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BEYOND IMAGINATION: INTEGRATED IMAGING APPROACH TO PELVIC FLOOR DISORDERS

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Pelvic floor disorders (PFD) represents a significant social and economic problem involving about 25% of women older than 60 years with a 13% lifetime risk of undergoing surgery for PFD. Optimal management is impossible without comprehensive assessment of pelvic floor and multimodal approach. A combination of ultrasonic methods has several advantages (low cost, wide accessibility and availability, office procedure performed by clinicians, intraoperative technique, relatively time consuming, good compliance) and should be performed as first-line assessment in PFD.

[Key words: Pelvic floor disorders, pelvic organs prolapse, obstructed defecation, pelvic floor ultrasound]

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Pelvic floor (PF) is one of the most complex anatomical and functional areas of the human body [1,2]. Despite it is still artificially divided in anterior, middle and posterior compartments, PF acts as a unit and therefore should be approached with on holistic vision. Pelvic floor abnormalities due to obstetric trauma, pelvic surgery, aging, hormonal status, lead to a variety of disorders, such as vaginal bulge, pelvic organs prolapse (POP), voiding or defecatory dysfunctions, urinary (UI) or anal incontinences (AI), chronic pelvic pain and sexual dysfunction, that frequently coexist (multicompartmental disorders), severely affecting quality of life [3-10]. As consequences, PF should be approached with a unitary vision by a multidisciplinary team of colorectal surgeons, urologists, urogynecologists and radiologists.

Pelvic floor disorders (PFD) represents a significant social and economic problem It is estimated that 25% of women older than 60 years suffer from some degree of PFD, and more than 300.000 operations for PFD are performed annually in the US only [1,2]. Women in the United States have a 13% lifetime risk of undergoing surgery for PFD [3]. Although PFD can occur in younger women, the peak incidence of PFD symptoms is in women aged 70-79 years [4]. Reliable assessment of the anatomy of the pelvis in PFD is frequently difficult by physical examination alone. Anterior or posterior vaginal wall prolapse may be identified clinically and described by using POP quantification system (POP-Q) however the organs prolapsed into the «sac» (bladder, uterus, rectum, sigmoid colon, small bowel) or the coexisting damages of the anatomical structures of support (levator ani muscle, endopelvic fascia, pubocervical fascia, rectovaginal fascia, uterosacral or cardinal ligaments, perineal body and perineal membrane) are very challenging to be detected by the urogynecologist or the colorectal surgeon [9, 10]. Moreover, a single symptom such as obstructed defecation (OD), can be due to a variety of «occult» conditions often underestimated, rather than to what it is clinically evident, as reported in the «iceberg diagram» by Pescatori et al. [11]. These causes, if present, are not uppermost in patients' consciousness and must be searched for by the clinician, before recommendation for treatment.

Imaging plays an important role to go beyond imagination. It provides a better understanding of the pathophysiology of PFD, visualizing abnormalities undetected by the clinicians and/or confirming clinical findings to correlate with symptoms [12-15]. Although, in recent years, new techniques have been dramatically improved the diagnostic accuracy in patients with PFD, there is still no single modality than can provide a comprehensive overview of the PF. In order to obtain as much information as possible, it is therefore fundamental an integration of different techniques (x-ray, ultrasound and magnetic resonance imaging) to overcome the limitations of each method (Fig. 1).

Evacuation proctography (EP) is the traditional modality used by colorectal surgeons to assess the causes of OD syndrome (ODS): rectal prolapse, rectocele, intussusception, anismus. In the urogynecology setting, it is frequently used in a modification called cysto-urethro-colpo-defecography and it requires the administration of contrast medium per os and in the bladder, vaginal lumen and distal colon. The movement of contrasted pelvis organs at rest, during evacuation phase and squeezing is referred to the pubo-coccygeal line (PCL).

Routine use of ultrasound (US) techniques is an useful adjunct to clinical investigation and allows to

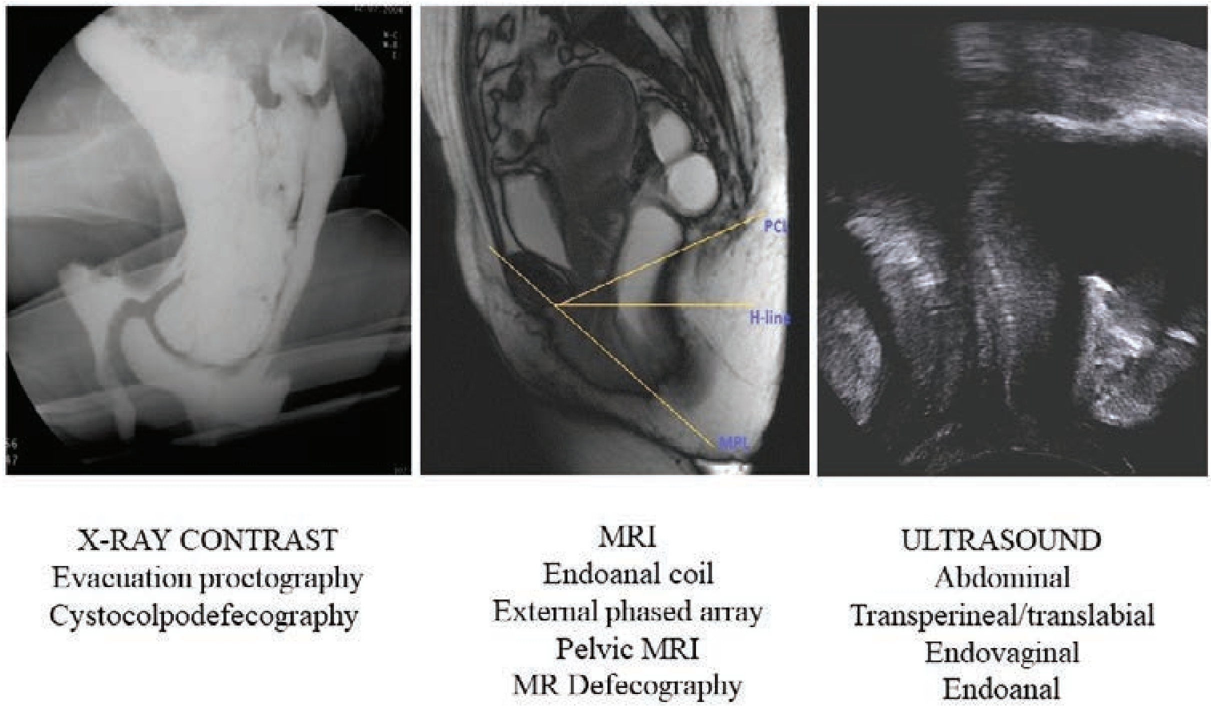

Figure 1. *Imaging modalities for pelvic floor assessment*

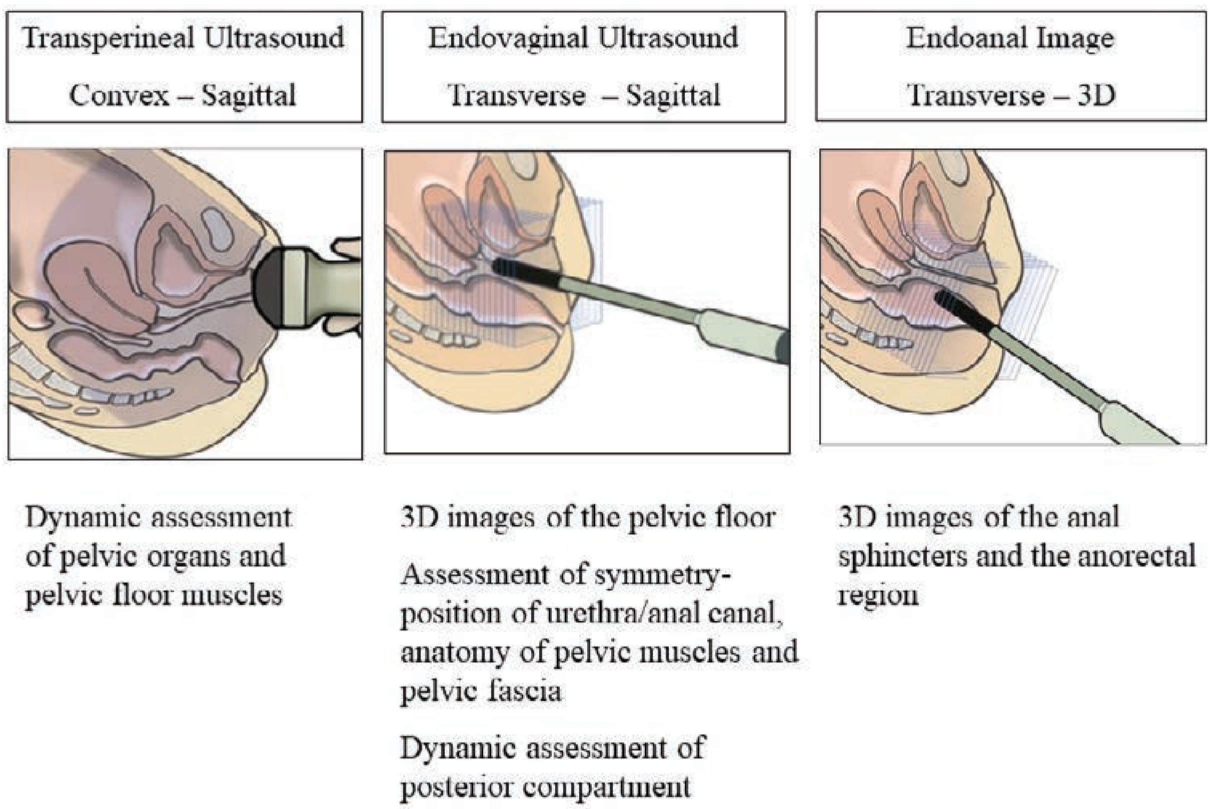

Figure 2. *Ultrasound modalities for pelvic floor assessment*

assess multicompartmental disorders. In most cases ultrasound imaging is adequate to select a correct management, reducing the number of unnecessary surgeries and thus, minimizing the risk of failures, as well as faster and more effective treatment of post-operative complications. Pelvic floor US (PFUS) may be performed with endovaginal (EVUS), transperineal/translabial (TPUS/TLUS), endoanal approaches (EAUS) [16] (Fig. 2).

Technological innovations such as high-resolution 3D or 4D ultrasound, new software options and data post-processing capabilities, have further increased the accuracy of this procedure. TPUS/TLUS is usually performed by convex transducers with 2-6 MHz frequency range or by endovaginal end-fire transducers with 6-10 MHz frequency range. It enables visualization of the pelvic organs in the sagittal, oblique and transverse sections [12,17] at rest and during dynamic maneuvers (Fig. 2). It main aim is to assess the contraction and relaxation of the levator ani/puborectalis muscle, the dimension of the levator hiatus, the mobility of the urethra and bladder neck, the displacement of the pelvic organs during maximal squeezing and straining [12, 17] (Fig. 3). Stress urinary incontinence (SUI), cystocele, enterocele and rectocele severity, pelvic floor dyssynergy, position of implanted tapes or meshes can all be evaluated by this modality. Three-dimensional/four dimensional US, surface and volume render mode (SRM, VRM), multiplanar reconstructions (MPR) or tomographic ultrasound imaging (TUI) provide further assessment of the pelvis at selected levels including position of urethra, vagina and anus in the axial plane, symmetry between each other and compared to pubic symphysis, evaluation of levator ani muscle and its attachment to the inferior pubic rami, measurement of biometric indices of levator hiatus [18-20] (Fig. 3).

3D TPUS/TLUS is mainly used to visualize defects of the levator muscle components and to measure the urogenital hiatus in both nulliparous and multiparous women with PFD which are correlated to organ prolapse severity and are risk factors for recurrence after surgery [21-23]. The simultaneous assessment of three perpendicular planes can also be performed real-time (4D US). Axial images of the pelvis with high frequency 3D EVUS (9-16 MHz) are similar to those with 3D TPUS, however, the higher frequency provides better resolution of the examined structures [24]. High resolution 3D EVUS allows an accurate evaluation of the symmetry between urethra and the anal canal, the morphology of the urethra (rhabdosphincter, lisosphincter) and of the supporting ligaments and fascia [25], the levator ani muscle subdivisions [26], the indices of levator hiatus (area, length and width) 27], the integrity of the perineal body and the rectovaginal fascia [28], the post-operative evaluation of tapes and meshes to identify displacement, shrinkage, fluid collections, abscesses or hematomas (Figs. 2-3). EVUS performed with electronic biplane transducer (type 8848 B-K Medical) or linear electronic transducer (type 8838 B-K Medical) allows a dynamic assessment of the anterior and posterior compartment [12]. By asking patient to squeeze and to strain, it is possible to detect urethral hypermobility, cystocele, rectal prolapse, rec-

Modality	Probe	Frequency	Imaging planes	Dynamic study	Urethra vascularity	LA/PR LH measure	UGH Perineal muscles	Anterior compart.	Central compart.	Posterior compart.
2D-TPUS	Convex	3-6 MHz	Sagittal Coronal	√		√	√	√	√	√
3D-TPUS	Convex	3-8 MHz	Axial Tomographic			√	√	√	√	√
4D-TPUS	Convex	3-8 MHz	Axial Tomographic	√		√	√	√	√	√
2D-EVUS	Biplane	5-12 MHz	Sagittal Axial	√	√			√		√
3D-EVUS	Biplane 180° rotational	5-12 MHz	Multiplanar		√			√		√
3D-EVUS	360° rotational	9-16 MHz	Multiplanar			√	√	√		√
3D-EAUS	360° rotational	9-16 MHz	Multiplanar				√			Anal sphincters

Figure 3. *Combination of different US modalities for the integrated, multicompartmental assessment of pelvic floor (2D: two-dimensional; 3D: three-dimensional; EAUS: endoanal ultrasound; EVUS: endovaginal ultrasound; LA: levator ani; LH: levator hiatus; PR: puborectalis muscle; TPUS: transperineal ultrasound; UGH: urogenital hiatus)*

tocele, intussusception, enterocele and anismus [12]. 3D-EAUS performed by high multifrequency 360° rotational probes has become the first step of imaging in proctology for the assessment of perianal fistulas and for the preoperative staging of anorectal cancers [29] (Fig. 2). It is the «gold standard» investigation of anal sphincter integrity in patients with obstetric anal sphincter injuries (OASIS) [30] or fecal incontinence [31-33], allowing accurate measurements of the anal sphincters and differentiation of abnormalities (thickening, thinning, atrophy, scars, defects) [12]. 3D dynamic endorectal US (echodefecography) also allows to identify dysfunctions of the posterior compartment such as rectoceles, intussusception, mucosal prolapse and paradoxical contraction (anismus) as well as of the middle compartment (enterocele/sigmoidocele) [34].

Static Magnetic Resonance (MR) provides a comprehensive visualization of all pelvic structures [32] (Fig. 1). It is performed at a magnetic field strength of 1.5 Tesla (T), using pelvic or phased-array coils and T2-weighted fast-spin echo (FSE) sequences. The spatial resolution can be enhanced by using endoluminal (endorectal, endovaginal) coils. In combination with T2-weighted FSE sequences, endoluminal coils provide improved signal-to-noise ratio (SNR) and high resolution images. The prominent PF structures of the posterior compartment visualized at MR are the perineal body, the superficial perineal muscles, the anal sphincters, the puborectalis muscle and levator ani, the rectum and the rectal support. With the development of fast multi-slice sequences, MR has gained increasing acceptance for dynamic imaging of the posterior compartment (MR defecography) [33]. Piloni et al. [35] described the methodology of this technique, the diagnostic criteria and grading for ODS. The proposed system in five grades of combination of abnormalities seen at MR-defecography was correlated to therapeutic options. Recently, diffusion and tractography MRI techniques [36,37] have been introduced in the diagnosis of PFD.

In 2010, an IUGA/ICS joint report on the terminology for female pelvic floor dysfunction [32] stated that US has become an increasingly frequent adjunct investigation in urogynecology and female urology both in the office and in the urodynamic laboratory allowing assessment of postvoid residuals, intercurrent pelvic pathology, uterine version, bladder or urethral abnormalities. Six years later, an IUGA/ICS joint report on the terminology for female POP [33] stated that imaging may assist the clinical assessment of POP or intercurrent PFD. The use of any of the different imaging modalities is, however, entirely optional. In 2017, an IUGA/ICS joint report on the terminology for female anorectal dysfunction defined the role of imaging in the diagnosis and management of posterior compartment disorders [38]. Ultrasound has been increasingly incorporated as a useful investigation in patients with AI, anal pain and ODS. The 6th ICI, based on the concept that pelvic organ dysfunction includes multiple conditions, proposed integrated PFUS with a combination of different modalities (2D, 3D, 4D, dynamic as well as EVUS, EAUS, TPUS) for a global and multi-compartmental perspective [39] (Figs. 2-3). However, the values of this approach in routine assessment of PFD is yet to be evaluated [39]. Clinicians are increasingly adopting a more holistic approach with a combination of different US modalities for a multicompartmental assessment of PFD [12] (Fig. 2). Lone et al. [40] found a good to excellent agreement between two examiners in the evaluation of all three compartments and suggested that multicompartment PFUS should be considered as a systematic integrated approach to assess the PF.

Ultrasound has several advantages (low cost, wide accessibility and availability, office procedure performed by clinicians, intraoperative technique, relatively time consuming, good compliance) and should be performed as first-line assessment in PFD [41]. Dynamic US (TPUS/EVUS/Echodefecography) has the potentiality to replace EP in the evaluation of ODS, allowing to differentiate enterocele, rectocele, internal intussusception, mucosal rectal prolapse and paradoxical anal sphincter and puborectalis contraction (anismus) [12]. Electronic transducers with Color Doppler mode provide information on the vascularity of the urethra, which is characterized by different flow parameters [42-45]. Vascular abnormalities may be related to UI. Ultrasound has also been demonstrated useful in the postoperative assessment of the position of mesh and sling. Transobturator (TOT) or transvaginal (TVT) tapes positioned between 50 and 80 percentile of urethra length resulted in a success rate of 91% in patients with SUI [46].

MR provide a comprehensive evaluation of the PF, however still has limited accessibility, high cost and requires highly specialized equipment and qualified medical staff. It should be considered as second-line assessment tool after ultrasound. In highly specialized urogynaecological centers, dynamic MR defecography replaced EP, enabling not only to reduce exposure to radiation, but also to obtain a much larger dose of information compared to the traditional X-ray study [35,47,48].

Van Gruting et al. [49] evaluated the diagnostic accuracy of EP, MR, TPUS and EVUS for detecting posterior compartment disorders in patients with ODS. There was no optimal test, however all imaging modalities showed similar accuracies. Because TPUS and EVUS had good accuracy and the best patient acceptability, the Authors proposed that these techniques should be used as initial screening tools in ODS. In another study, Van Gruting et al. [50] compared 2D and 4D TPUS in order to assess if 4D technique has additional value in the diagnosis of ODS. They found no superiority of 4D over dynamic 2D US and concluded that these two techniques could be used interchangeably to screen women with ODS. Hainsworth et al. [14] compared the accuracy of integrated total PFUS (transperineal, transvaginal, endoanal) to defaecatory MR. The results supported the use of integrated US as a screening tool for defaecatory dysfunction. When normal, defaecatory MR can be avoided, as rectocele, intussusception and enterocele are unlikely to be present.

In conclusion, history, use of questionnaries and physical examination based on POP-Q system to define the grade of anterior and/or posterior vaginal prolapse are still considered adequate to select surgical treatment of POP [51]. However, patient's symptoms don't always correspond to physical examination findings, because rather than to what it is clinically evident, a variety of coexisting occult conditions are often underestimated [11] and must be searched for by the clinician before recommendation for surgery. Imaging plays an important role to provide detailed structural and dynamic information of the PF which can be correlated with clinical examination. Integration and combination of different imaging modalities allows a comprehensive assessment of the anatomic damages and dysfunctions of the PF and overcomes the fractured uni-disciplinary approach, guiding to an optimal management (Fig. 1). Standardization of techniques and unified multidisciplinary diagnostic and therapeutic algorithms will lead to a wider acceptability of imaging in the routine clinical practice. Due to accessibility, compliance, accuracy, cost, time consuming, office or intraoperative procedures, PFUS should be considered as the first-line technique. Evacuation proctography and pelvic floor MR may be indicatedas second-level of assessment in selected cases when US findings are not exhaustive.

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