Quantification of major morphological abnormalities of the levator ani

H. P. DIETZ
University of Sydney, Nepean Clinical School, Penrith, Australia

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ABSTRACT

Objectives Morphological abnormalities of the levator ani are found in a significant minority of women presenting with symptoms of pelvic floor dysfunction. In this study quantification of such injuries using tomographic three-dimensional (3D) pelvic floor ultrasound was attempted.

Methods In a prospective observational study undertaken at two tertiary urogynecological clinics, 262 consecutive women referred for complaints of lower urinary tract dysfunction and prolapse underwent an interview, clinical assessment and 3D translabial ultrasound imaging. Blinded offline analysis of volume datasets was performed at a later date using 4D View software. Main outcome measures were craniocaudal and ventrodorsal extent of defects of the pubovisceral muscle.

Results Avulsion injuries were diagnosed in 50 women (19%; 21.3% of the vaginally parous). Defects were found unilaterally (right, n = 17; left, n = 12) and bilaterally (n = 21). In some women they affected the entire volume; in others defects were visible in only two of 16 slices. Hiatal area on Valsalva was correlated weakly with defect score (r = 0.28, P = 0.05) and total defect width (r = 0.4, P = 0.005). Defect score (P = 0.001) and maximum width (P = 0.002) were significantly higher in women who presented with symptoms of prolapse. Defect score was associated with cystocele as assessed clinically (P = 0.021) and on ultrasound (P = 0.014).

Conclusions Depth and width of levator ani defects can be quantified by tomographic pelvic floor ultrasound. These parameters are associated with the likelihood of symptoms of prolapse and cystocele descent, but not with incontinence. Copyright © 2007 ISUOG. Published by John Wiley & Sons, Ltd.

INTRODUCTION

It has become clear recently that major trauma to the levator ani muscle is a consequence of vaginal childbirth in a considerable minority of women. The most obvious form of trauma, i.e. avulsion of the anteromedial aspects of the pubovisceral muscle off the arcus tendineus, can be detected on palpation, as described by Howard Gainey in 1943, and it could be argued that levator defects were first documented by Halban and Tandler in Vienna in 1907. However, the existence of such defects seems to have been disregarded for the last 60 years, with no mention in recent standard texts, either of pelvic floor medicine or physiotherapy. One reason for our continuing ignorance is that most levator ani trauma is occult at the time of childbirth, and that palpation of levator trauma requires significant training. Fortunately, diagnosis has now become much easier with the help of modern imaging methods. Since the early 1990s there have been isolated descriptions of levator ani trauma as visualized by magnetic resonance imaging (MRI), but the lack of functional imaging capacity and the sheer cost of MRI have resulted in limited progress.

It has been shown recently that translabial three-dimensional (3D)/4D ultrasound can be utilized to document major levator ani trauma, both in symptomatic women, and before and after childbirth. The prevalence seems to range between 15 and 35% of vaginally parous women, with maternal age at first delivery a predictor both in MRI and ultrasound studies. Levator trauma seems to be associated with prolapse of the anterior and central compartments rather than with incontinence and may well be the ‘missing link’ between vaginal childbirth and pelvic organ prolapse, an association that is obvious in the epidemiological literature (see DeLancey for a review of current evidence).
Most recently, there have been attempts at classifying levator ani trauma on MRI\textsuperscript{12}. One of the latest developments in 3D ultrasound, ‘tomographic ultrasound imaging’ or ‘multi-slice imaging’, now allows a previously unattainable degree of quantification of levator ani trauma, with both the dorsoventral and the craniocaudal extent of defects measurable in a standardized fashion, and at a very limited cost and post-processing effort. The aim of this study was to determine whether tomographic 3D pelvic floor ultrasound imaging can be used to quantify morphological abnormalities of the levator ani, and to correlate findings with symptoms and signs of pelvic floor dysfunction.

METHODS

Over the course of 2 years, 262 women were seen at two tertiary urogynecological units for symptoms of urinary incontinence, pelvic organ prolapse and recurrent urinary tract infections. They were interviewed and examined clinically for prolapse, using prolapse staging according to the grading system of the International Continence Society (ICS POP-Q)\textsuperscript{14}. In all cases 4D pelvic floor ultrasound was performed after voiding, with the patient in the lithotomy position, with ankles close to the buttoks and about 20–30 cm apart to reduce discomfort and fatigue. A GE Kretz Voluson 730 expert system (GE Kretz Ultrasound GmbH, Zipf, Austria) was utilized to acquire volume imaging data with the patient at rest, on maximum Valsalva (best of three or more attempts) and on maximum pelvic floor contraction, as described previously\textsuperscript{9}. Volume datasets were analyzed in a blinded fashion after several weeks or months, with the help of the proprietary software, GE Kretz 4D View V 5.0. For two-dimensional analysis, we determined bladder neck descent, retrovesical angle and urethral rotation to define anterior compartment mobility, and maximum descent of cervix and rectum, as described previously\textsuperscript{15}. The detection of levator ani defects by 3D/4D pelvic floor ultrasound has been shown previously to be highly reproducible\textsuperscript{10}. Our method of obtaining hiatal dimensions has been published previously\textsuperscript{16}, and its reproducibility has since been confirmed by others\textsuperscript{17–19}.

Using multi-slice imaging (TUI\textsuperscript{TM}, tomographic ultrasound imaging), a set of eight tomographic slices was obtained in the axial or C-plane at intervals of 2.5 mm, from 5 mm caudad to 12.5 mm cephalad of the plane of minimum dimensions\textsuperscript{9}. Figure 1 demonstrates the identification of this plane, in both midsagittal and oblique axial planes, in a patient with intact pubovisceral muscle. Figure 2 demonstrates typical findings after a right-sided avulsion injury, as seen on MRI and translabial ultrasound, and as evident clinically in a patient with a large vaginal tear and concomitant levator ani avulsion.

Best resolutions were achieved when assessing volumes obtained on pelvic floor muscle contraction, and these volumes were used for defect quantification. Defects were scored according to the number of slices in which a discontinuity of the muscle with the pelvic sidewall was documented, with a minimum score of 0 and a maximum score of 16 in a patient with complete bilateral avulsions. Defect width was measured along the central axis of the remaining portion of the pubovisceral muscle in all slices with a clearly recognizable defect (Figure 3), from the edge of the muscle remnant to the pelvic sidewall which appears hyperechoic, likely representing the inferior pubic ramus and/or the obturator internus muscle. Figures 4 and 5 show the appearance of typical complete unilateral and bilateral defects on tomographic ultrasound imaging (defect scores of 8 and 16).

A test–retest series of 20 assessments was performed by a Fellow trained in translabial ultrasound who had

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**Figure 1** Translabial three-dimensional ultrasound of the pelvic floor at rest, demonstrating identification of the plane of minimum hiatal dimensions in the midsagittal (a) and an oblique axial (b) planes. The lines in each image indicate the location of the other image.
Figure 2 Typical right-sided avulsion injuries as seen on magnetic resonance imaging (a), translabial ultrasound (b, rendered volume) and as evident clinically (c) in a patient with a large vaginal tear and concomitant levator avulsion. The arrow in (a) points to the site of avulsion. From Dietz HP, Ultrasound Obstet Gynecol 2006; 28: 629–634; Magnetic resonance imaging courtesy of Dr Lennox Hoyte, Boston.

Figure 3 Determination of maximum defect width on tomographic ultrasound imaging in a patient with a partial left-sided avulsion injury (defect score, 5; maximum width, 19.7 mm).

not previously performed defect recognition or defect quantification using tomographic ultrasound, i.e. who was naïve to the method used in this study. The results were analyzed using Cohen’s kappa and the intraclass correlation coefficient (ICC; consistency definition, single measures).

Institutional ethics committee approval was obtained for analysis of case notes and volume ultrasound
datasets obtained during the course of routine clinical care. Statistical analysis was performed after normality testing (histogram analysis and/or Kolmogorov–Smirnov testing), using Minitab V. 13 (Minitab Inc., State College, PA, USA). Pearson’s correlations were used to compare normally distributed continuous variables. Analysis of variance and Student’s t-test were also employed. P < 0.05 was considered statistically significant.

RESULTS

Of the 262 patients, 27 had never delivered vaginally. Neither nulliparae nor those delivered exclusively by Cesarean section showed evidence of levator ani trauma. Avulsion injuries were diagnosed in 50 women (19% of the entire population; 21.3% of the vaginally parous population), to whom all of the following results relate. The mean age was 54 (range, 26–82) years and the average parity was 2.7 (range, 1–6). Seventeen (34%) women had undergone a forceps delivery. Thirty-one (62%) women complained of stress urinary incontinence, and 29 (58%) of symptoms of prolapse, that is, the sensation of a vaginal lump or bulge or a dragging sensation. On clinical assessment, 42 (84%) women suffered from cystocele (Grade 1, n = 14; Grade 2, n = 16; Grade 3, n = 12), 19 (38%) women from uterine prolapse (Grade 1, n = 8; Grade 2, n = 7; Grade 3, n = 4) and 37 (74%) women from rectocele (Grade 1, n = 17; Grade 2, n = 14; Grade 3, n = 6).

The mean bladder neck descent was 32 (range, 10–51) mm. In the majority of patients (27/50; 54%), the retrovesical angle stayed intact, i.e. below 130°, but marked rotation of the proximal urethra was common (mean, 74.6°; SD, 38.5°), as was a marked increase in the dimensions of the hiatus on Valsalva (mean, 34.9 cm²; range, 16–58.1 cm²). Fifty volume datasets were examined using tomographic ultrasound imaging, with volumes on levator contraction used for numerical analysis. All datasets could be assessed for defects, which were found unilaterally on the left (n = 12, Figure 3), unilaterally on the right (n = 17, Figure 4) and bilaterally (n = 21, Figure 5).

When defects were analyzed for depth relative to the reference plane of minimum hiatal dimensions, a wide variety of distributions was documented. In some women, defects reached over the entire volume assessed, uni- or bilaterally (Figures 4 and 5), while in others, defects were visible in only a few slices. The mean

Figure 4 Complete unilateral right-sided detachment of the pubovisceral muscle from the pelvic sidewall (defect score, 8). Defects in the three central slices are indicated (*).
Quantification of levator ani trauma

The mean maximum defect width, as measured in Figure 3, was 20.1 (SD, 6.3) mm on the right and 21.6 (SD, 6.3) mm on the left. There were weak correlations between defect score and hiatal area on Valsalva ($r = 0.28$, $P = 0.05$) and between total defect width and hiatal area on Valsalva ($r = 0.4$, $P = 0.005$). With respect to the association between defect score and anterior, central and posterior compartment prolapse, clinically and on ultrasound, defect score was associated with cystocele as assessed both clinically ($P = 0.021$, ANOVA) and on ultrasound (Pearson’s $r = −0.35$; $P = 0.014$), and it was associated with uterine prolapse as assessed clinically ($P = 0.07$) but not sonographically. Defect score was not associated significantly with rectocele. Defect score ($P = 0.001$) and width ($P = 0.002$) were significantly higher in women who complained of prolapse, but there was no association with symptoms of bladder dysfunction apart from urinary frequency ($P = 0.05$).

The results of the test–retest series of 20 assessments performed by a Fellow new to the study method were as follows. For the diagnosis of defects in any given slice obtained independently from cine volume datasets, we determined a Cohen’s kappa of 0.613, signifying ‘substantial’ agreement. For maximum defect width, the ICC was 0.762 (95% CI, 0.593–0.866), signifying excellent agreement, and total defect score gave an ICC of 0.533 (95% CI, 0.13–0.785), signifying moderate agreement.

DISCUSSION

Tomographic ultrasound imaging in conjunction with 4D pelvic floor ultrasound allows definition of morphological abnormalities of the pubovisceral muscle to a previously unattainable degree. In this series of 262 women, defects were common (19% overall or 21.3% in vaginally parous women), confirming previously reported MRI series\(^8\) and own data obtained in an unrelated population\(^10\). They occurred more frequently (but not significantly so) on the right side, but were often bilateral, the latter diagnosed more commonly than has been observed previously\(^10,11\). This increased prevalence of bilateral defects may have been due to the improved detection of smaller abnormalities with tomographic imaging. Defects seemed best defined on levator ani contraction, and the use of volumes obtained on contraction may also
have improved the detection compared with previously used methodology\textsuperscript{10}.

I propose an assessment system which describes the depth of the injury by counting the number of slices in which defects are identified (giving a score of between 0 and $8 \times 2 = 16$), as well as the maximum width of the defect in mm. This method seems reproducible, even when used by staff not previously trained in the analysis of tomographic ultrasound. As shown previously, the presence of levator ani trauma is associated with prolapse of the anterior (and possibly the central) compartments\textsuperscript{10}, and from the results of this study it appears that the larger the defect, the more likely are patients to show objective evidence of (and to report symptoms of) prolapse. Both cystocele grading as well as bladder descent on Valsalva were associated with higher defect scores and maximum total defect width. However, it was also evident that bladder function in this particular cohort was not greatly influenced by the extent of the levator ani defect, and again this finding is in agreement with results from previous unrelated studies\textsuperscript{10}.

Tomographic ultrasound imaging and quantification of defects will hopefully allow us to investigate the etiology and pathogenesis of levator ani trauma in greater detail, in order to define personal risk factors and the impact of obstetric variables. It is expected that more detailed assessment of trauma will increase the power of a longitudinal study currently in progress at our unit that aims to assess the prevalence and extent of trauma and its association with obstetric parameters in women after their first vaginal delivery. Such work will not only aim at defining pathogenesis, but may become useful in prediction and primary prevention, realizing a vision achieved for improved prevention and treatment. It is expected that more detailed assessment of trauma will increase the power of a longitudinal study currently in progress at our unit that aims to assess the prevalence and extent of trauma and its association with obstetric parameters in women after their first vaginal delivery. Such work will not only aim at defining pathogenesis, but may become useful in prediction and primary prevention, realizing a vision achieved for improved prevention and treatment.

In conclusion, depth and width of levator ani defects can be quantified by tomographic pelvic floor ultrasound. These parameters are associated with the likelihood of symptoms of prolapse and cystocele descent, but not with incontinence.

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