

As announced (*Pelviperrineology* 2011; 30:5) these are the second and third of a series of articles highlighting the different sections of the book "Pelvic Floor Disorders, Imaging and a Multidisciplinary Approach to Management" edited by G.A. Santoro, P. Wiczorek, C. Bartram, Springer Ed, 2010.

## Pelvic floor imaging

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The second section of the book "Pelvic floor disorders - Imaging and Multidisciplinary Approach to Management" is entitled "Pelvic Floor Imaging" and consists of six chapters describing the different imaging techniques of normal female pelvic floor.

In the first chapter "Endovaginal Ultrasonography: Methodology and Normal Pelvic Floor Anatomy" Santoro et al. describe the role of high-resolution three-dimensional endovaginal ultrasonography (3D-EVUS) in the assessment of pelvic floor structures including muscles and the levator ani complex, the lower urinary tract, and the anorectal region. The methodology of this examination is reported in details including patient preparation, and position, technique of examination and manner of performing measurements. Many types of ultrasound transducers have been developed for pelvic floor assessment (mechanical radial probes with 360° field of view, electronic biplanar probes with linear and transverse curved arrays, and endfire probes).

Endovaginal US performed with 360° rotational transducer gives an overall view of pelvic structures, allows their precise assessment and to perform reliable measurements. In the axial plane four standard levels for the evaluation are defined (Figure 1): Level 1: corresponding to the bladder base and the inferior one-third of the rectum; Level 2: corresponding to the bladder neck, the intramural part of the urethra, and the anorectal junction. At this level the levator ani muscle subdivisions (puboperinealis, puboanalis, pubovaginalis, puborectalis, iliococcygeus) can be identified; Level 3: corresponding to the inferior pubic rami and symphysis pubis, the midurethra, and the upper one-third of the anal canal; Level 4: corresponding to the superficial perineal muscles, the perineal body, the distal urethra, and the middle and inferior one-third of the anal canal. In the axial plane can be measured levator hiatus dimensions; paravaginal spaces area; pubovisceral muscle thickness; urogenital hiatus diameters and superficial perineal muscles lengths.

Endovaginal US performed with an electronic biplane 180° rotational transducer provides an accurate evaluation of urethral morphology (rhabdosphincter and urethral smooth muscle) and vascularity and gives images of the posterior compartment (internal and external anal sphincters, anorectal junction, perineal body, rectovaginal septum) in the mid-sagittal plane. Using this transducer, it is also possible a dynamic assessment during contraction or Valsalva maneuvers.

The second chapter "Translabial Ultrasonography: Methodology and Normal Pelvic Floor Anatomy" by Peter Dietz describes technical requirements, equipment, and the methodology of transperineal ultrasound (2D/3D/4D TPUS) in the diagnostics of pelvic floor and lower urinary tract disorders. A convex transducer (frequency 3.5- 8 MHz) is placed on the perineum providing midsagittal view

of the pelvic organs (symphysis pubis, bladder, urethra, vagina, anorectum). 3D data is obtained with the use of volumetric probe that combines an electronic curved array of 3-8 MHz with mechanical sector technology, allowing fast motorized sweeps through a field of vision. 4D-US implies the real-time acquisition of volume US data, which can be represented in multiplanar reconstructions or rendered volumes. 4D-TPUS performed during Valsalva maneuver allows to visualize downwards displacement of the pelvic organs, to reveal pelvic organ prolapse, and to demonstrate distensibility of the levator hiatus. Measurements of diameters and areas of the levator hiatus in this plane appear highly repeatable and correlate well with those obtained on MRI.

For the identification of levator trauma (detachment of the muscle from the inferior pubic rami) rendered volumes are used. However, the most reproducible method for identifying abnormalities of the puborectalis muscle at present seems to be tomographic or multislice imaging obtained during pelvic floor maximal contraction.

The third chapter entitled "Endoanal and Endorectal Ultrasonography: Methodology and Normal Pelvic Floor Anatomy" written by G.A. Santoro and G. Di Falco reports in details the technique of 3D-EAUS and 3D-ERUS performed with 360° rotational transducer. In the axial plane, the anal canal is divided in three levels: Level 1 (upper level): corresponding to the puborectalis sling, the deep part of the external anal sphincter (EAS) and the complete ring of the internal anal sphincter (IAS); Level 2 (middle level): at this level the superficial transverse perineal muscles and the two complete rings of the EAS and the IAS are identified; Level 3 (lower level): corresponding to the subcutaneous part of the EAS. The muscles of the lower and the upper part of the anal canal are different. The deep part of the EAS cannot be differentiated from puborectalis muscle posteriorly due to similar echogenicity. Moreover, the differences between genders exist in the anterior part of the EAS: it is symmetrical at all levels in males; while in females, it is shorter anteriorly, and there is no evidence of an anterior ring high in the anal canal. EAUS provides excellent measurements of sphincter dimensions, however its most relevant utility is the detection of localized sphincter defects.

Endorectal US is performed with a water-filled latex balloon covering the transducer in order to achieve good acoustic contact with the rectal wall and to have its adequate distension. Five layers are visualized: the first hyperechoic layer corresponds to the interface of the balloon with the rectal mucosal surface; the second hypoechoic layer corresponds to the mucosa and muscularis mucosae; the third hyperechoic layer corresponds to the submucosa; the fourth hypoechoic layer corresponds to the muscularis propria; the fifth hyperechoic layer corresponds to the serosa or to the

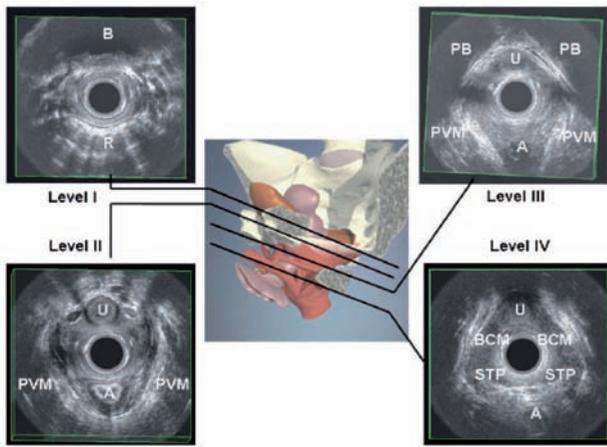


Figure 1. – Four standard levels of assessment of the female pelvic floor with 3D-EVUS. With the use of 360° rotational transducer. A-anal canal; B-bladder; BCM-bulbo-cavernosus muscle; PB-pubic bone; PVM-pubovisceral muscle; R-rectum; STP-superficial transverse perineal muscle; U-urethra.

interface with the mesorectum. 3D-ERUS is highly important in the staging of rectal cancer.

The fourth chapter “*Technical Innovations in Pelvic Floor Ultrasonography*” by Santoro et al. presents the most recent developments in the ultrasonographic imaging of the pelvic floor. Volume render mode (VRM) is a technique for analysis of the information inside a 3D volume by digitally enhancing individual voxels. Opacity, luminance, thickness and filter could be used as post-processing functions in order to provide better visualization of pelvic floor structures. Maximum Intensity Projection (MIP) improves the visualization of the spatial distribution and localization of urethral vessels, reducing the intensity of the gray scale voxels. Sculpting is a post-processing tool that allows to mark and to remove volume voxels, during off-line assessment. It can be performed in two ways: drawing an outline and removing everything within that outline or drawing an outline and removing everything outside this outline. It might facilitate the assessment of pelvic floor structures allowing comparison of the morphology in different disorders. Fusion imaging (simultaneous capturing of scans obtained by two different examinations - US/MRI) provides the information gathered by both modalities fused, compensating the deficiencies of one method and retaining the advantages of another one. PixelFlux is a dedicated software that allows an automated calculation of blood flow velocity, area of the vessels and perfusion intensity in arbitrary regions of interest (ROIs) of different organs. It can be used for the evaluation of vascular parameters in different part of the urethra in continent as well as incontinent patients. Motion tracking is a modality for the assessment of biomechanical properties of tissues and organs and it appears to be a feasible and valuable tool for the assessment of bladder neck mobility and the evaluation of the anorectal angle displacement during TPUS and Valsalva manoeuvre. Motion tracking provides quantitative assessment (displacement, velocity, acceleration, trajectory, motility, strain) of pelvic floor muscles, which allows to distinguish continent from incontinent females.

The fifth chapter entitled “*Magnetic Resonance Imaging: Methodology and Normal Pelvic Floor Anatomy*” by Jaap Stoker describes the MRI anatomy of the female pelvic floor or obtained with either an anatomical coil or an external phased array coil. On T2-weighted turbo spin-echo sequences, muscles are relative hypointense appearing grey on the images, ligaments and fascia are hypointense (black), and

fat and smooth muscles are hyperintense (white). The anatomy of the urethra and its supportive structure including endopelvic fascia, periurethral ligaments and compressor urethrae is precisely visualized by MRI such as the complex anatomy of the perineal body with its muscular and fascial attaching structures (longitudinal muscle, EAS, perineal membrane, superficial transverse perineal muscle, and bulbospongiosus).

The IAS is easily recognized on MRI as a circular hyperintense structure. The intersphincteric space is the fat-containing space between the IAS and the outer striated muscle layer. The longitudinal muscle is the continuation of the smooth muscle longitudinal layer of the rectum and courses through the intersphincteric space. The puborectalis muscle forms the upper outer striated layer of the anal sphincter and appears as a sling that opens anteriorly. Anal and rectal support as well as perineal membrane, pelvic diaphragm and levator ani morphology are also precisely described by MRI.

In the last chapter of Section II “*Technical Innovations in Magnetic Resonance Imaging of the Pelvic Floor*” Dominik Weishaupt and Caecilia S. Reiner present the role of dynamic MRI in detection and characterization of functional pelvic floor abnormalities. The authors describe their own imaging protocol, which starts with the sequences allowing the assessment of anatomy and continues with fast sequences enabling good visualization at squeezing, straining, and during defecation.

Development of fast multislice sequences, has resulted in the possibility of performing dynamic MRI of the pelvic floor. Due to the fact that the posterior compartment is traditionally in the focus of interest, it is often called MR defecography. Dynamic pelvic MRI may be performed in an open configuration MR system in the sitting position, or in a closed-configuration MR system in the supine position. Although, the sitting position is the physiological position during defecation, it has been reported that MR defecography in the supine position and in the seated position are

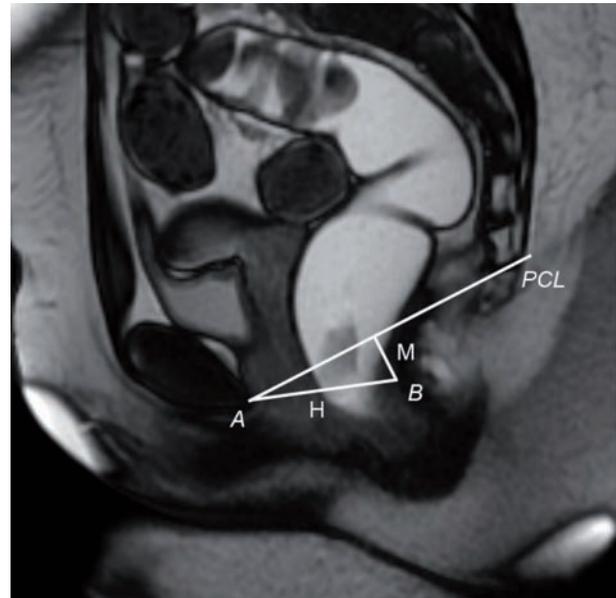


Figure 2. – Midsagittal balanced SSFP T2-weighted image, during straining with landmarks used in the HMO system. A-the inferior aspect of the symphysis pubis, B-the posterior wall of the rectum at the level of the ano-rectal junction. The H line (H) represents the anteroposterior hiatal width and extends from A to B. The M line (M) represents hiatal descent and extends perpendicular from the pubococcygeal line (PCL) to the posterior end of the H line.

equally effective in identifying most of the clinically relevant abnormalities of the pelvic floor.

Image analysis is performed for three compartments by the assessment of morphological changes at different pelvic floor positions. The most commonly used reference line for image evaluation is the pubococcygeal line (PCL), defined on midsagittal images as the line extending from the inferior border of the symphysis pubis to the last or second-last coccygeal joint. The length of the bladder base, the cervix, or vaginal vault, and the ano-rectal junction is measured at a 90° angle to the PCL in the different pelvic floor positions. To determine pathologic pelvic floor descent, the measurements are made on the images showing maximal organ descent.

Another system for grading pelvic floor abnormalities is the "HMO system". This system distinguishes pelvic organ prolapse and pelvic floor relaxation. In pelvic floor relaxation, the pelvic floor becomes weakened, leading to hiatal

descent and widening. The degree of pelvic floor relaxation is measured with two reference lines: the H line, representing hiatal widening and extends from the inferior aspect of the symphysis pubis to the posterior wall of the rectum at the level of the anorectal junction, and the M line, representing hiatal descent and extends perpendicularly from the PCL to the posterior end of the H line (Fig. 2). Abnormal pelvic floor relaxation is present, when the H line exceeds 6 cm, and when the M line exceeds 2 cm.

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## Pelvic floor damage due to childbirth

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The *third section* of the book "Pelvic floor disorders - Imaging and Multidisciplinary Approach to Management" is entitled "Pelvic Floor Damage Due to Childbirth" and consists of three chapters describing mechanisms of pelvic floor trauma during vaginal delivery as well as ways of prevention.

In the first chapter "Mechanisms of Pelvic Floor Trauma during Vaginal Delivery" Minini et al. describe physical consequences of vaginal childbirth, which may vary from mild subclinical conditions to significant severe pathologies appearing immediately or in the long-term. Among various events during woman's lifetime affecting muscles of the pelvic floor and other supporting structures of the pelvic organs, pregnancy, childbirth, menopause and ageing have got the most pronounced influence on damage of pelvic organs. The long-term gynecological sequelae of pelvic floor weakness are pelvic organ prolapse, stress urinary incontinence, dyspareunia, fecal incontinence, and perineal pain.

Pelvic organ prolapse is a common condition affecting up to 15% of the female population and is responsible for about 20% of women on waiting lists for major gynecological surgery. The main risk factors associated with prolapse are parity and increasing age, while smoking and obesity are secondary factors. Parity shows the strongest correlation to prolapse as women who delivered four or more babies vaginally are found to have 11 times risk of significant pelvic organ prolapse compared to nulliparous women.

Rates of urinary incontinence range from 20% to 30% in the general population. Risk factors for the development of urinary incontinence are ageing and childbirth. Stress incontinence is more common in parous women compared with nulliparous women. Urinary symptoms are found antenatally in up to 60% of pregnant women. Postnatally, the reported prevalence of urinary incontinence varies from 6% up to 34%, and its increase is observed during pregnancy, immediately after birth, and with age 30 years or greater at the time of the second vaginal delivery.

Physiologically the uterus and vaginal apex are supported by a muscular component, requiring an intact nerve supply, and by a fascial component. Damage of any of these structures can lead to prolapse of the pelvic organs. Three factors are implicated in the etiology of prolapse and stress urinary incontinence: myogenic damage, neuromuscular injury, and damage to the endopelvic fascia. Damage of the nerve supply of the pelvic floor caused by childbirth may determine progressive denervation of the musculature. Subsequent reinnervation of the pelvic floor leads to an altered function. Trauma may affect the pudendal nerve and its branches, the anal sphincter, the levator ani complex, or the pelvic fascial structures.

Many women undergo significant trauma to pelvic floor structures as a consequence of attempts at vaginal delivery. Many risk factors for perineal damage at delivery have been identified, among which the most important are multiparity, forceps application during operative delivery, sacral rotation of the occiput, prolonged second stage of labor, epidural analgesia, third-degree tears, and fetal macrosomia. Some forms of trauma may also occur as a result of rapid labor. Regarding prolapse, pregnancy and childbirth are well documented as major risk factors.

The identification of women at high risk for delivery-related pelvic floor trauma should be a priority for everyday good clinical practice. Obstetric perineal damage cannot be avoided, but it certainly can be limited, by means of preventive strategies and therapeutic improvement: that is perineal risk factors, improving assistance, and timely rehabilitation.

The second chapter entitled "Posterior compartment disorders and management of acute anal sphincter" written by Abdul H. Sultan and Raneer Thakar focuses on obstetric trauma to posterior compartment. The posterior compartment consists of all the structures that include the posterior vaginal wall and structures posterior to it. During the process of vaginal delivery, fascia, muscles, and nerves may be stretched or disrupted. However, while these changes could

be attributed to the physiological process of childbirth, in some women they can lead to pathological events with long-term consequences. Obstetric trauma to the posterior compartment has been implicated in the development of rectoceles, perineoceles, and fecal incontinence. However, as many women develop these conditions many years after childbirth, either a direct link to its causation is not considered or it is attributed to the effects of ageing or the menopause.

A rectocele may be the result of overdistensibility of an intact rectovaginal septum, disruption of the perineal membrane and detachment from the perineal body. It remains to be established whether modification of obstetric practice, and in particular meticulous restoration of the perineal and vaginal anatomy when repairing episiotomies and genital lacerations, may minimize the development of rectoceles.

Obstetric anal sphincter injuries (OASIS) are reported to occur in 1.7% (2.9% in primiparae) of women in center where mediolateral episiotomies are practiced, compared to 12% (19% in primiparae) in centers practicing midline episiotomy. In order to standardize the classification of perineal trauma, Sultan proposed the following classification that has been adopted by the Royal College of Obstetricians and Gynaecologists and also recommended by the International Consultation on Incontinence.

Obstetric trauma to the posterior compartment can result in pelvic floor denervation, disruption of the fascial supports, and injury to the anal sphincter. Injuries to the anal sphincter can give rise to anal incontinence, and therefore accurate detection and diagnosis of the full extent of the injury is mandatory at delivery. Repair of OASIS should only be conducted by a doctor who has been formally trained (or under supervision) in primary anal sphincter repair and the aim should be to restore the normal high-pressure zone of the anal canal represented by the anal length. Failure to identify and repair the internal sphincter at the time of the acute injury will increase the risk of fecal incontinence and jeopardize the ability to repair at a later date. Attention needs to be focused on training of doctors and midwives internationally in the identification and repair of OASIS.

In the third chapter "*Prevention of perineal trauma*" authors Abdul H. Sultan and Raneer Thakar describe how obstetrical perineal trauma might be minimized. Proven strategies include the practice of perineal massage in the antenatal period, delayed pushing in the second stage of labor with an epidural in situ, restrictive use of episiotomy, preference of a mediolateral over a midline episiotomy, and the use of a vacuum extractor instead of forceps for instrumental delivery.

Perineal trauma may occur spontaneously during vaginal birth or when surgical incision (episiotomy) is intentionally made to enlarge the diameter of the vaginal outlet. Approximately 85% of women sustain some form of perineal trauma during vaginal delivery. The prevalence of perineal trauma is dependent on variations in obstetric practice, including rates and types of episiotomy.

Perineal massage during the last month of pregnancy may increase the flexibility of the perineal muscles, leading

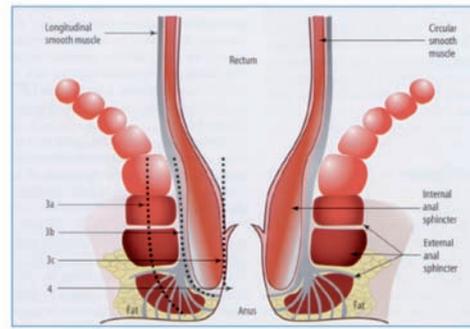


Fig. 13.2 Diagrammatic representation of the anal sphincters demonstrating the classification of major degrees of perineal tears (3a-e and 4). Reproduced from [9], with permission

to a reduction in muscular resistance. This would allow the perineum to stretch at delivery without tearing, thereby avoiding the need for episiotomy. Water birth shows no significant difference in second-, third-, or fourth-degree tears, instrumental delivery, or sectarian section. Whether the upright or lying down position during labor and birth can be beneficial is still controversial. The method of pushing during second stage of labor plays an important role in prevention of perineal trauma - passive descent increases a woman's chance of having a spontaneous vaginal birth, decreases the risk of having instrumental delivery, and shortens the pushing time. Systematic vaginal application of obstetric gel shows significant reduction in second-stage duration and a significant increase in perineal integrity, without any adverse effects. Perineal warm packs potentially reduce risk of perineal trauma and increase comfort during late second stage of labor due to dilatation of blood vessels, increasing blood flow, and reducing the level of nociceptive stimulation, and collagen extensibility. Second-stage perineal massage does not decrease perineal trauma, postpartum pain, or urinary or anal incontinence.

Among proposed techniques reducing perineal trauma antenatal pelvic floor muscle training, epidural analgesia, head flexion, and active restraint of delivery of the head are described.

Obstetric perineal trauma can have a devastating effect on a woman's social life, with associated psychological sequelae. It is important to implement interventions that may be used to minimize perineal trauma. While cesarian section may eradicate perineal trauma, it is associated with an increased risk of mortality and morbidity and therefore should only be offered selectively.

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