

High definition T2-weighted MR imaging of the female uro- genital supporting system using an external coil

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Abstract: *Aim* To provide evidence of the imaging features of such anatomic structures. *Materials and Methods* The imaging series of sixty-eight consecutive nulliparous females (mean age 51.5 ± 4.2 yrs, range 18-72 yrs) who underwent pelvic MR examination between April 2017 and June 2019, were reviewed. With no history of lower urinary tract symptoms (LUTs), evacuation dysfunctions or pelvic organ prolapse, clues for the examination included: known or suspected pudendal nerve neuropathy and ano-perianal sepsis. Patients with prior surgery for prolapse repair, partial or total hysterectomy and pelvic reconstruction for neonatal congenital anomalies were excluded. MR images were analyzed for evidence and imaging features of ligaments connecting the urethra, uterus and vagina to the internal boundaries of levator ani hiatus and pelvic side walls. The optimal scan plane for their identification and the frequency with which the various ligaments could be recognized as a distinctive anatomic structure were calculated. *Results* The axial MR images proved most informative (diagnostic yield as high as 89%); however, tilting the scan plane obliquely, perpendicular to the long axis of the anal canal improved the visibility of some structures in over half the cases. Three groups of ligaments supporting the female urethra were recognized, as follows: the periurethral ligaments (87%), running ventrally to the urethra; the paraurethral ligaments (60%), originating at the two and ten o'clock position of the urethra's outer border, respectively; and the pubourethral ligament (57%), hammock-like structure in close contact with the posterior aspect of the urethra. On the same plane, the vagina appeared as a three-layer structure showing different morphology in the upper (horizontal line), middle (H-shaped) and lower third (U-shaped) with faint, low intensity signal lateral attachments seen only occasionally (< 20 %) inside the paracolpium. The parametrium was seen in different proportions as low signal intensity condensations, showing linear (uterosacral and round ligaments, 68% and 96%, respectively), reticular (cardinal ligaments, 81%), or wide fold feature (broad ligaments, 35%), connecting the sides of the uterus to the walls and floor of the pelvis. Finally, the perineal body was better visualized on sagittal than on axial images (only 22%) as a hypointense pyramidal structure between the posterior labial commissure and the anal verge.

Conclusions MRI allows precise characterization of most relevant female urogenital supporting structures. In case of pathology, it can be used to guide surgeons and researchers to develop new focal-defect repair techniques.

Keywords: Magnetic resonance imaging; Female pelvis; Urethral support system; Parametrium and paracolpium; Endopelvic ligaments

INTRODUCTION

Clinical evaluation of women presenting with voiding dysfunctions, urogenital prolapse and sexual complaints is often difficult and imaging techniques are more and more frequently involved to obtain objective data on the status of pelvic anatomy and relationship among various structures. During the last two decades, the prevailing interest of clinicians and researchers has been focused on the assessment of the visceral fascia which covers the pelvic organs and provides their attachment to the side walls. Despite the plethora of references in the literature, however, there is still little objective information on that sheet of fascia that extends longitudinally and lines the walls of the pelvis giving origin to a number of linear condensations of connective tissue called ligaments. In particular the supporting system of the female pelvis, a term used to describe a composed of collagenous, elastic fibers and smooth muscle cells that provides stability to the bladder neck, urethra, vaginal canal and uterus, is still in search of final definition. Magnetic resonance imaging (MRI), the most powerful diagnostic tool available today, is particularly suited to the scope and we hereby report the results of our current experience with the study of female pelvic anatomy which, hopefully, will contribute to improve the knowledge of this relevant structure.

MATERIALS AND METHODS

Patient population

Between April 2017 and June 2019, sixty-eight consecutive nulliparous females (mean age 51.5 ± 4.2 yrs, range 18-72 yrs) with no symptoms of voiding or evacuation dysfunctions, pelvic organ prolapse nor fecal incontinence, were enrolled into the study. Clues for MRI examination included chronic pelvic pain from known or suspected pudendal neuropathy and ano-perianal sepsis. Patients with prior surgery for prolapse repair, partial or total hysterectomy and pelvic

reconstruction for neonatal congenital anomalies were excluded.

Imaging protocol

All MR imaging studies (NL, TF, JA, FP) were performed on a 1.5 T scanner (Siemens; Aera model, phased array external coil, Germany). For the examination, with no need for prior rectal cleansing nor intravenous contrast administration, patients are asked to void just before imaging, so as to have their bladder empty; then, they are placed in the supine position on the diagnostic table. For the assessment of perianal sepsis and fistulas, a modified 3 mm wide rubber catheter is positioned intra-anally to act as marker and subsequent acquisition of pelvic images in the true midcoronal and midaxial (oblique) planes taken parallel and perpendicular, respectively, to the long anal axis. In case of suspected pudendal nerve neuropathy, a cardiac gating, peripheral optic device called PPU (peripheral pulse unit) is employed which is applied at the extremity of the 2nd finger of right hand so as to obtain images directly or indirectly involved in the phenomenon of blood pulsatility.

Imaging technique

At the beginning, a localizer scout scan is performed in the three planes (HASTE pulse sequence, TR/TE 3.83/1.92 ms, FA° 54-70, slice thickness 6-7 mm, FOV 400 mm, two averages, matrix 256 x 156, total images 14-20) to mark the boundaries of the region of interest (ROI). The field of view extends from the anal verge (bottom level) to the upper margin of the iliac crest (upper level) and from the sacrococcygeal bone (backward) to the anterior margin of the pubic bone (forward) so as to include all relevant anatomy. Then, the pelvic anatomy is depicted in the midsagittal plane, using the turbo spin-echo (TSE) T2-weighted pulse sequence (TR/TE 3880/91 msec, FA° 150, slice thickness 4 mm, FOV 260, one average, matrix 384 x 384, FOV, 350 mm; scan time 4.33 min; total images 36). Thereafter, taking the

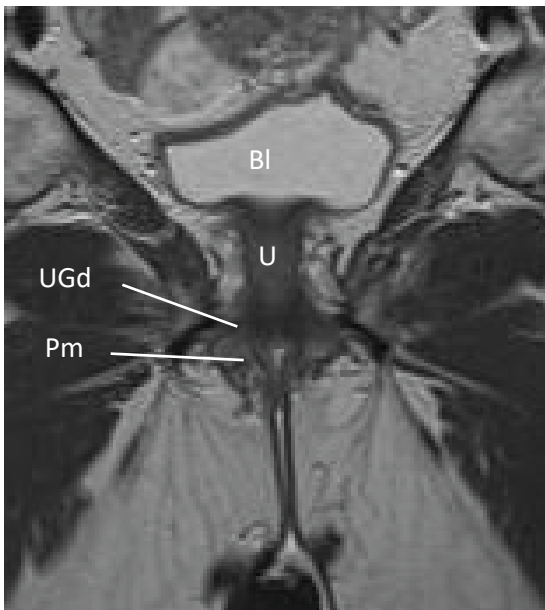


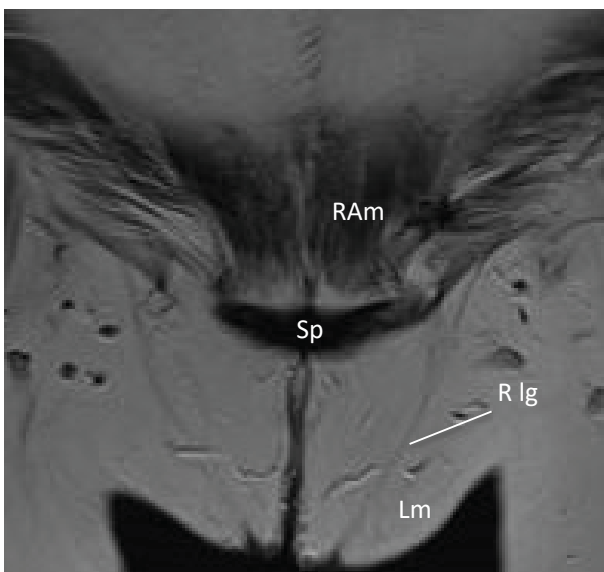
Figure 1 MR anatomy of female lower urinary tract and supporting structures.

(a) Coronal T2-weighted image taken at the level of bladder neck and urethra showing the horizontal, 4 mm-thick, low signal intensity stripe of the **urogenital diaphragm** (UGd) and the triangular- shaped **perineal membrane** (Pm).

(b) Axial T2- weighted MR image showing the **periurethral ligament** (1) coursing ventrally to the urethra, the **paraurethral ligament** (2) arising at the 10 o' clock position from the outer border of the urethra, and (3) the horizontal **pubourethral ligament**. Bl= bladder; U= urethra; UGd= urogenital diaphragm; Pm= perineal membrane; V= vaginal canal; A= anal canal.

intra-anal marker as reference, the sequence is repeated with use of the same parameters in the true midcoronal and midaxial (oblique) planes taken parallel and perpendicular to the long axis of the anal canal, respectively. At this point, the short tau inversion recovery (STIR) pulse sequence (TR/TE 2800/29 msec; TI, 150 msec; FA° 150°; slice thickness 3 mm, FOV 380, one average, matrix 245x 320, scan time 2.48 min, total images 40) is employed in patients referred for fistula-in-ano disease, while the TSE T2-W double inversion recovery (IR), fat sat (FS) dark blood (DB) pulse sequence is used in those with suspected pudendal neurop-

Figure 2 Coronal T2-weighted MR image taken at the level of symphysis pubis. Note the thin linear, low signal intensity structure of the **round ligament** coursing vertically in oblique manner through the labia major. RAM= rectum abdominis muscle; Sp= symphysis pubis; Lm= labia major; R lg = round ligament.



athy. Finally, regardless of the clue, a straight axial TSE T2 weighted series is also obtained in all patients.

Image analysis

All examinations are taken to a viewing station and systematically reviewed (V.P) and analyzed with regard to the urethral and genital ligaments according to the basic criteria described by Kim JK et al¹, and Tunn R. et al.², as reported in a previous report³. In addition, the method of Chou Q. et al.⁴ was employed to systematically analyze the location and identity of various supporting structure for proper differentiation of anatomic variations from abnormalities. In particular, the criteria for assignment of integrity of ligaments included the following: (a) tightness along the entire length; (b) no discontinuity or fluttering; (c) visibility at the expected site. Quantification of the levator ani hiatus anterior/posterior and transverse diameters (mm) and area (cm²) is beyond the scope of the present paper. Readers interested in the issue are referred to a recent article by us⁵.

RESULTS

The axial MR images were the most informative (see Table 1). On the other hand, a combination of coronal, axial and sagittal scans were found necessary for proper depiction of the lower urinary tract anatomy and support system (Figure 1). With regard to the genital organs, the **round ligaments** were the most frequently recognizable structures (up to 96% of cases) originating at the uterine horns as low signal intensity structures in the parametrium, exiting the pelvis via the deep inguinal ring, then passing through the inguinal canal and terminating on to the labia majora (Figure 2). At the other end of the spectrum, the **pubocervical ligaments**, i.e. collagen containing structures connecting the side of the cervix to the pubic symphysis, were seen only rarely as distinct structures on MR images. The **broad ligaments**, resulting from the double layer of peritoneum that, after covering the uterus anteriorly and posteriorly, comes in direct contact with itself on the sides, appeared in only 35% of cases as wide folds of peritoneum that connects the sides

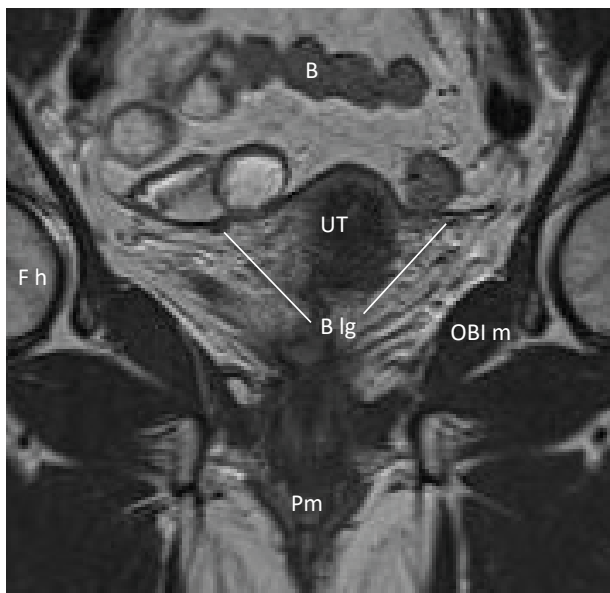


Figure 3 Coronal T2- weighted MR image obtained at the level of femoral heads: after covering the uterus, the double layers of peritoneum come into contact one to another on the sides to produce the 3-mm thick linear appearance of the **broad ligament**. Note the wing-like feature of the ligament connecting the uterus to the pelvic side walls. B= bowel; UT= uterus; OBI m = obturator internus muscle; Pm= perineal membrane; B lg= broad ligament; Fh= femoral head.

of the uterus to the walls and floor of the pelvis (Figure 3). Conversely, the **cardinal ligaments** (or **Mackenrodt’s ligament**.) were seen in 81-85% of cases as reticular or troncular shaped structures containing fibrous tissue and blood vessels, located at the base of the broad ligament which attach the cervix to the lateral pelvic wall by means of the fascia of the obturator internus muscle. The **uterosacral ligaments** (or **recto-uterine ligaments**) were identified (68% of cases) as linear, low signal intensity structures containing considerable amount of fibrous tissue and non-stripped muscular fibers which travel from the upper part of the cervix to the anterior aspect of the sacrum (Figure 4).

As described in details in a previous report [3] the vaginal canal appeared as a three-layer structure showing high signal intensity in the center (mucous or secretion), and two, 3-mm thick layers of low-to-intermediate signal layers on both sides (walls). On axial MR images, its morphology was consistently seen as a linear, horizontally oriented structure in the upper third, H-shaped in the middle and U-shaped in the lower third.

Also, three categories of urethra’s support system, were observed, as follows: the periurethral and paraurethral ligaments (83%) at the level of the proximal third of the urethral length, as a curvilinear hypointense structure coursing ventrally and as a triangular-shaped structure

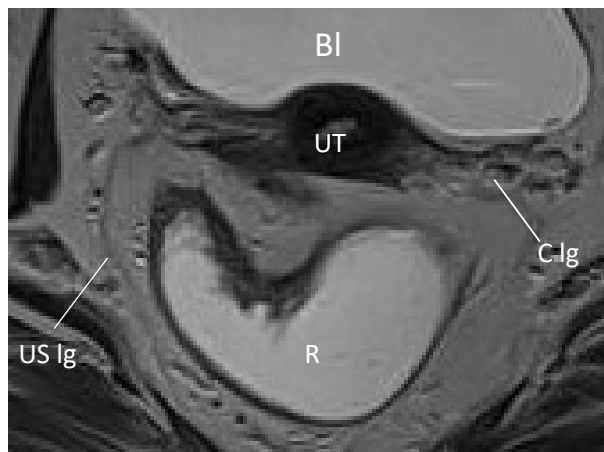


Figure 4 Axial T2_ weighted MR image showing the reticulo-troncular feature of the **cardinal ligament** as opposed to the thin, curvilinear appearance of the **uterosacral ligament** travelling toward the anterior aspect of sacral bone. BI= bladder; UT= uterus; R= rectum; US lg= uterosacral ligament.

originating at 2- and 10- o’ clock position from the outer margin of the urethra, respectively; and the pubourethral ligament (58%) seen at the half of urethra length as a hammock-like structure in close contact with its posterior margin (Figure 1b). Finally, other relevant structures belonging to the support system which were consistently depicted included the sacrospinous ligaments, the sacrotuberous ligaments, the perineal body and the perineal membrane (Table 1).

DISCUSSION

Thanks to its superior contrast tissue resolution and panoramicity, magnetic resonance imaging (MRI) is unanimously considered today as unsurpassed modality in the diagnosis of pelvic pathology. More specifically, the advantage of MRI over ultrasonography, its current major competitor, relies on the ability to display in exquisite details all the components of pelvic anatomy, including fat tissue recesses, the connective network, fascial attachments and condensations, i.e., ligaments. Undoubtedly, the adoption of rigorous imaging protocols and multiplanarity, combined with the well known multiparametric capabilities and lesser operator dependence, make the MRI modality unique for depiction of the endopelvic fascia, which is considered by researchers

the key factor for characterization of both, organic and functional pathology.

This was largely confirmed by the present study which highlighted how frequently (see Table 1) the various supporting structures of female lower urinary tract and genital organs could be recognized at best using a conventional scan system and coil with no need for additional costs or expensive devices. Contrary to what could have been expected, however, not every existing structures of the supporting system found a match with a distinctive MR feature — as it occurred with the pu-

Table 1 Visibility of urogenital support system at MRI by scan plane (n=68)

Compartment	Scan plane			
	Axial		Coronal	Sagittal
	Straight	Oblique		
Anterior				
Arcuate lg	68 (100%)	68 (100%)	68 (100%)	-
Periurethral lg	59 (87%)	57 (84%)	8 (12%)	-
Paraurethral lg	41 (60%)	47 (69%)	-	-
Pubourethral lg	39 (57%)	44 (65%)	2 (3%)	-
Perineal membrane	-	-	68 (100%)	-
Middle				
Round lg	46 (68%)	43 (63%)	65 (96%)	-
Broad lg	-	-	24 (35%)	-
Cardinal	55 (81%)	58 (85%)	4 (6%)	-
Uterosacral	46 (68%)	47 (69%)	-	-
Pubocervical	-	-	-	-
Perineal body	-	15 (22%)	-	66 (97%)
Posterior				
Sacrospinous	68 (100%)	68 (100%)	51 (75%)	-
Sacrotuberous	68 (100%)	68 (100%)	61 (90%)	68 (100%)

Note: Numbers in parenthesis are percentages; lg: ligament

bocervical ligaments, for example — , despite their recognized relevance and well known anatomic location. Similarly, not all the anatomic structures visualized on MR images could necessarily be considered clinically relevant. Besides all the above, two issues deserve special consideration and should be brought to the attention of the reader, as follows: first of all, the efficacy of tilting the scan plane in obtaining better visualization of some anatomic structures, such as the pubourethral ligaments, should be emphasized. Secondly, and most important, the overt difficulty encountered by the examiner when establishing the threshold beyond which an unusual appearing morphology of a structure should be considered as an anatomic variation rather a clear abnormality, cannot be overlooked.

At present, the only way to assign the judgement of presence or absence of any abnormality relies on the frequency with which a single structure is visualized in a given location with a given shape. Obviously, better certainty can only be expected from further studies on larger series including nulliparous and parous subjects⁶, as well as investigation comparing MR features with anatomic samples. Hopefully, the information yielded by the present study will stimulate researchers to develop new surgical procedures for focal defect-repair techniques.

CONCLUSIONS

The integrity of the urethral support system and that of female genital organs can be assessed noninvasively in living individuals using conventional 1.5 T MR scanner and external coil with no need for contrast administration. Although important individual variation can be encountered, recognizing the same structure with the same shape in the same anatomic site remains the basis for the diagnosis of normal vs. abnormal condition in singular cases. The technique described in this article seems ideally suited to be adopted in a standardized fashion in the clinical practice. Perspectively,

its routine use after vaginal delivery may be suggested so as to distinguish those women requiring simple pelvic floor rehabilitation from surgical repair.

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Disclosures statements

There was no conflict of interest, informed patient consent was obtained, and the study was approved by the local ethical committee. The authors of the publication did not receive any financial support by any grant/research sponsor.

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Multidisciplinary UroGyneProcto Editorial Comment

To improve the integration among the three segments of the pelvic floor, some of the articles published in *Pelviperrineology* are commented on by **Urologists, Gynecologists, Proctologists/Colo Rectal Surgeons or other Specialists**, with their critical opinion and a teaching purpose. Differences, similarities and possible relationships between the data presented and what is known in the three fields of competence are stressed, or the absence of any analogy is indicated. The discussion is not a peer review, it concerns concepts, ideas, theories, not the methodology of the presentation.

Anatomist... The breakthrough in the imaging of female uro-genital supporting system

The role of the imaging in the modern medicine is crucial to provide evidence of the features of such anatomic structures. Clinical evaluation of women presenting with voiding dysfunctions, urogenital prolapse and sexual complaints is often difficult and imaging techniques are more and more frequently involved to obtain objective data on the status of pelvic anatomy and relationship among various structures. There are a lots of papers in the literature about the female urogenital supporting system, but few objective information on that sheet of fascia that extends longitudinally and lines the walls of the pelvis giving origin to a number of linear condensations of connective tissue called ligaments. De Caro et al in 1998 (Morphometric analysis of the fibroadipose tissue of the female pelvis. *J Urol* 1998;

160: 707-13) concluded after a morphometric analysis of the fibroadipose tissue of the female pelvis that it has the function to sustain the pelvic viscera and it is based on the descriptions of connective condensations forming visceral fascia (rectal, cervicovaginal and vesical fascia) and ligaments. The possibility to see these structures with MRI it would become very important in the planning of surgery at the pelvis, helping the surgeons in the correct surgical identification of the anatomic structures and in monitoring the healing processes in the post-surgery and in the follow-up. Therefore, it is revolutionary relearn our anatomy and to be able to see with the unsurpassed MRI in the diagnosis of pelvic pathology.

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Uro-gynecol... This is a brilliant paper. The MRI figures provide some excellent insights into the ligamentous attachments of the organs to the skeleton. I have no criticisms of this paper. I would point out, though, that the cardinal ligament has an important reflection onto the anterior cervical

ring which is not mentioned. This is evident just below the broad ligament in fig 3.

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Gyn... The Integral Theory says that there are 9 pelvic connective structures (pubourethral ligaments\PUL, external urethral ligaments\EUL, suburethral hammock, pubocervical fascia PCF, arcus tendineous fascia pelvica\ATFP, cervical ring, uterosacral ligaments\USL, rectovaginal fascia\RVF, perineal body\PB) whose damage is responsible for symptoms (pain, nocturia, urgency, etc.) and signs (prolapses and incontinence) that characterize the functional diseases of the pelvic floor. The impairment of these anatomical sites would be responsible for syndromic pictures even in the absence of important degrees of genital prolapse. In fact, in the etiopathogenesis of fecal incontinence, also the ligaments of the anterior compartment appear to be involved (EUL, hammock, PUL), while symptoms such as pelvic pain and nocturia involve

structures of the posterior compartment (USL, RVF, PB). Piloni's proposal is quite interesting as the anatomical evaluation obtained by MRI would allow to correlate the symptomatology referred to an objective description of the site of impairment of ligaments and fasciae. The re-evaluation with post-operative imaging, in the same patients, with an adequately long follow-up, and in a sufficiently large number of cases, would allow to verify, in vivo, the tissue reactions "caused" by the inserted polypropylene tapes (TFS) responsible for the creation of neo-ligaments and the possible improvement of the symptomatology.

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Proctol... According to the Integral Theory (IT) the intriguing relationships between the three pelvic compartments allow the treatment of fecal incontinence with the creation of neoligaments in the anterior pelvis (B.Abenstein. *Pelviperineology* 2008; 27: 114). With slings surgery, IT has achieved global success in SUI. Although there are significant clinical reports from pelvic reconstructive surgery centers in Germany, Austria, Japan, widespread skepticism surrounds IT interpretations about the physiopathology of conditions such as some forms of constipation and anal incontinence and the treatments offered with TFS. It is vital that in order to overcome such resistance and consequently

provide for a therapy that at present has very poor alternatives, to document the damage of the different ligaments and the possible improvement after the appropriate surgical therapy. The work of Piloni corresponds to this need, i.e. to demonstrate the ligamentous structures by means of pelvic MR and provides us with a sort of atlas of normal anatomy in which the MR must clearly show the five main structures: pubo-urethral, uterosacral, cardinal ligaments, arcus tendineous, perineal body.

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