Ultrasound Imaging in Urogynaecology

The history of ultrasound dates back to 1794 when Lazzaro Spallanzani, an Italian biologist demonstrated that the ability of bats to navigate accurately through the dark was due to echo reflection from high frequency inaudible sound. In 1826, Jean-Daniel Colladon, a Swiss physicist, successfully determined the speed of sound in the waters of Lake Geneva, but the real breakthrough in the evolution of high frequency echo sounding techniques came when the piezo-electric effect in certain crystals was discovered by Pierre and Jacques Curie in Paris in 1880. Two researchers are noted in the history of ultrasound and medical imaging. They are: Doctor Karl Theodore Dussik of Austria, who published the first paper on medical ultrasonics in 1942 based on his research on transmission ultrasound investigation of the brain; and Professor Ian Donald of Scotland, who developed practical technology and applications for ultrasound in the 1950s.

Ultrasound imaging is rapidly emerging as the investigational and diagnostic tool of choice in the assessment and diagnosis in patients with pelvic floor dysfunction. This is largely due to the fact that, apart from two-dimensional imaging (2D), the recent advent of three-dimensional (3D) and four-dimensional imaging (4D) now provides us with new opportunities in understanding the pathophysiology and biomechanics of pelvic floor dysfunction. The technological development of motorized acquisition has enabled integration of two-dimensional sectional images into three-dimensional volume data. While magnetic resonance imaging (MRI) is an excellent tool for describing anatomy, ultrasound imaging has found more widespread use due to more favourable cost and accessibility issues, and because of superior imaging qualities. A number of important biometric parameters can be studied in the anterior, middle and posterior compartment using translabial ultrasound.

The Anterior Compartment

Since it was postulated that a hypermobile bladder neck was an important factor in the aetiology of female urinary stress incontinence, bladder neck mobility was one of the earliest parameters in the anterior compartment to be examined using ultrasound. The bladder neck position is measured relative to the inferoposterior margin of the symphysis pubis[1] and is measured at rest and on maximal Valsalva maneuver. The difference yields a numerical value for bladder neck descent (BND) which has been shown to have a strong association with the diagnosis of urinary stress incontinence.[2] Cut-off values of 15, 20, 25mm and even 30mm have been proposed to define hypermobility. BND may be a predictor of success after suburethral slings, as patients with a fixed urethra are less likely to be stress dry (continent) postoperatively.[3] Funneling of the internal urethral meatus may also be observed on Valsalva maneuver although the

anatomic basis is unclear. Marked funnelling has been shown to be associated with poor urethral closure pressures.[4,5] Recently there has been renewed interest in detrusor wall thickness (DWT) measurements. While it has been suggested that a thickness of more that 5mm is associated with detrusor overactivity[6,7,8] this has also been disputed by other authors.[9]

Prolapse quantification may also be assessed using translabial ultrasound. Based on a receiver operator characteristic curve, Dietz has shown that descent of the bladder to more than 10mm below the pubic symphysis is strongly associated with symptoms of prolapse and has been proposed as constituting ''significant'' anterior compartment prolapse.[10]

Apart form the above, the following may also be demonstrated by translabial ultrasound i.e. residual urine, the urethral rhabdosphincter, urine leakage with colour Doppler, urethral diverticula and levator activity.

Central and Posterior Compartment

For prolapse quantification in the posterior compartment the leading edge of the rectocele contents or the most caudal part of the rectal ampulla are used, again with the line of reference from the inferoposterior margin of the symphysis pubis. In the middle compartment the cervix or pouch of Douglas is used. Note that ultrasound quantification of central and middle compartment seems to agree well with clinical prolapse assessment (ICS POP-Q)[11], with correlations of r = 0.77 for uterine prolapse, r = 0.72 for anterior vaginal wall prolapse, and r = 0.53 for posterior vaginal wall prolapse.[12] In the posterior compartment a cut-off value of 15mm descent below the symphysis has been proposed as ''significant descent'', based on receiver operator curve characteristics.[10]

Translabial ultrasound enables one to distinguish between a true rectocele, perineal hypermobility and enterocele.[13] This distinction matters since it has been shown that only true rectoceles produce symptoms of obstructed defecation i.e. straining at stool, incomplete bowel emptying, and vaginal digitation.[14] An enterocele which may be overlooked at clinical examination is easily demonstrated with translabial ultrasound. This is visualized as a herniation of fluid-containing peritoneum, small bowel, sigmoid or omentum anterior to the anorectal junction, separating the vagina from the rectal ampulla. Invasive and expensive investigations such as defaecogaphy and MRI may be avoided. Translabial ultrasound also offers the advantage of uncovering rectal intussusception or occult rectal prolapse.

The uterus is identified as an isoechoic or hypoechoic structure, similar to vaginal tissues, with a specular (line-like) echo often indicating the leading edge of the cervix. Visualisation of Nabothian follicles often help with identification of the cervix. This may be more challenging in postmenopausal women.

Conventionally, the anal sphincter is imaged by high resolution endoanal probes with a field of vision of 360°. The anal sphincter complex may also be visualized exoanally using the coronal plane. This is advantageous since a dynamic evaluation of the anal sphincter and anal mucosa can be done with minimal distortion of the anal sphincter complex. The anal mucosa appears as a star-shaped hyperechoic area, while the internal anal sphincter (IAS) is seen as a hyperechoic ring and the external anal sphincter (EAS) as an echogenic structure surrounding the internal sphincter.[15,16,17] Occult obstetric anal sphincter injuries (OASIS) may occur in up to 24.5% of women after vaginal childbirth[18], the rate being doubled when re-examined.[19] Inadequately repaired third or fourth degree tears seems to be associated with decreased sphincter pressures and increased risk of anal incontinence.[20] On translabial ultrasound sphincter defects appear as a discontinuity of the ring structure of the EAS and/or IAS. In a longitudinal plane the length of the defect may also be measured relative to the total sphincter length.

Imaging of the Levator Ani Complex

Imaging of the levator ani muscle complex is relatively a recent area of interest. In the axial plane the entire levator hiatus and pubovisceral muscle (puborectalis and pubococcygeus) can be visualized with translabial ultrasound provided that the acquisition angles are at or above 70°. In both MRI and ultrasound studies no asymmetries in the pubovisceral muscle were found in nulliparous women, which supports the hypothesis that major morphologic abnormalities of the levator are likely to be evidence of delivery- related trauma.[21,22,23] Levator hiatal diameters and area measurements seem highly reproducible (intra-class correlation coefficients 0.70-0.82) and correlate strongly with pelvic organ descent both at rest and on Valsalva maneuvre.[22] To put levator hiatal area into perspective, note that the area required by a term-sized fetal head is between 70-90cm2. This dynamic ''ballooning'' of the pubovisceral muscle complex may be an indirect measure of levator elasticity and compliance which may influence successful pessary placement, surgical prolapse correction, future development of prolapse and even progress of labour. The most common morphological abnormality of the levator ani is an avulsion of the pubovisceral muscle off the pelvic sidewall. This is often palpable as an asymmetric loss of substance in the inferomedial or ventrocaudal aspect of the muscle, although this requires significant training. Detection of an avulsion injury which may be unilateral or bilateral by translabial 3D/4D ultrasound seems highly reproducible.[24] Tomographic ultrasound enables one to identify these defects which are more clearly evident on levator contraction.

Imaging of Implant Materials

Due to the high echogenicity of some implant material such as the TVT, Sparc, TOT and Monarc, these are clearly detectable on ultrasound. Especially with the use of 3D ultrasound the implant material can be located over its entire intrapelvic course.[25] Apart from evaluating the course, width, symmetry, possible tape twisting the operator is able to evaluate the tightness of the tape-which is will be evident as c-shaped at rest and is close to the urethra. Use of 3D pelvic ultrasound is also a good method for auditing transobturator

mesh repairs. In a study by Shek[26] the transobturator mesh for large/recurrent cystocele was visible in all 48 patients at an average of 11 month follow-up.

Several of the injectables used in anti-incontinence surgery are highly echogenic as well e.g. Macroplastique and can be visualized as a hyperechoic donut shape surrounding the urethra. It seems that in the future ultrasound will play a vital role in the assessment and optimization of the new surgical procedures.

Conclusion

Although the role of 3D/4D pelvic floor imaging in urogynaecology is still in its infancy, it will in all probability have a significant impact over the next few years. Translabial ultrasound is gaining widespread use because of its wide availability, non-invasive nature and elimination of tissue distortion (as is the case with transvaginal ultrasound). It offers both a static and dynamic evaluation of the pelvic floor and occult injuries may be also detected. Similar to the evolution of multichannel urodynamics, 3D/4D pelvic floor ultrasound may become an integral part of any urogynaecological work-up in the future.

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