pelvic Organ Prolapse Quantification (POP-Q) [17], Richardson's examination [18], and urodynamics. Forty patients included 23 cases with anterior vaginal wall prolapsed, 11 cases with paravaginal defects, 22 cases with posterior vaginal wall prolapse, and three cases with stress urinary incontinence (SUI). This study was conducted with approval from the Ethics Committee of Southwest Hospital, the Third Military Medical University. Written informed consent was obtained from all participants.

All the data were obtained by using a 3.0 T MR scanner and a four-channel body phased-array coil. The images were scanned in the transverse and coronal planes at rest. MRI haste technique was used to image the sagittal plane at rest and strain (Valsalva). The transverse and coronal plane images were obtained with sequences of turbo spin echo (TSE) technique T_2WI, repetition time [TR] 3100 ms, echo time [TE] 30 -33ms, 0-mm gap, field of view 20×20 cm, matrix 376 × 512, stimulation 2. The transverse plane included images at one-mm slice thickness and the coronal plane

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Table 1. — *Baseline characteristics of the two groups population ($\bar{X} \pm S$).*

	Number	Age (years)	BMI (kg/m^2)	Pregnance (times)	Labour (times)	Postmenopausal (n)
Uterine prolapse	40	53.1 ± 8.3	23.5 ± 1.1	3.43 ± 1.2	2.23 ± 1.3	28
Normal support	40	47.8 ± 9.5	22.7 ± 1.4	3.24 ± 1.8	2.74 ± 0.9	26
p value		0.508	0.447	0.982	0.523	0.927

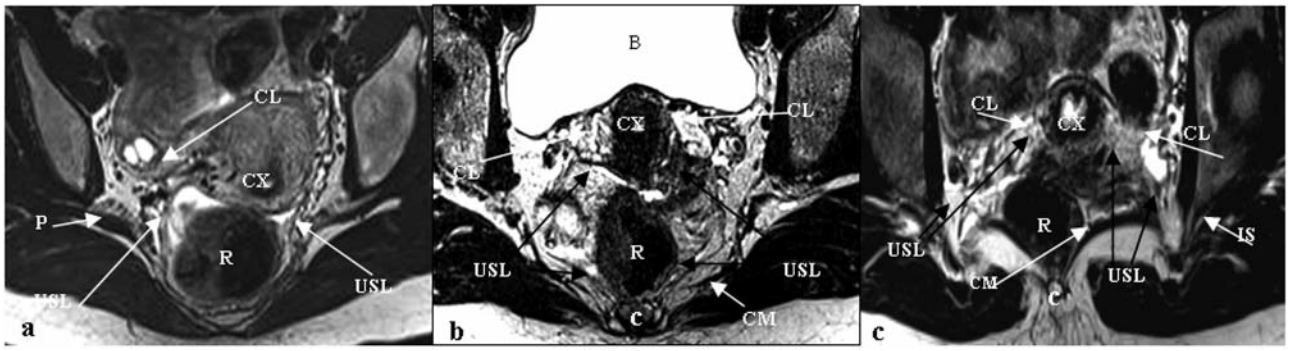

Figure 1. — Transverse scan at the level of the cervix and coccyx in healthy women. The images demonstrate origins and insertions of the USL and CL. USL origined from Panel a: piriformis muscle, Panel b: coccygeus muscle; Panel c: ischial spine. CX = cervix, R = rectum, W = whirlbone, IS = ischial spine, C = coccyx, S = sacrum, P = piriformis muscle, CM = coccygeus muscle, CL = cardinal ligament, USL = uterosacral ligament.

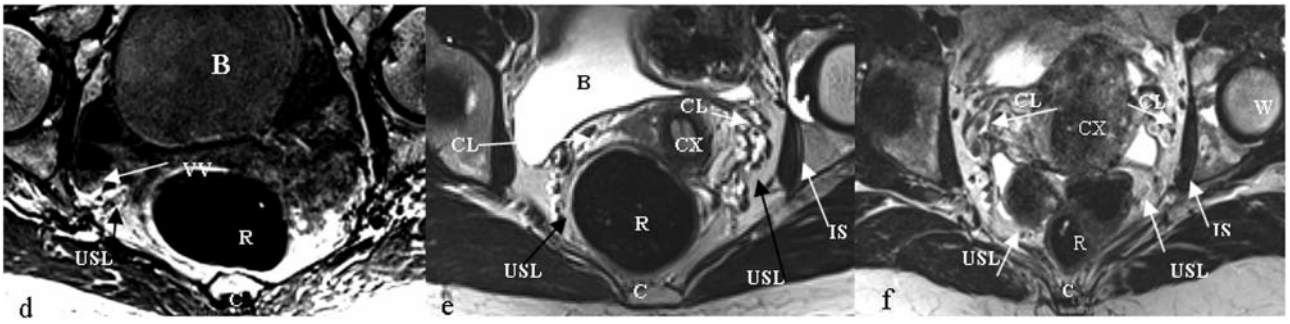

Figure 2. — Transverse scan in uterine prolapsed women. The images demonstrate defects of the USL on MR. Panel d, at the level of the vaginal and coccyx, the right USL detachment from vaginal vault at the white arrowheads. Panel e, at the level of the cervix, ischial spine and coccyx. The right USL is thinner than the left, the left USL split from ischial spine. Panel f, at the level of the cervix and coccyx. the right USL is thinner than the left. B = bladder, VV = vaginal vault, CX = cervix, R = rectum, W = whirlbone, IS = ischial spine, C = coccyx ,CL = cardinal ligament, USL = uterosacral ligament.

images at four-mm slice thickness. The MR examination time was approximately 35 minutes.

Transverse images were imported into a 3D imaging program and aligned using bony anatomic landmarks. The gray and scale were adjusted to identify the borders of ligaments [19]. Manual segmentation of MR images of the USL, CL, and pelvic organs on transverse plane was performed. A 3D model of the USL, CL and pelvic organs was also reconstructed. The models' smooth surface was adjusted in order to avoid distortion.

Results

Baseline characteristics of the two groups population.

In the study, there was no significant differences in age, BMI, pregnant times, labour times, and postmenopausal number between the two groups ($p > 0.05$) (Table 1).

Anatomic characters of the USL and CL based MRI and MRI 3D in uterine prolapse

From the MRIs and 3D models viewed, 40 cases were found with anatomical and structural alterations of the USL, with paravaginal defects in ten cases, and levator ani (LA) torn in 30 cases.

The patients with uterine prolapse MRI are shown in Figure 2 (Pane l d-f). The USL was best shown in transverse plane, the CL was easily identified in coronal plane.The USL appeared as thin strips and the CL as vascular sheath. Compared to normal women (Figure 1: Panel a-c), the geometric changes of the USL can occur via a variety shapes (Panel d-f, m). 1) the attachment defects, (e.g.) the USL in the insertion end of cervix or vaginal vault was split, Origin

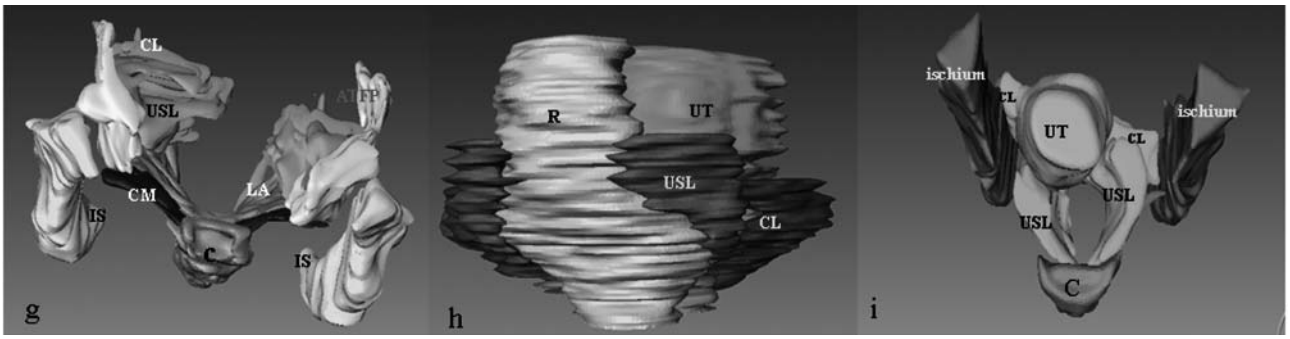

Figure 3 — Healthy female MRI 3D models. Panel g, from above behind observe the anatomical relation between the CL, USL, IS, ATFP and LA. Panel h, from behind observe the anatomical relation between the CL, USL, rectum and uterus. Panel i, from above observe the anatomical relation between the CL, USL, uterus, coccyx and ischium. B=bladder, UT=uterus, R=rectum, IS= ischium, C=coccyx, CM=coccygeus muscle, LA=levator ani, ATFP=arcus tendineus fasciae pelvis, CL=cardinal ligament, USL=uterosacral ligament.

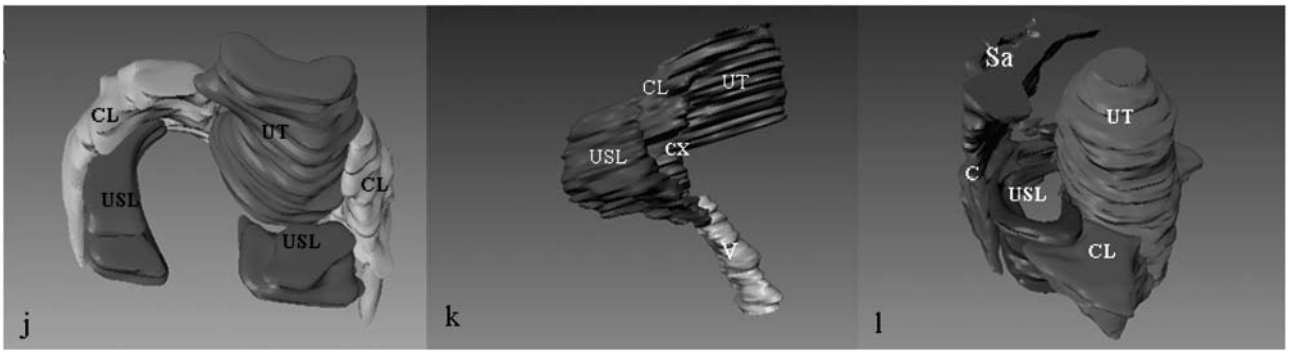

Figure 4. — Uterine prolapsed women MRI 3D models. Panel j, from above behind observe the USL "\/" , the left detachment from the cervix. Panel j, from right side observe the right USL insert into vaginal. Panel k, from right side observe the relation between the right USL and coccyx. UT=uterus, CX=cervix, R=rectum, Sa=sacrum, C=coccyx, CL=cardinal ligament, USL=uterosacral ligament.

Table 2. — *Comparison of the origin and insert end of the USL between the uterine prolapsed and normal women*

	Number	Sacrum* (n)	Coccygeus/sacrospinous complex* (n)	Ischial spine / piriformis muscle* (n)	Cervix# (n)	Vaginal# (n)	Cervix and vaginal# (n)
Uterine rolapse	40	4	32	4	16	4	20
Normal support	40	12	26	2	12	4	24
χ^2		5.000	2.257	0.180	0.879	0	0.808
P value		0.025	0.133	0.671	0.348	1.000	0.369

*the origin of the USL; #the insert end of the USL.

Table 3. — *Comparison of the origin and insert end of the CL between the uterine prolapsed and normal women*

	Number	The greater sciatic foramen * (n)	Cervix# (n)	Vaginal# (n)	Cervix and vaginal# (n)
Uterine rolapse	40	40	16	8	16
Normal support	40	40	16	4	20
χ^2		0	0.180	1.569	0.808
P value		1.000	0.671	0.210	0.369

*the origin of the CL, #the insert end of the CL.

point detached from the ischial spine or sacrospinous complex was found with trauma and avulsion. 2) bilateral USL were found with an asymmetric origin, in the unilateral continuity was interrupted or thinner. 3) unilateral USL was absent. The CL originated on the pelvic sidewall at the level of the greater sciatic foramen and distributed in cervix, bladder and upper-third of the vagina.

From MRI 3D model of the normal women groups Figure 3 (Panel g-i), the complete shape and geometric characters of the CL and USL can be seen; the origin and

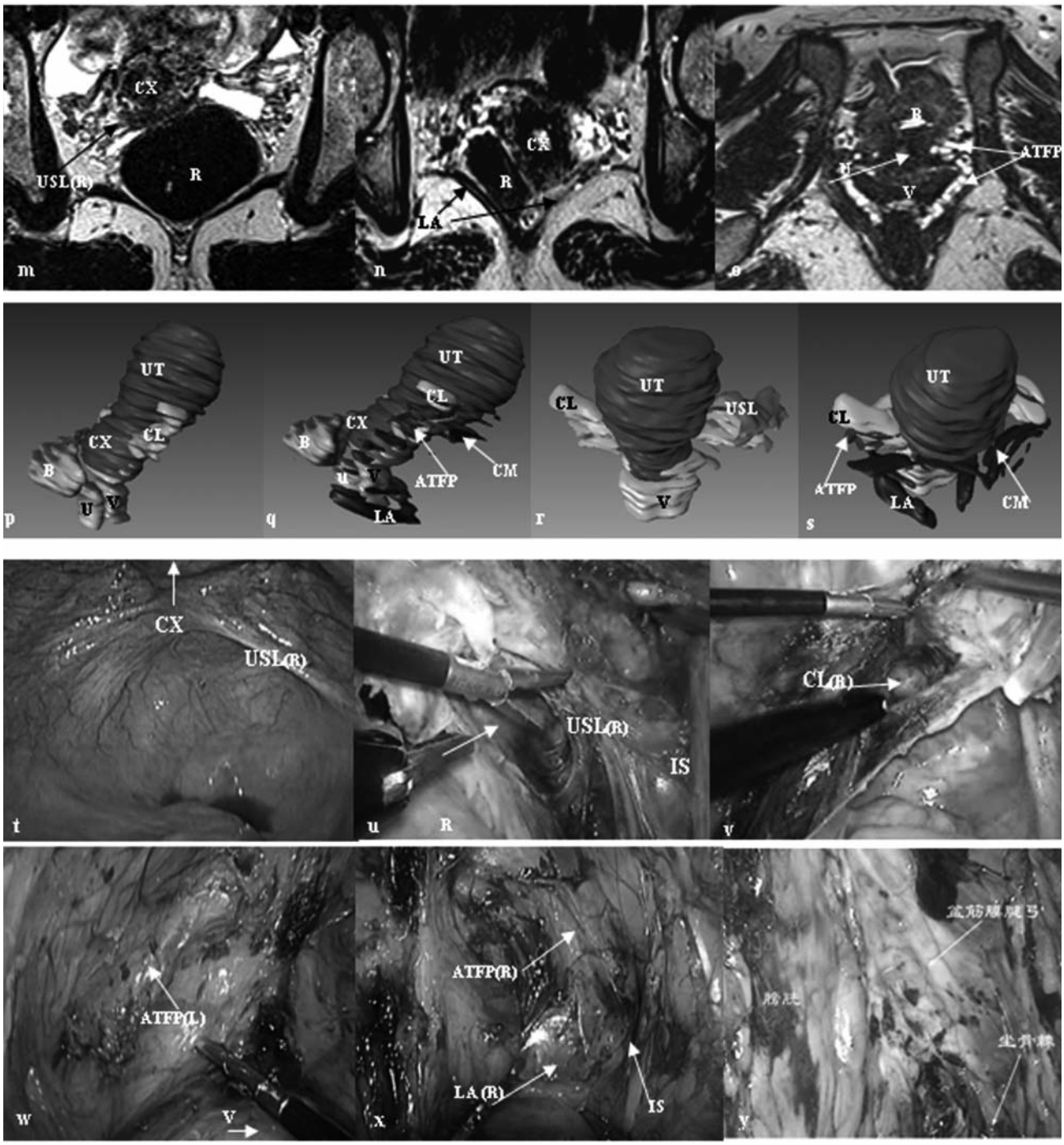

Figure 5. — MRI, MRI 3D models and the intraoperative detection of laparoscope demonstrate the relations between the USL, CL, uterus, IS and ATFP in a 43- year-old woman with uterine prolapse. Panel m, MRI demonstrates the left USL detached from cervix; it is difficult to identify the origin. Panel n, MRI demonstrates the left LA avulsion and split. Panel o, MRI demonstrates compared to the right, the left ATFP with a larger grid gap. Panel p, MR3D model shows from left side, the left USL that is absent. Panel q, MR3D model shows from left side, the relations between uterus, CM, ATFP (blue), and LA, and relations between ATFP, cervix, vagina, and urethra. ATFP shape is thin and weak, with attachment to cervix which is not compact, and vaginal side suspension is weak. Panel r, MR3D model as seen from behind. Panel s, MR3D model from left behind demonstrates the relations between uterus, ATFP, and LA. Panel t, the intraoperative detection of laparoscope demonstrates the left USL detached from cervix; it is difficult to asses the origin. The right USL is clearly seen. Panel u, dissection shows the right USL origined from IS. Panel v, the intraoperative detection of the right ATFP detachment from the ischial spine.

CX = cervix, V = vaginal, R = rectum, U = urethra, B = bladder, IS = ischial spine, CM = coccygeus muscle, LA = levator ani, CL = cardinal ligament, USL = uterosacral ligament, ATLA = arcus tendineus levator ani, ATFP = arcus tendineus fasciae pelvis.

inserted end of the ligaments, the anatomical association of ligaments with uterus, rectum, LA, sacrum, ischial spine and ATFP can also be observed. Compared to normal women, (Figure 4, Panel j) MRI 3DR of uterine prolapsed patients, the USL changed arcus shape into "/ \" or "\ /". The origin and inserted end of the USL and CL are shown in Tables 2 and 3. There was significant difference in the dorsal USL attached to sacrum between the two groups. There was no significant difference in the inserted end of the USL between the two groups, nor in the origin and inserted end of the CL.

Intraoperative anatomic characters of the USL and CL in uterine prolapse

Through intraoperative detection with a laparoscope, 22 cases of 40 patients with uterine prolapse were found with anatomical general changes of USL and 13 cases with paravaginal defects. Surgical dissection could not detect the USL avulsion completely, and borders of the ligaments were difficult to establish on dissection, and also difficult to define their origin and insertion.

Figure 5 shows a 43-year-old patient with uterine prolapsed Stage II and anterior vaginal wall prolapse Stage II. In the intraoperative detection with a laparoscope (Panel t), the left USL was visualized with a complete interrupted shape and its origin and border could not be assessed. On dissection, the right USL originated from ischial spine (Panel u); the right ATFP (Panel v) was detached from the ischial spine with avulsion.

Discussion

The female normal pelvic floor is a balanced and interrelated system, composed of muscle, connective tissue (CT), ligaments, and nerve components. The cardinal/uterosacral complex comprises level I (apical) suspension, which is critical to pelvic organ support. Any alteration can lead to uterine and the vaginal vault prolapse [1, 3, 4]. The USL and CL have been studied both in cadavers and during surgery. However in cadaveric studies, muscle tension is lost and spasticity is maintained; hence, there is some difference between the cadaver and living body in the pelvic morphology and geometry parameters [20]. In living women, the anatomic borders of the ligaments are difficult to definitely establish on dissection. MRI has be widely used as a quantitative evaluation technique for the pelvic floor. The USL cannot easily be distinguished from pelvic soft tissues by traditional MRI techniques, therefore MRI study on anatomical characters of the USL and CL in living women with uterine prolapse is still limited [4, 12-16].

The speciality of this study is using thin-layer MRI and MRI 3D technique to demonstrate anatomical geometry characters of the USL and CL in women with and without uterine prolapse. Traditional MRI study used pelvic MRI of four- to five-mm slice thickness sequences, in which the borders of pelvic organ and soft tissues were relatively clear, but the deficiency is that the scan layers are fewer, hence the torn ligaments can only be partly observed, and the MRI 3D reconstruction model is somewhat distorted. Research on MRI with thin layer sequence (one-mm slice thickness), can visualize the origin and inserted end of the ligaments, and identify borders especially from rectum fascia. The MRI 3D can accurately demonstrate anatomical characters and displacement of the USL and CL, which is appropriate to observe the anatomical defects and pathological changes of ligaments.

From MRI and MRI 3DR, the preliminary findings regarding the USL in different stage of uterine prolapse include some geometric changes, bilateral asymmetric USL or unilateral USL with avulsion or unilateral absence. The authors also detected its origin or insert end defects, detached or avulsion from the cervix, vaginal or the ischial spine/sacrospinous complex. The patients in which the USL origined from sacrum (4/40) were significantly different from that in normal women (12/40).

Meanwhile, the authors detected different stages of paravaginal defect and LA avulsion on MRI and MRI 3DR, consistent with the Petros' integral theory. They found the intraoperative detection of laparoscope are difficult to dissect the borders of the ligaments, and are difficult to avoid some intraoperative iatrogenic defects.

Above all, the advantages of MRI and MRI 3D technique such as high soft tissue resolution, non-invasiveness, etc. supposedly to be a preoperative evaluation system of POP, can aid in surgical planning [21], which has a great value for personalized reconstruction of uterine prolapse.

The authors also found the important pole of the ischial spine in pelvic support structure, which is not only attachment point to sacrospinous complex, ATFP, and ATFR, but also origin of a part of the USL. The ischial spine is not only the junction of the pelvic levels I and II, but may also be the mechanical transmission fulcrum. Associated connective tissue around ischial spine is the most vulnerable to damage, such as in USLs or ATFP attachment avulsion with forceps delivery or due to anatomical tissue defect [21-25]; the principle needs to be confirmed in further study of pelvic finite element analysis. There was no abnormality found in the anatomical characters of the CL.

There are several limitations. This study presents only the preliminary findings in 40 cases of uterine prolapse and the study number is not sufficient. The anatomical characters regarding the USL for example, bilateral asymmetric USL or unilateral USL absence were also found in two cases with normal support. It testifies that USL defects are not the unique reason for uterine prolapse, which can be accompanied by other tissue defects causing uterine prolapsed [27-28].

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