Original article

MR imaging of vaginal morphology, paravaginal attachments and ligaments. Normal features

VITTORIO PILONI

Iniziativa Medica, Diagnostic Imaging Centre, Monselice (Padova), Italy

Abstract: Aim: To define the MR appearance of the intact vaginal and paravaginal anatomy. *Method:* the pelvic MR examinations achieved with external coil of 25 nulliparous women (group A), mean age 31.3 range 28-35 years without pelvic floor dysfunctions, were compared with those of 8 women who had cesarean delivery (group B), mean age 34.1 range 31-40 years, for evidence of (a) vaginal morphology, length and axis inclination; (b) perineal body's position with respect to the hymen plane; and (c) visibility of paravaginal attachments and ligaments. *Results:* in both groups, axial MR images showed that the upper vagina had an horizontal, linear shape in over 91%; the middle vagina an H-shape or W-shape in 74% and 26%, respectively; and the lower vagina a U-shape in 82% of cases. Vaginal length, axis inclination and distance of perineal body to the hymen were not significantly different between the two groups (mean ± SD 77.3 ± 3.2 mm vs 74.3 ± 5.2 mm; 70.1 ± 4.8 degrees vs 74.04 ± 1.6 degrees; and +3.2 ± 2.4 mm vs + 2.4 ± 1.8 mm, in group A and B, respectively, $P > 0.05$). Overall, the lower third vaginal morphology was the less easily identifiable structure (visibility score, 2); the uterosacral ligaments and the paraurethral ligaments were the most frequently depicted attachments (visibility score, 3 and 4, respectively); the distance of the perineal body to the hymen was the most consistent reference landmark (mean +3 mm, range -2 to + 5 mm, visibility score 4). A failure rate of up to 40% in the depiction of uterosacral, cardinal and round ligaments occurred in both groups. *Conclusions:* nulliparous women and women after cesarean delivery do not differ significantly in their vaginal and paravaginal anatomy. Although MR mapping seems a promising tool, failure to depict any support structure in singular cases cannot be considered evidence of abnormality.

Keywords: Female pelvic MRI; Vaginal and paravaginal MR anatomy; Endopelvic fascia; MR imaging of normal parametrium and paracolpium.

INTRODUCTION

MR imaging, the newest technique used to evaluate pelvic floor anatomy, can provide detailed visualization of minute structures and could be helpful in the evaluation of the vaginal and paravaginal supporting anatomy, both of which are potentially involved in determining pelvic organ prolapse (POP). Compared with the more traditional techniques such as fluoroscopy and ultrasonography, MRI has several advantages including lack of ionizing radiation and superior contrast resolution of soft tissues. Unfortunately, to our knowledge little attention has been given in the literature to the issue of the MR imaging of vaginal and paravaginal anatomy as it appears in women before vaginal delivery. In addition, it seems likely that the vagina itself largely varies in shape in the healthy population. The aim of the present paper was to revitalize interest in this issue and highlight the role of MRI for proper identification of vaginal and paravaginal anatomy. With this purpose, MR series obtained in a group of nulliparous women with no evidence of pelvic organ prolapse were compared with those of a group of women who received cesarean section at delivery.

MATERIALS AND METHODS

Between January 10 and December 30, 2014 we reviewed the MR series of pelvic examinations performed at the diagnostic Imaging Centre of the Iniziativa Medica institute, Monselice (Padua), Italy in 25 nulliparous women aged 28-35 years, mean 31.3 years (group A) and in 8 women aged 31-40 years, mean 34.1 years (group B) who had had at least one cesarean delivery. Clues for the examination included characterization of known or suspected benign pathology such as uterine fibroid, ovarian cyst and search for endometriosic foci. Before the examination, the subjects answered a set of standardized questions on their history of urinary symptoms, bowel habit, and sexual activity, if any. Subjects with symptoms/signs of pelvic organ prolapse at physical examination, evacuation dysfunctions or lower urinary tract (LUT) symptoms, and those with history of prior pelvic surgery were excluded. Patients were imaged with a 1.5 T superconductive, horizontally oriented, magnet system (Philips Medical System, Achieva model, The Netherlands) equipped with high-speed gradients and a surface phased-array coil (Body SENSE XL Torso) wrapped around their pelvis. The typical examination was usually conducted on the following lines: T2-weighted images were obtained in all three planes (sagittal, axial and coronal) to provide a complete evaluation of pelvic floor anatomy using fast recovery spin echo pulse sequence (TR/TE, 3704/90 ms; FA, 90°; FOV, 320 cm; BW, 253.0; slice thickness, 4 mm; interslice gap, 1 mm; matrix size, 444 x 310; ETL, 18 and four excitations; scan time, 2.24 min). When needed, for better depiction of paravaginal anatomy, ligaments and levator ani muscle attachments, a proton density (PD) and a short tau inversion recovery (STIR) pulse sequences were also obtained in the axial and coronal plane. Occasionally, using specially adjusted oblique planes was also found useful. A single radiologist (P.V.) used a standardized approach for image analysis which followed the basic principles described by Tunn, Chou and coworkers.[1-3] With regard to the terminology, the vaginal canal was used to denote the fibromuscular conduit that extends from the vulva to the the cervix of the deep uterus at approximately a 90 degree angle and about 60 degrees to the horizontal; the term vaginal wall included the vaginal mucosa, submucosa, and muscularis; and the term endopelvic fascia indicated those tissues between the vaginal muscularis and adjacent organs or the pelvic side walls.[4] Special attention was given to visibility, signal intensity, and identification of vaginal wall structure and morphology at the De Lancey level I, II, and III.[5] In addition, the MR features of fascial condensations in the expected sites including the perineal membrane, uterosacral, cardinal and round ligaments, paraurethral ligaments, as well as the attachments of levator ani muscle to the inside of lateral vaginal wall and to the internal obturator muscle were noted. Also, based on the symphysis pubis as anatomic landmark, the hymen plane was identified on sagittal MR images by drawing a line from the most posterior inferior point of the pubic bone through the external urethral orifice and the external vaginal opening (Figure 1). As such, with

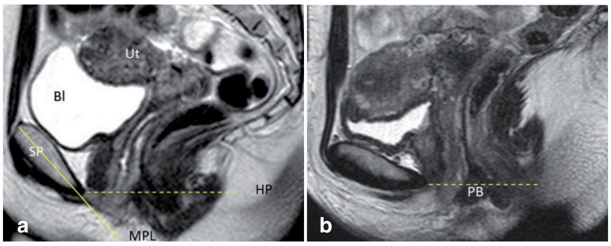
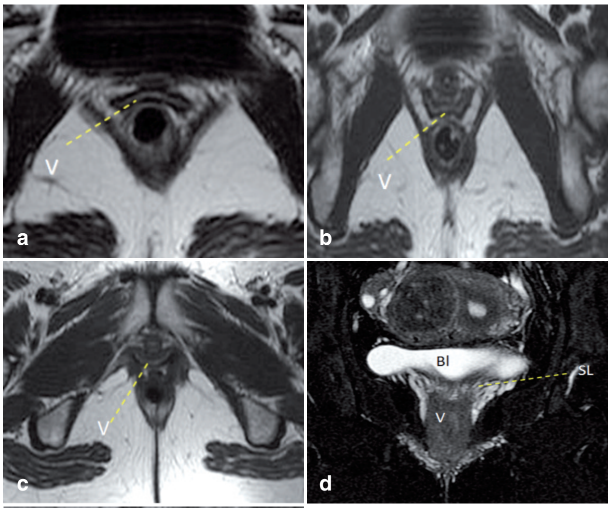


Figure 1. – (a): Method for tracing the hymen plane on T2-weighted TSE midsagittal MR images of female pelvis (a): a line is drawn *(dotted line)* starting at the lowermost posterior point of the pubic bone through the external urethral and vaginal orifices. The midpubic line *(continuous line)* is depicted for comparison. (b): The hymen plane is used as reference to measure the position of the perineal body and the distal vaginal angle. BL= bladder; UT= uterus; SP= Symphysis Pubis; MPL= midpubic line; HP= Hymen plane.



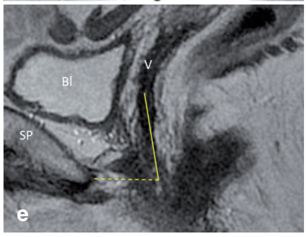


Figure 2. – (a) Normal vaginal morphology at MRI as seen on axial, coronal and sagittal planes: T2-weighted TSE axial images taken at DeLancey level I (a), Level II (b), and level III (c) for evidence of the three different vaginal shapes *(dotted line)*; (d) coronal STIR midvaginal image showing the vaginal apex and the site at which the suspensory vaginal support structures converge on both sides (dotted line); (e) sagittal T2 weighted TSE image showing the paracolpium as an hyperintense structure beyond the anterior and posterior vaginal walls. A vaginal angle of 72 degrees is formed by the intersection of the reference line *(dotted line)* with the distal vaginal axis (continuous line). V= vagina; BL= bladder; SL= suspensory ligaments; SP= symphysis pubis.

the plane of hymen being defined as zero, the location of the perineal body, expressed as millimeters above (negative numbers) or below (positive numbers) the hymen, was calculated. Moreover, the distal longitudinal vaginal axis relative to a horizontal reference line, referred to as the "distal vaginal angle" and the total vaginal length, defined as the greatest depth of the vagina,[6] were measured. Finally, the MR anatomy appearance was characterized on individual pictures with regard to its (a) overall image quality, defined as the sharpness with which the single structure was depicted; (b) organ definition, defined as the ability to distinguish the various components as distinct anatomic structures; and (c) visibility score, defined as the frequency with which the presence (or absence) of the structure was visualized for each scanning level. To quantify them, a 4-point grading scale was used according to El Sayed[7] when collecting data as follows: 1, not visible; 2, poorly visible; 3, moderately visible; 4, easily visible. Data analysis was performed with SPSS 5.1 (SPSS Inc, Chicago, III). Paired Student t tests were applied, with a significance level determined at $P < 0.05$ to assess the difference between group A and group B subjects. Values of various measurements were given as mean and standard deviation (SD).

RESULTS

The vaginal length varied from 68 to 84 mm and the mean was 77.3 mm (SD ± 3.2 mm) in nulliparae; in comparison, the length varied from 71.4 to 86.03 mm with a mean of 74.3 mm (SD ± 5.2 mm) in women after cesarean delivery, $P > 0.05$. The average distal vaginal angle was 70.1 degrees, range 58.2-77.4 degrees in nulliparous and 74.04 degrees, range 61.1-76.2 degrees in the cesarean group, $P > 0.05$. The average distance of the apex of the perineal body to the hymene plane was + 3.2 ± 2.4 mm, range -4 to +6 mm in nulliparous and + 2.4 ± 1.8 mm, range -1 to + 7 mm in the cesarean group, $P > 0.05$.

Vaginal Morphology: at the DeLancey level I, the cross-sectional vaginal configuration assumed a typical linear, horizontally oriented shape in over 91% of cases with a minimal (max 5°) obliquity toward the right or left side in the remaining 9% of cases. By contrast, a typical butterfly or H-shape of the vaginal morphology was seen in 74% and a W-shape in 26% of cases at the DeLancey level II showing a symmetric insertion to the inside of LA muscle and to the outer lateral margin of rectum (also called posterior vaginal sulcus), as opposed to a U-shape at the DeLancey level III in 82% of cases, respectively. Overall, the *en-face* vaginal morphology was depicted at best in the mid-coronal MR images as a rectangular structure of low signal intensity with thin bilateral, more or less symmetric linear stripes originating from its upper lateral corner, interpreted as the suspensory vaginal ligaments. On the other hand, the midsagittal MR images were ideal for determining vaginal axis inclination, total vaginal length, and perineal body's position with respect to the hymeneal plane (Figure 2).

Vaginal Walls: most commonly, on T2-weighted axial images the structure of the vagina had a two-layered, 2-3 mm thick consistent appearance showing homogeneous hypointense signal intensity which represented the combined anterior and posterior walls faced together with their virtual internal lumen showing a high-signal-intensity due to mucous or secretion in the center (see Figure 2 b). Occasionally, three vaginal wall layers could also be identified from internal to external as follows: a low-signal-intensity inner layer, an intermediate-signal-intensity middle layer, and a low-signal-intensity outer layer. These correspond to layers of squamous keratinized epithelium, lamina propria of loose connective tissue, and a muscular layer, respectively.[8] T2-weighted sagittal images allowed easier depiction and interpretation of the vaginal wall layers probably because of more favorable contrast and spatial resolution with adjacent structures.

Parametrium and paracolpium: the uterosacral and round ligaments were seen alternatively on axial and/or coronal MR images with a variable frequency of 71% and 58% of cases as thin linear structures of low signal intensity (Figure 3) extending from the upper part of the cervix to the sides of the sacrum, and from the angles of the uterus downward, laterally and forward through the inguinal canal to the labia majora, respectively. Despite their superior visibility rate (up to 79% of cases), the cardinal ligaments couldn't be recognized as isolated structures; rather, their identity was synonimus with the visible accompanying vas-

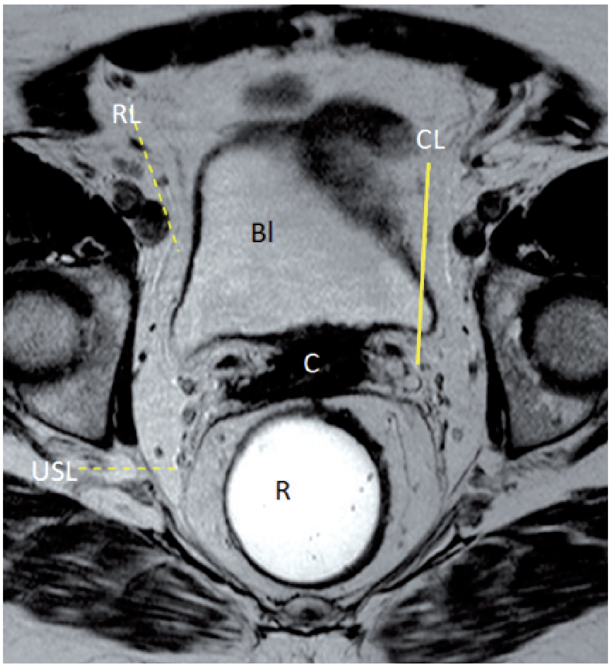


Figure 3. – Axial T2-weighted TSE image taken at the level of uterine cervix showing the supporting structures of the uterosacral ligaments as thin curvilinear hypointense stripes coursing backward *(short dotted line)* and a portion of the round ligaments *(long dotted line)* coursing forward; the site of the cardinal ligaments is inferred by the presence of vessels, limphatics and nerves *(long continuous line)*. C= cervix; BL= bladder; R= rectum.

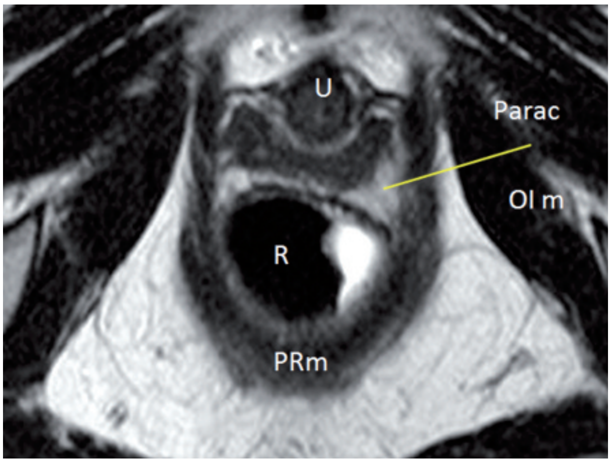


Figure 4. – The paracolpium on axial T2-weighted TSE image is depicted as an hyperintense structure surrounding the vaginal walls *(continuous line)*. Parac= paracolpium; U= urethra; OIm= obturator internus muscle; PRm= puborectalis muscle; R= rectum.

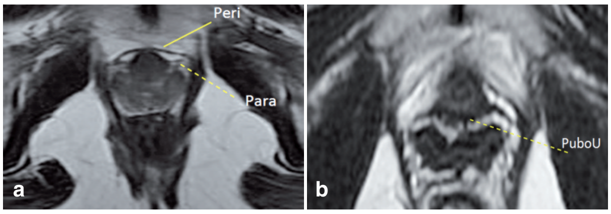


Figure 5. – (a) Paraurethral supporting structures seen on axial T2-weighted TSE MR images: periurethral ligament *(continuous line)* and paraurethral ligament *(dotted line)*; (b) pubourethral ligament (dotted line). Peri= periurethral ligaments; Para= paraurethral ligaments; PuboU= pubourethral ligaments.

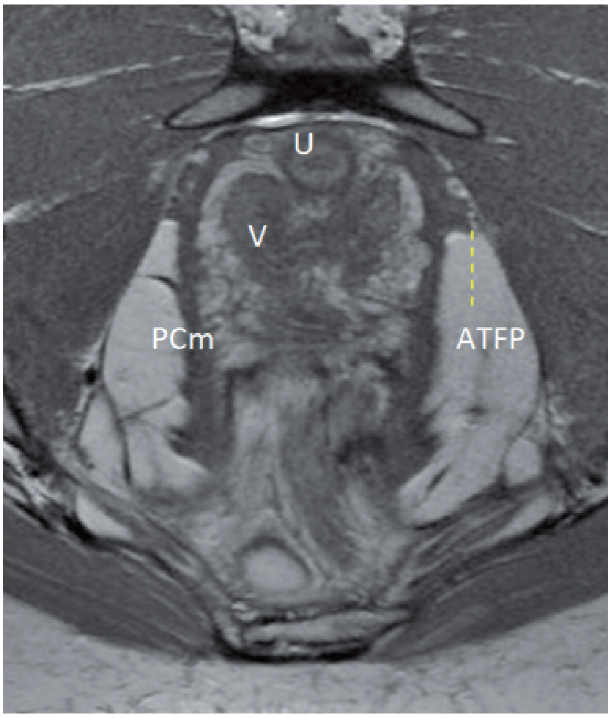


Figure 6. – Insertion of the pubococcygeus to the obturator internus muscle through the endopelvic fascia *(dotted line)* as seen on axial oblique proton density (PD) pulse sequence. ATFP= arcus tendineus fasciae pelvis; U= urethra; V= vagina; PCm= pubococcygeus muscle.

cular supply, nerves and fat forming the parametrium. Overall, a failure rate of up to 40% in the depiction of the uterosacral and round ligaments at MR imaging was registered in both groups. The paracolpium was identified as a hyperintense structure surrounding the vaginal wall anteriorly, laterally and posteriorly with variable thickness. Its high signal intensity is considered a result of a combination of connective tissue and venous plexus which is bulkier around the upper third of the vagina (Figure 4).

Paraurethral attachments: three components were consistently recognized on axial MR images (Figure 5) in all but three cases, as follows: the periurethral ligaments as a thin hypointense arcuate structure coursing ventrally to the urethra and connecting the medial aspect of the puborectalis muscle of one side to the other; the paraurethral ligaments as a slightly oblique, hypointense thin structure originating at the 4 and 8 o'clock position of the urethra and connecting its lateral wall to the periurethral ligament described above; and the pubourethral ligament, as a thin hypointense structure distinct from the anterior vaginal wall, located behind the posterior aspect of the urethra as an hammock which connects the urethra to the arcus tendineus fascia pelvis.

Levator ani muscle attachments: the insertion of iliococcygeus muscle to the inner border of the internal obturator muscle border, as seen on both T2-weighted axial and coronal images, served to localize the arcus tendineus fasciae pelvis while the insertion of the pubococcygeus muscle to the inside of the pubic bone and to the obturator internus muscle (Figure 6) testified the integrity of the pubocervical fascia.

Perineal membrane, perineal body and urogenital diaphragm: the perineal membrane is a primarily fibrous structure of intermediate signal intensity, triangular in shape spanning the space between the two ischiatic rami (Figure 7). It includes also a muscular component composed by the compressor urethrae and urethrovaginal sphincter. Superficial and inferior to the perineal membrane lies the perineal fascia made up of an adipose and membra-

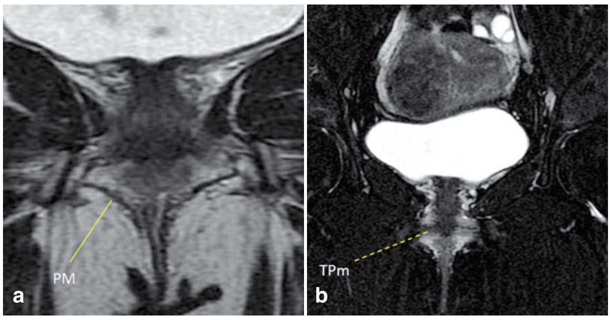


Figure 7. – (a) The perineal membrane is depicted on coronal T2-weighted TSE images as a triangular shaped structure of intermediate signal intensity *(continuous line)*, uniting the ischiopubic rami of one side to the other. Figure (b) Corresponding STIR image (b) showing at best the superficial transverse muscle of perineus as a hypointense horizontal structure *(dotted line)*. PM= perineal membrane; TPm =trasversus perinei muscle.

nous layer providing the fatty tissue of the labia majora, and attached laterally to ischiopubic rami and posteriorly to the free margin of the urogenital diaphragm. Between its inferior fascia and the perineal fascia is the perineal space which contains the ischiocavernous and bulbospongiosus muscles and the perineal body. The latter appears as a pyramidal hypointense, fibromuscular structure lying in the midline of the perineum, posterior to the vagina and anterior to the anal canal (see Figure 1 b). It provides an anchor point for several muscles including the deep and superficial transverse perinei, the external anal sphincter, the pubovaginalis and sphincter urethrae and is depicted at best on both T2-weighted images taken in the sagittal and in the oblique axial plane (Figure 8).

A complete summary of the MR anatomic features and parameters observed in the patient population is presented on Table 1 and 2.

DISCUSSION

The term *vagina* is derived from Latin *vāgīnae*, literally “sheath”. **Anatomically,** its precursor, called vaginal plate, derives from the growth of tissue that is located where the solid tips of the paramesonephric ducts (Müllerian ducts) enter the dorsal wall of the urogenital sinus as the Müllerian tubercle. Eventually, the central cells of the plate break down to form the vaginal lumen which is not fully canalized until sexual differentiation between males and females is completed. While the urogenital sinus persists as the vestibule of the vagina, two urogenital folds develop on the belly aspect of the genital tubercle giving rise to the labia minora, and to labioscrotal swellings which enlarge to form the labia majora.[9] Progressively, the human vagina develops into an elastic fibromuscular canal resembling a deflated tube approximately 7.5 cm long across the anterior wall (front), and 9 cm across the posterior wall (rear), making the posterior fornix deeper than the anterior. While the anterior and posterior walls are touching each other, the lateral walls, especially in their middle area, are relatively more rigid; because of this, the vagina has an H-shaped cross section. From the lumen outwards, three layers are commonly described in the wall of the vagina, as follows: an internal layer consisting of a mucosa of non-keratinized stratified squamous epithelium with an underlying lamina propria of connective tissue forming folds which are more prominent in the caudal third of the vagina and appear as transverse ridges whose function is to provide the vagina with increased surface for extension and stretching; an in-

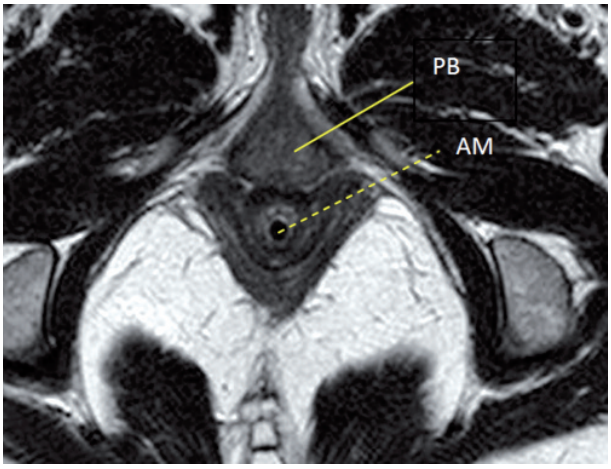


Figure 8. – Efficacy of the axial oblique plane for depiction of the perineal body *(continuous line)* as a distinct structure from the anal sphincter. The black dot *(dotted line)* indicates the intra-anal marker. PB= perineal body; AM= intra-anal marker.

Table 1. – Measurement of vaginal length, distal vaginal angle and perineal body position In nulliparous (Group A) and after cesarean delivery (Group B).

Parameter		Group A (n = 25)	Group B (n = 8)	*P* §§
Age (yrs)	mean range	31.3 28-35	34.1 31-40	n.s.
Parity (n°)		0	1.2 (1-3)	
Vaginal length (mm)	mean range	77.3 (3.2) 68.2 - 84.5	74.3 (5.2) 71.4 - 86.03	n.s.
Vaginal Angle (°)	mean range	70.1 (4.8) 58.2 - 76.4	74.04 (1.68) 61.1 - 78.2	n.s.
Perineal Body position (mm)	mean range	+ 3.2 (2.4) -4 /+6	+2.4 (1.8) -1/+6	n.s. n.s.

§ - Relative to the hymeneal plane - (above) or + (below); §§- *P* value .05; numbers in parenthesis are SD.

Table 2. – Visibility of vaginal and paravaginal anatomy at pelvic MRI in nulliparous and after cesarean delivery.

Observed structure	Item: Overall Image quality	Item: Organ definition	Item: Visibility score (€)	Scan plane
Vaginal wall	4	4	4	Axial
Vaginal shape				
Upper	4	4	4	
Middle	4	3	3	Axial
Lower	2	2	2	
Vaginal Inclination	4	4	4	Sagittal
Parametrium (ligmnt)				
Uterosacral	4	4	3	Axial
Cardinal	3	2	2	Axial
Round	3	3	2	Axial/Coronal
Paracolpium	4	4	4	Axial/Sagittal
Paraurethral (ligmnt)				
Periurethral	3	3	3	
Paraurethral	2	2	2	Axial
Pubourethral	3	3	2	
Endopelvic Fascia (Insertion)				
Iliococcygeus m.	4	3	3	Axial/Coronal
Obturator int. m.	4	3	3	Axial/Coronal
Pubococcygeus m.	3	3	3	Axial
Perineal Membrane	4	4	4	Coronal
Perineal Body	4	4	4	Sagittal

€ 1-4 point visibility score according to El Sayed.[7]

termediate layer of smooth muscle composed by an outermost layer of longitudinal muscle and an innermost layer of circular muscle with an oblique muscle fibers in between; finally, an external layer called adventitia consisting of thin dense layer of connective tissue blending with the loose connective tissue which contains blood vessels, lymphatic vessels and nerve fibers present between pelvic organs. **Functionally,** the vagina is known to expand in order to hold what's inside it, be the sperm released by male penis during sexual intercourse, a baby during vaginal delivery, or the menstrual flow which includes the unfertilized egg, blood and pieces of mucosal tissue. Less attention, however, has received the fact that, through its paravaginal connective tissues, the vagina acts as an adhesive "glue" which plays a vital role in maintaining the correct position and stability of pelvic organs relative to the pelvic side walls. More specifically the vagina, together with a series of fascial condensations arising from its lateral aspect (paracolpia) and some ligaments (parametria), is continuous with several muscular and connective structures, namely the levator ani muscle and the endopelvic fascia. The latter envelopes the entire vaginal canal, extending from apex to perineum. In his classic paper[5] DeLancey described the connective tissue support of the vagina as having 3 levels. Level I support is composed of the uterosacral/cardinal ligament complex that originates at the cervix and upper vagina and inserts at the pelvic sidewall and sacrum. This ligamentous complex suspends the uterus and upper vagina in its normal orientation. It helps maintain vaginal length and normal vaginal axis. Level II support comprises the paravaginal attachments that run through the length of the vagina and are suspended by the arcus tendineus fasciae pelvis (ATFP), a fibrous band that is attached in the front to the pubic bone and in the back to the ischial spine. Level III support is provided by the perineal membrane, perineal body, and superficial and deep perineal muscles, recently renamed by DeLancey as compressor urethrae and urethrovaginal sphincter. With regard to **imaging**, various techniques have been developed in search of accurate visualization and quantitative assessment of the vaginal canal, including vaginography combined with defecography[10] and transperineal sonography:[11] both are well suited for the static and dynamic examination but their drawbacks include high exposure to ionizing radiation and absence of information on surrounding soft tissue, and excessive dependence on operator skill, respectively. The advantages of MRI include non exposure to ionizing radiation, high soft-tissue contrast resolution and multiplanarity which allow clear depiction of all pertinent anatomy. First of all, the position of the hymen plane, which provides a universally accepted and consistently visible reference structure, could always be depicted clearly in the present study allowing easy identification of vaginal length, its orientation, and location of the perineal body. Hence, this reference line, coterminous with the clinical level described by Bump et al.,[6] seemed to us preferable when compared to the midpubic line (MPL), i.e. a line extending along the long axis of the pubic bone as proposed by Singh et al.,[12] because of the excessive variability in the inclination of the latter (see Figure 1a) potentially leading to erroneous measurements of established parameters and overdiagnosis of pelvic organ prolapse. Secondly, with regard to the vaginal morphology, there still seems to exist a lot of controversy in the literature and very little published data on normal pattern. Moreover, while some researchers reported that a flattened vagina on axial images is associated with loss of vaginal support,[13] evidence is given in the present paper that its cross sectional configuration depends mainly on the distribution of the paravaginal attachments and that three vaginal shapes could consistently be recognized in healthy subjects with no prior parity and after cesarean delivery, as follows: a linear-shape (91%) in DeLancey level I; an H-shape or, less frequently, a W-shape (74% and 26%, respectively) in level II; and an U-shape (82%) in level III. Overall, with regard to anatomical identification at axial MR imaging, the upper third linear vagina was the most easily seen (average visibility score, 4); the middle third vagina was the most peculiar and variable in shape (average visibility, score 3); the lower third U-shaped vagina was the most difficult to be recognized as a distinct structure from adjacent structures (visibility score, 2). In such cases, proper obliquity of axial scan planes proved helpful to distinguish the various structures (see Figures 6 and 8). Besides the ability to depict vaginal configuration, the most striking finding of the present study is definite demonstration that (a) cesarean section left unaltered the vaginal and paravaginal anatomy; and (b) fascial condensation such as uterosacral, cardinal and round ligaments were seen at MRI more than occasionally. However, the frequency with which they could not be seen in women with normal pelvic support of both groups (up to 40%) seems to indicate that lack of visibility *per se* does not prove their absence or even rupture. For these reasons, absent visibility of ligaments should be interpreted with caution before assigning a verdict of pelvic support defect by keeping in mind potential limitations which frequently occur such as variation in normal anatomy or superimposed bowel loops. A more specific consideration should be deserved to the issue of vaginal morphology according to body position. Most likely, vaginal shape, as depicted in the present paper, corresponds to that of women during sleeping and/or sexual intercourse rather than walking, as images were taken with a conventional (horizontally oriented) MR scanner. Presumably, it can be hypothesized that vaginal axis inclination and paravaginal orientation might appear differently in upright position. Lastly, according to the well known theory that the vagina undergoes significant changes in its passive mechanical properties throughout pregnancy which recover post partum,[14] it is interesting to note that no significant different values for vaginal and paravaginal structures were observed in the group of women of our study who received caesarian section when compared to nulliparous women.

CONCLUSIONS

The vagina is a fibromuscular tube capable of a high degree of distention, both during intercourse and particularly during childbirth, but also serves as the outlet for menstrual flow and is the primary supporting structure of female pelvic organs. Using high-resolution MR imaging with external coil allows visualization of vaginal and paravaginal attachments, fascial condensations called ligaments, and pelvic floor musculature with exquisite details in both nulliparae with normal pelvic support and in women who delivered by cesarean section. With no need for organ opacification for visualization, use of ionizing radiation or excessive dependence on operator skill and technology, precise visualization of MRI anatomy is the prerequisite for identifying normal features and discerning them from variations in the vaginal canal and its supporting structures. It is likely that early recognition of most common abnormalities might become the anatomic basis for interpretation of evacuation and voiding dysfunctions and will be important in patients with pelvic floor disorders for both selecting treatments and estimating their efficacy. These speculations need further investigation.

REFERENCES

1. Tunn R, DeLancey JO, Quint FF. Visibility of pelvic organ support system structures in magnetic resonance images without an endovaginal coil. Am J Obstet Gynecol 2001; 184: 1156-1163.
2. Chou Q, DeLancey JOL. A structured system to evaluate urethral support anatomy in magnetic resonance images. Am J Obstet Gynecol. 2001; 185: 44-50.
3. Tunn R, DeLancey JOL, Howard D, et al. Anatomic variations in the levator ani muscle, endopelvic fascia, and urethra in nulliparas evaluated by magnetic resonance imaging. 2003; 188: 116-121.
4. DeLancey JOL. Structural anatomy of the posterior pelvic compartment as it relates to rectocele. Am J Obstet Gynecol. 1999; 180: 815-823.
5. DeLancey JOL. Anatomic aspects of vaginal eversion after hysterectomy. Am J Obstet Gynecol 1992; 166: 1717–28.
6. Bump RC, Mattiasson A, Bo K, et al. The standardization of terminology of female pelvic organ prolapse and pelvic floor dysfunction. Am J Obstet Gynecol. 1996; 175: 10-17.
7. El Sayed RF, Morsey MM, El Mashed SM, Abdel-Azim MS. Anatomy of the urethral supporting ligaments defined by dissection, histology, and MRI of female cadavers and MRI of healthy nulliparous women. AJR 2007; 189: 1145-1157.
8. Kim JK, Kim YJ, Choo MS, et al. The urethra and its supporting structure in women with stress urinary incontinence: MR imaging using an endovaginal coil. AJR; 180: 1037-1044.
9. Cai Y. Revisiting old vaginal topics: conversion of the Müllerian vagina and origin of the "sinus" vagina. Int J Dev Biol. 2009; 53: 925-934.
10. Vanbeckevoort D, Van Hoe L, Oyen R, et al. Pelvic floor descent in females: comparative study of colpocystodefecography and dynamic fast MR imaging. J Magn reson Imaging. 1999; 9: 373-377.
11. Schaer GN, Koechli OR, Schuessler B, et al. Perineal ultrasound for evaluating the bladder neck in urinary stress incontinence. Obstet Gynecol. 1995; 85: 220-224.
12. Singh K, Reid WMN, Berger LA. Assessment and grading of pelvic organ prolapse by use of dynamic resonance imaging. Am J Obstet Gynecol. 2001; 187: 71-77.
13. Klutke C, Golomb J, Barbaric Z, Raz S. The anatomy of stress incontinence: magnetic resonance imaging of female bladder neck and urethra. J Urol. 1990; 143: 563-566.
14. Feola A. Impact of pregnancy and vaginal delivery on the passive and active mechanics of the rat vagina. Am Biomed Eng. 2011; 39: 549-558.

Correspondence to:
Vittorio Piloni, M.D. Radiologist
Iniziativa Medica - Imaging Centre
Via Rialto 14 - Monselice (Padova) - 35043 Italy
E-mail: vittorio.piloni@libero.it

Multidisciplinary UroGyneProcto Editorial Comment

To improve the integration among the three segments of the pelvic floor, some of the articles published in *Pelviperineology* 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.

UROLOGIST

The manuscript on normal MR vaginal morphology by Vittorio Piloni is an excellent example how to proceed with the evaluation of new diagnostic techniques or new application. Although applied to the pelvic floor since almost a decade no real objective evaluation and classification of MRI findings of the female pelvic floor has been performed.

There are primarily two important main objectives that need to be addressed, if imaging of the pelvic floor is evaluated:

1. Is it used to proof a theory or a hypothesis or a pathophysiological concept.
2. What is the clinical utility or the added value in everyday clinical practice, if compared to current techniques, such as pelvic ultrasound.

Addressing the first objective MRI is certainly a promising technique, as it has the capability of identifying structures that might not be visible with current techniques. In this regard the limitation of the MRI itself in the study have to be mentioned. The 1.5 T MRI apparently has limitations in the correct identification of ligamentous structures. This is elegantly described in the table 2 of the manuscript, which could serve as a reference table for further investigations in this field. Future developments and applications of higher levels of MRI (3 and more T MRI) could overcome low identification rates of certain anatomical structures such as cardinal ligaments, perineal body or endopelvic fascia (Wagenlehner et al. 2013).[1] Another important aspect is the dynamic part of anatomy. Functional MRI of the pelvis is an emerging and improving technique, which could be applied to correlate defective structures with defective function.

Addressing the second objective the added value is sometimes difficult to assess, as in urogynecology a careful investigation including history taking can enlight many clinical questions already (Wagenlehner et al. 2013).[2] Sonography also has improved considerably in the past decade, with regard to identifying important structures. However it has not come to the detail of identifying ligamentous structures, which are of paramount importance in the anatomy and functional processes of the pelvic floor (Wagenlehner et al. 2010).[3] In this aspect novel imaging by MRI could be very important, when defective ligamentous structures could be identified in relation to their functional importance. Exact diagnosis could then be used to guide site specific repair perhaps more accurate than only applying physical exam techniques and sonography.

REFERENCES

1. Wagenlehner FM, Del Amo E, Santoro GA, Petros P. Live anatomy of the perineal body in patients with third-degree rectocele. Colorectal Dis. 2013; 15: 1416-22.
2. Wagenlehner FM, Liedl B, Bschleipfer T, Petros PE. Comment on Nager: the urethra is a reliable witness: simplifying the diagnosis of stress urinary incontinence. Int Urogynecol J. 2013; 24: 1413-4.
3. Wagenlehner FM, Bschleipfer T, Liedl B, Gunnemann A, Petros P, Weidner W. Surgical reconstruction of pelvic floor descent: anatomic and functional aspects. Urol Int. 2010; 84: 1-9.

F. Wagenlehner
Clinic for Urology, Pediatric Urology and Andrology
Justus-Liebig-University Giessen, Germany
Florian.Wagenlehner@chiru.med.uni-giessen.de

GYNECOLOGIST

The pelvic floor remains a mystery for most clinicians. Until very recently, all anatomical knowledge has been derived from cadaveric dissections where the pelvic diaphragm is by definition collapsed. Live pelvic floor anatomy is vastly different from cadaveric anatomy. It is my belief that many of the problems which have arisen from large mesh implants can be traced back to the method of teaching, exclusively in cadavers. We, as practising surgeons, need to disregard cadaveric anatomy. The whole pelvic floor anatomy has now to be re-set in dynamic live anatomy terms. Dr Piloni is one of the pioneers of the imaging of pelvic floor anatomy. Works such as this on the anatomy of the vagina, its ligaments and muscles is critically important, because without normal reference points, we can never develop the methodology to accurately assess dysfunction Dynamic 2D transperineal ultrasound is cheap and helpful as regards understanding the movement of organs and muscles on coughing and straining. Unfortunately, dynamic transperineal ultrasound cannot be accurately measured. The other problem with 2D ultrasound is the potential for distortion of the image. MRI is considered more accurate, but even here, up to 40% of structures in Dr Piloni's images were not well defined. The more important question as regards imaging is "What are we looking for". What do we write on the imaging request form?

My own imaging investigations had two major objectives, to gain insights into pelvic floor function and dysfunction and to test the Integral Theory's predictions for truth or falsity.

Within this limited context, I would like to comment on some of Dr Piloni's findings based on my own investigations[1-4] and many thousand of transperineal ultrasounds over the past 20 years. I can confirm his findings that "the upper vagina had an horizontal, linear shape in over 91%; the middle vagina an H-shape".

We assessed the vaginal axis differently from Dr PIloni. We checked the organ compression normally seen on straining. During effort, the upper part of the vagina was stretched backwards and downwards against the perineal body. Compression of level 2 on standing lateral X-ray appeared to be related to the angle of the upper vagina to the horizontal at rest. In 23 patients in whom the angle was 450 or more to the horizontal, only 2 demonstrated significant angulation of the upper vagina and therefore compression of level 2 on straining. In contrast, all 27 patients with an angle less than 450 to the horizontal demonstrated both vaginal angulation and compression. In a live anatomical study, we examined the perineal body again differently from Dr Piloni. We measured its total length which averaged approximately 4 cm. The relevance of muscle forces to the three anatomical levels of support, the cardinal/uterosacral ligament complex (level 1), the rectovaginal fascia (level 2) and the perineal body (level 3), was analyzed. We found that the 3 directional forces operated normally even in the cases where the lax connective tissue prevented organ rotation and compression of level 2. We biopsied the suspensory ligaments. Histology demonstrated smooth muscle and nerves in the suspensory ligaments, indicating an active contractile role for these structures.

REFERENCES

1. Petros PE and Ulmsten U Role of the pelvic floor in bladder neck opening and closure: I muscle forces. Int J Urogynecol and Pelvic Floor, 1997; 8: 74-80.
2. Petros PE and Ulmsten U Role of the pelvic floor in bladder neck opening and closure: II vagina. Int J Urogynecol and Pelvic Floor, 1997; 8: 69-73.
3. Petros PE Vault prolapse 1: dynamic supports of the vagina, Int J Urogynecol and pelvic floor. 2001; 12: 292-295.
4. Wagenlehner F. M. E., Del Amo E, G. A. Santoro GA and P. Petros. Live anatomy of the perineal body in patients with third-degree rectocele. Colorectal Dis. 2013; 15: 1416-22.

P. Petros

St Vincent's Hospital, University of NSW, Sydney Australia

pp@kvinno.com

COLORECTAL SURGEON

The excellent paper on MR imaging of vagina, paravaginal attachments and ligaments, gives some ideas to Coloproctologists. Rectocele and rectoanal intussusception are related to changes of rectal morphologies and dynamics and inevitably there are also attendant alterations of vagina. MRI pelvic findings, measured as suggested by Vittorio Piloni, will be useful to evaluate the qualitative and quantitative alterations of vaginal morphology: the close connection between posterior wall of vagina and anterior wall of rectum will be better defined and it could help to choose the best surgical option, if prosthetic or resective. Moreover the MR evaluation of paravaginal attachments and ligaments offers a hint of truth on performance of these anatomic landmarks. The anatomic anchor of ligaments on vagina and rectum and their influence on rectal static will be better studied: simultaneous pathophysiology of pelvic organ prolapses and rectal diseases will be better understood. Thank you dr. Piloni!

Filippo Pucciani

Dipartimento di Chirurgia e Medicina Traslazionale

Università di Firenze

filippo.pucciani@unifi.it

AUTHOR'S REPLY

For some aspects, pelviperineologists seem to be a number of different inhabitants living around a lakeshore, with some of them standing side-by-side and others on opposite shores. Accordingly, different views and perspectives of the same reality are perceived by their eyes. Nevertheless, should a windy air drift arise from one side of the "lake", it will inevitably produce an effect on the other shore which, occasionally, could be even more resounding. This is the case which has been encountered with the two most common clinical problems , i.e. urinary incontinence and rectocele, with much debate between the involved specialists (urologist vs gynecologist, and gynecologist vs coloproctologist , respectively) including the issues of terminology, classification and treatment. Undoubtedly, the intuition of the Editor to obtain a comment on my paper from Petros, Wegenlehner and Pucciani was great: potentially, a hornet's nest might have been stirred up, ranging from interest to curiosity, indignation or controversy. As it would have been expected, however, rather than a unitary thought, just a sort of side-to-side dialogue between "neighbours" emerged, and no more than a trend towards the need for better integration of different specialists onto a mutual society. Probably, as a radiologist familiar with all the three physical sources of diagnostic imaging (X-ray, Ultrasonography, and MRI) my privilege comes from the capability to see through the barriers of pelvic floor compartments, thus overcoming the limitations of the other perineologists.