Original article

Freehand acquisition of 3D transperineal pelvic floor volume does not yield accurate measurements

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Abstract: Objective: Abstract: Objectives: Assess the accuracy of freehand 3D Transperineal ultrasound (TPUS) compared to 3D endovaginal ultrasound (EVUS) for obtaining pelvic floor measurements. *Methods:* We compared 30 freehand 3D transperineal ultrasounds and 360 degrees endovaginal ultrasounds of patients referred to our clinic with different urogynecologic symptoms during January-June 2011. The minimal levator hiatus (MLH) height (AP), width (RL), and area were obtained by 3D transperineal and endovaginal ultrasound. *Results:* A total of 60 3D volumes (30 for each modality) were reviewed . The mean age of women in our study group was 52.36 years (SD ± 15.86), median parity 2 (range 0-5). The median stage of prolapse was 1 (range 0-3). The mean weight was 166.16 pounds (SD ± 59.07). The mean MLH height, width and area in TPUS measurements were 60.72 mm (SD ±9.30), 54.17 mm (SD ±11.10), and 26.16 cm^2 (SD ±7.72) respectively. The mean MLH height, width and area in EVUS measurements were 51.54 mm (SD ±6.36), 37.41 mm (SD ±5.86), and 15.08 cm^2 (SD ±3.67) respectively. Bland Altman analyses of each measurement demonstrated that the two modalities do not consistently provide similar measurements. *Conclusions:* Our study demonstrated that freehand acquisition of 3D transperineal volumes does not provide accurate measurements when compared to 3D endovaginal ultrasonography.

Key words: Transperineal Ultrasound; Endovaginal Ultrasound; Minimal Levator Hiatus; Pelvic Floor; Levator Ani Muscle.

INTRODUCTION

Growing awareness of pelvic floor disorders over the last two decades has led to development and introduction into clinical practice of new imaging techniques; with increasing importance of ultrasonography. Endoanal, endovaginal, and transperineal approaches, using both 2-dimensional and 3-dimensional (3D) imaging, have been used for evaluation of the anatomy of the pelvic floor. Endoanal ultrasonography is recognized as the gold standard for evaluation of the anal sphincter complex.[1] 3D Endovaginal ultrasonography (EVUS) has gained popularity in the evaluation of patients with pelvic floor disorders since it provides valuable anatomic information about the levator ani muscles, anterior and posterior compartments, and minimal levator hiatus.[2-7] Many Urogynecology and Colorectal centers that utilize 3D EVUS and 3D EAUS (BK ultrasound, Peabody, MA, USA), also perform a freehand acquisition of a 3D transperineal volume as a quick overview because the system does not provide an automatic transperineal transducer as with GE (Waukesha, WI, USA) or the other manufacturers (Figure 1). The problem with standardization of image acquisition technique is long recognized and worthy of attention since we need a common language to interpret the results.[8, 9] It is not known whether freehand acquisition will provide equivalent measurements of static images of pelvic floor anatomy, compared to 3D EVUS. In this study we aimed to assess the accuracy of freehand 3D transperineal ultrasound (TPUS) compared to 3D EVUS measurements which have been shown to be repeatable with good inter and intraobserver reliability.[7]

METHODS

Our study had IRB approval at our institution and informed consents were signed by patients. Freehand 3D TPUS and 3D EVUS volumes obtained from 30 patients who were referred to our Urogynecology clinic with various pelvic floor complaints between January–June 2011 were reviewed. Our inclusion criteria were completed charts and good quality of ultrasound volumes. "Good quality" 3D TPUS and 3D EVUS were defined as the ability to visualize the pubic bone and the levator plate in the sagittal view. We screened ultrasound volumes from 200 patients and we chose the first 30 patients that had best 3D volume quality for both ultrasound modalities. 30 3D TPUS and 3D EVUS volumes from the same patients were available for comparison.

3D Transperineal Ultrasonography (TPUS)

All 3D TPUS examinations were performed with the patient placed in the dorsal lithotomy position, with hips flexed and abducted, and a convex transducer positioned on the perineum between the mons pubis and the anal margin (perineal approach). We used the BK 3D convex 8802 frequency 4.3-6 MHZ probe, which has a focal range of 6-114 mm. To obtain 3D images, the probe was manually moved to sweep the pelvic floor structures in a constant speed from right to left in 30 seconds (Figure 1A), which is consistent with the standardized method described by the manufacturer and for which the software was designed. All volumes were obtained at rest. The 2D transperineal approach allowed visualization of the bladder neck and the mobility of the urethra and anorectum. During the examination, the patient was asked to perform a Valsalva maneuver and contract her pelvic floor muscles to facilitate dynamic imaging of the anatomical structures.[2]

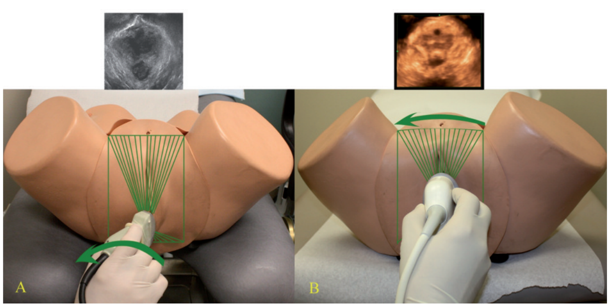

Figure 1A. - Freehand 3D transperineal ultrasound shows freehand movement of probe. The hand sweeps from patient's left to right at a constant speed to obtain a 3D volume.
Figure1B. - TPUS shows automatic movement of probe. Neither the hand, nor the transducer move, the 3D volume is obtained by internal rotation of the transducer crystals.

3D Endovaginal Ultrasound (EVUS)

3D EVUS was performed on the same patient in the same position after completion of 3D TPUS. A high multi-frequency (9-16 MHz), 360 degrees rotational mechanical probe (type 2050, B-K Medical) was used for all 3D EVUS examinations. The transducer was inserted into the vagina in a neutral position and excessive pressure on surrounding structures was avoided to prevent distorting the anatomy. 300 axial images obtained every 0.2 mm along a 6 cm course were compiled to create a 3D volume.

Measurement protocols

Minimal levator hiatus (MLH), width (MLH RL), height (MLH AP), and area were measured in all 3D TPUS and 3D EVUS volumes in the same manner. To obtain the measurements, the 3D TPUS and 3D EVUS volumes were rotated to position them in an anatomically correct orientation as if the patient was lying down with the mid-sagittal view facing the reader. In order to find the minimal levator hiatus, we located the shortest line between the pubic symphysis and the levator plate (Figures 2, 3). The anterior posterior (AP) line of the minimal levator hiatus was drawn. The axial plane was rotated posteriorly and was advanced cephalad parallel to the AP line (Figure 4). The mid-sagittal plane was expanded to make the whole volume visible (Figure 5). Minimal levator measurements (height, width, and area) were obtained in this plane, the "minimal levator hiatus plane" (Figure 6). LR was measured at the widest area of the minimal levator hiatus.

Statistical Analyses

SAS v9.2 (SAS Institute, Cary, NC) was used for all statistical analyses. Summary statistics were calculated for the patient population. Bland Altman analyses were used to measure agreement between the two ultrasound modalities. A range of agreement was defined as mean bias ±2 SD.

RESULTS

30 TPUS and 3D EVUS volumes from the same 30 patients were reviewed. The mean age of women in our study group was 52.36 (± 15.86 SD), median parity 2 (range 0, 5). The median stage of prolapse was 1 (range 0, 3). The mean BMI was 28.77 kg/m2 (SD±8.56). The chief complaints included mesh erosion (20%), prolapse (23%), fecal incontinence (20%), pelvic pain (13%), urinary incontinence (6%), and other urogynecologic symptoms (16.6%).

The mean MLH height, width and area in TPUS measurements were 60.72 mm (±9.30 SD), 54.17 mm (±11.10 SD), and 26.16 cm^2 (±7.72 SD) respectively. The mean MLH height, width and area in 3D EVUS measurements were 51.54 mm (±6.36 SD), 37.41 mm (±5.86 SD), 15.08 cm^2 (±3.67 SD) respectively. Bland Altman analyses (Figures 7, 8) indicated that the 95% level of agreement between the two techniques. This level of disagreement was clinically important and indicated that the two ultrasound

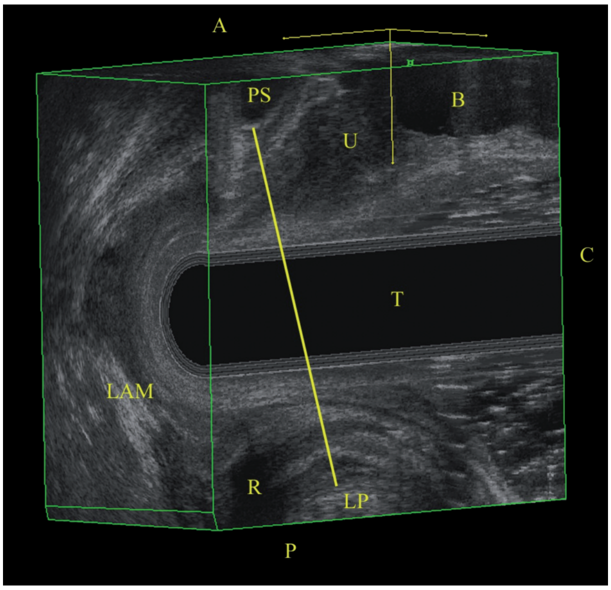

Figure 3. - Shortest line between pubic symphysis and levator plate in mid sagittal view by 3D EVUS; A: anterior, B: bladder, C: cephalad, LAM: levator ani muscle, LP: levator plate, P: posterior, PS: pubic symphysis, R: rectum, T: transducer, U: urethra.

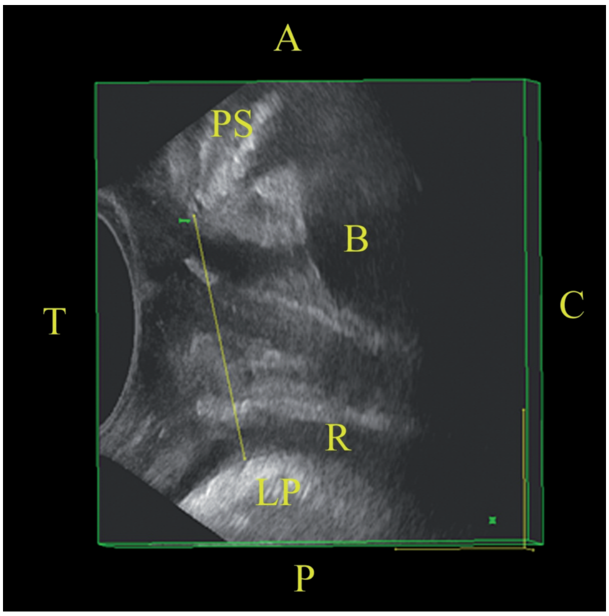

Figure 2. - Shortest line between pubic symphysis and levator plate in mid sagittal view by 3D TPUS; A: anterior, B: bladder, C: cephalad, LP: levator plate, P: posterior, PS: pubic symphysis, R: rectum, T: transducer.

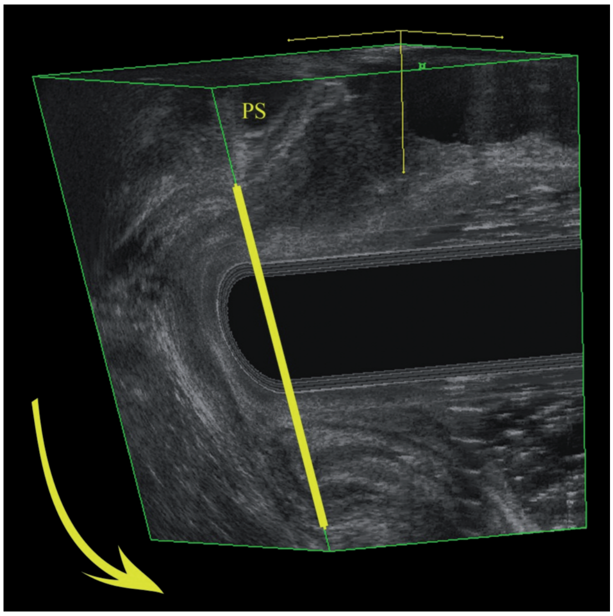

Figure 4. - The axial plane was rotated posteriorly and was advanced cephalad parallel to the shortest line between pubic symphysis and levator plate. PS: pubic symphysis.

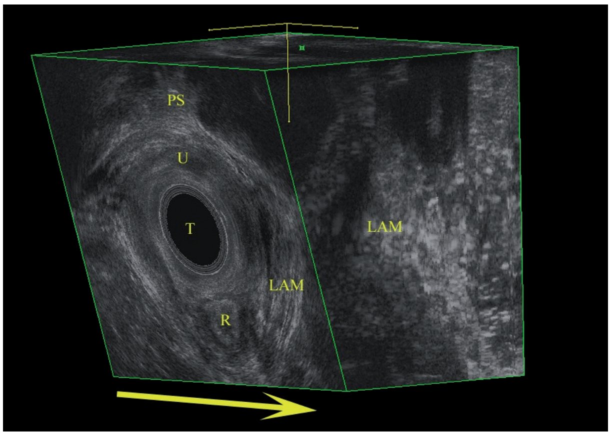

Figure 5. - The mid-sagittal plane was expanded to make the whole volume visible. LAM: levator ani muscle, PS: pubic symphysis, R: rectum, T: transducer, U: urethra.

techniques do not consistently provide similar measurements.

DISCUSSION

Using a strict measurement protocol, our study demonstrated that freehand acquisition of 3D transperineal images does not provide data that are comparable to those obtained from 3D EVUS imaging. This demonstrated the limited clinical use of 3D freehand transperineal measurements. Additionally, although not the focus of this study, 3D EVUS could demonstrate each levator ani subdivision, but 3D TPUS showed LAM as a single bulk.

A study showed that levator hiatus biometry in magnetic resonance imaging (MRI) of the pelvic floor correlates with severity of pelvic organ prolapse. 10 Other studies have shown that the dimensions of the levator hiatus are associated with progress in labor[11,12] and with pelvic organ prolapse[13] and may be an independent risk factor for prolapse.[14] The closest clinical equivalent, the genital hiatus, has been shown to be associated with prolapse and prolapse recurrence.[15,16] Hiatus biometry by 3D/4D TPUS multi-slice imaging has been determined in single plane images obtained at the plane of minimal hiatus dimensions,[17] a method that has been shown to be valid and repeatable by a number of different groups of investigators.[18-21] Dietz had shown that TPUS multi slice imaging is a reliable method to evaluate female pelvic floor.[22-25] Levator ani muscle avulsion can be detected reliably by TPUS multi slice imaging and physical examination.[26] Figure 9 shows a model for levator ani muscle avulsion that was described by Dietz et al. based on TPUS multi slice imaging.

Our study showed this different modality of TPUS, free hand acquisition, cannot be used reliably for pelvic floor biometry.

Our study has particular strengths and limitations. 3D EVUS is being rapidly adapted into research and clinical practice. Van Delft et al. showed a strong correlation be-

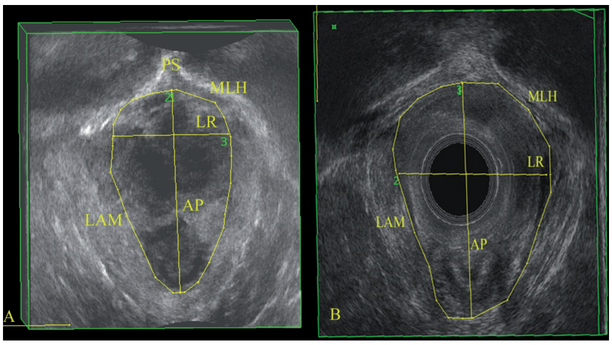

Figure 6A: Minimal levator hiatus biometry in 3D TPUS. AP: anterior posterior, LAM: levator ani muscle, LR: left right, MLH: minimal levator hiatus, PS: pubic symphysis.
Figure 6B: Minimal levator hiatus biometry in 3D EVUS. AP: anterior posterior, LAM: levator ani muscle, LR: left right, MLH: minimal levator hiatus.

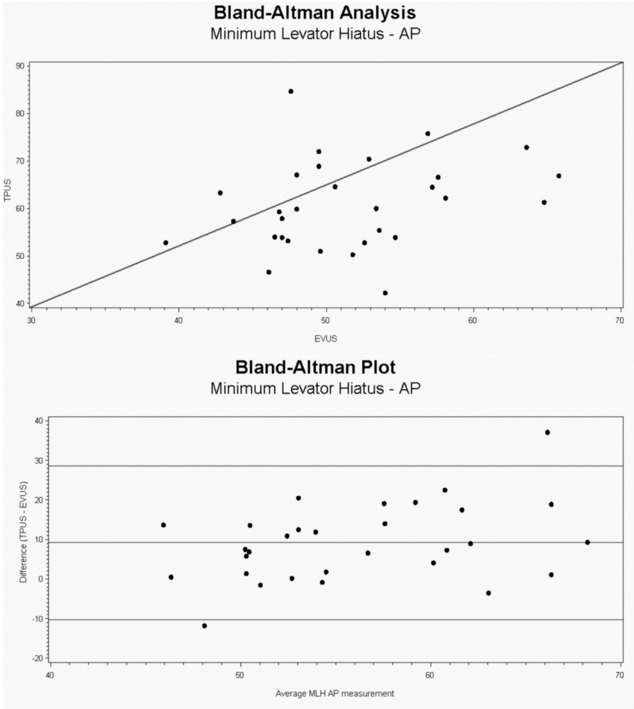

Figure 7. - Minimum Levator Hiatus - AP Bland-Altman Analysis 7a- Bland-Altman Plot 7b.

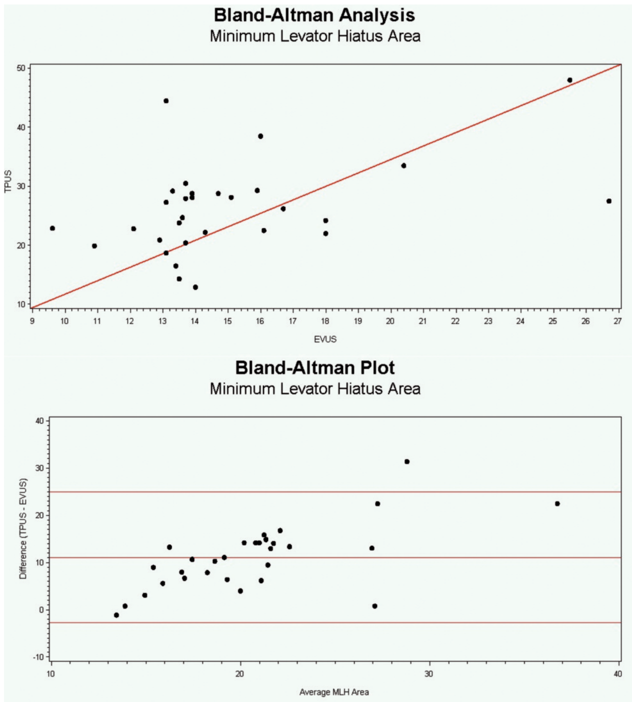

Figure 8. - Minimum Levator Hiatus Area Bland-Altman Analysis 8a- Bland-Altman Plot 8b

tween 3D/4D TPUS multi-slice hiatus biometry and 3D EVUS hiatus biometry (abstract 317, 2012 IUGA meeting, Van Delft et al., Comparison of 3D endovaginal and 3D transperineal ultrasonography measurements of the levator ani biometry at rest). Our own data derived from 29 patients showed good correlation between 3D EVUS and MRI.[27] Therefore, 3D EVUS is a valid standard to compare 3D freehand TPUS. The weakness of this study is that the number of the patients is rather small. However, we do not believe this significantly affected the results of our study.

In summary, the current study indicated that hiatus biometry in the accepted axial plane of minimal levator hiatus with freehand acquisition of 3D TPUS could not provide accurate measurements.

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Multidisciplinary Uro-Gyne-Procto 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 or more 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.

Imaging... While reading the article written by a gynaecologic research group with specific expertise in pelvic floor ultrasonography, a radiologist might be prompted to take into some of the following consideration: (a) few anatomic districts of the body as the pelvic floor are exposed to such a wild uncontrolled "horsey-riding" by various physicians who are backed by a so deep difference in preparation and commitment; (b) a common terminology, although highly desirable, is still far from being reached in perineology. In particular, the term minimal levator hiatus (MLH), i.e. the shortest line between the pubic symphysis and the levator plate that most gynaecologist are in love with, is an established parameter known in the radiologic literature since 1991 as the H line which is more consistently drawn from the inferior aspect of the pubic symphysis to the posterior wall of the rectum at the level of the anorectal junction. Also, when just defining the ability to visualize the pubic bone and the, levator plate as proof of good quality images at sonography, the anterior border of the puborectalis muscle should not be misinterpreted as the levator plate. Conceptually, this lack of accuracy, might invalidate the result of heavy work activity. Probably, unlike the radiologists who are trained with a severe imaging data management and discipline, a major concern for gynaecologists seems to come only from whether or not TPUS and TVUS are interchangeable tools in pelvic floor sonography. However, it should be realized that the starting and ending point of any measurement is always under the examiner decision and is freehand acquisition. As such, although computed assisted, just after a 30 seconds interval, two subsequent measurements of the same parameter by the same observer, hardly if ever will produce the same value. Consequently, rather than lack of interchangeability between TPUS and EVUS (as demonstrated at the Bland-Altman analysis by this paper), the inherent weakness of any instrumental device deserves consideration.

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Pelvic floor... Ultrasound has become an increasingly frequent adjunct investigation in female pelvic floor dysfunction as stated in 2010 in a joint report of IUGA and ICS, being performed with perineal, introital, transvaginal, transabdominal, transanal modality and 2,3,4D technique. It's potential role in urogynecology includes major morphological abnormalities such as levator defects and excessive distensibility of the puborectalis muscle and levator hiatus (ballooning). The 2013 International Consultation on Incontinence Guidelines state that pelvic organ dysfunction includes multiple conditions such as prolapse, urinary and anal incontinence, defecatory disorders and sexual dysfunction, and based on this concept integrated multicompartmental Pelvic Floor Imaging is described from a global and multicompartmental perspective. "The value of this approach in routine assessment of pelvic floor dysfunction is yet to be evaluated". Considering the levels of evidence and the recommendation of published studies there is no doubt that US imaging role will further expand in the future. Urologists, gynaecologists and colorectal surgeons should be able to perform ultrasound of the whole pelvic floor, since pelvic floor disorders are not isolated in nature, but often involve urological, gynaecological and colorectal issues and the artificial division of the pelvic floor in anterior, middle and posterior compartments, should be replaced by a transverse vision of a mechanical apparatus acting as a unit consisting of muscles under neural control, held together by connective tissues arranged in a 3D arrangement. Together, the structure formed of these three types of tissue influence pelvic organ support and function. Our ability to understand pelvic floor disorders treatment failures and prevention strategy must therefore arise from the understanding of these three tissue elements and their structural and functional interactions. Ultrasonography may play the role of identifying all pelvic floor dysfunctions providing an adequate information for a management that considers the consequences of therapy on adjacent organs and avoids sequential surgeries.

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Procto... The pelvis has almost become a metaphysical entity: apart from common cognition! Knowledge about the pelvis through very accurate diagnostic tools has increased considerably over the past 20 years and this development is largely due to the progress of diagnostic ultrasound. Specific probes and advanced software enable to view anatomical planes, and many different parameters and morphofunctional data. However despite these developments, this has not led to a proportional growth in the therapeutic strategy in dealing with the posterior pelvic compartment.

The role of endoanal ultrasonography on diagnosis and treatment of abscess and fistula in ano is not in doubt and also the function of transrectal ultrasonography in rectal cancer staging is a routine medical practice. On the other hand, in functional disorders of the posterior pelvis this technique seems less useful: in cases of fecal incontinence due to obstetric trauma, endoanal ultrasonography correctly identifies all sphincter defects at the time of surgery, but it does not correlate with anal sphincter pressure, continence score or outcome of a sphincter repair.[1]

In cases of functional disorders of the posterior pelvis what are the cornerstone medical diagnostic tests that can be used to reach a therapeutic decision in these cases? What assists us in decision making? Many diagnostic tests that aim to understand more are often only speculative and self-referential. Evidence based medicine eventually seems to be nothing more than an inadvertent application of the theory of computational complexity: the best algorithm for solving a problem with the minimum necessary resources, that is, for the posterior pelvic compartment, the history and physical examination, sometimes the defecography and little else…

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Urogyne... Pelvic floor medicine is a fast growing field over the past decades. With this field physician lack substantial objective measurements, especially when after the urodynamic tests, previously believed to be essential, lost much of it's value. Given that ultrasound provides not only a static an accurate demonstration of the pelvic floor but enables also dynamic real time and 3D pictures, this very important diagnostic tool quickly gained an important role with pelvic organ prolapse evaluation. Much was published regarding the accuracy of pointing out avulsion problems, as well as many other specific features related to the pelvic floor integrity disruption. Ultrasound scan for pelvic floor evaluation might be done trans-abdominally, trans-perineally or trans-vaginally. Physicians are frequently committed to one of these three methods, as if they were all equally effective and accurate. Thus, this pioneer comparison of the ultrasonic imaging modules is important for future better understanding the value of these tests with the evaluation of the damaged pelvic floor. This will definitely lead towards more efficient use of this important diagnostic tool and will definitely improve the intelligent and data based therapeutic approach to patients.

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