Int Urogynecol J (2016) 27:909–913
DOI 10.1007/s00192-015-2909-0

ORIGINAL ARTICLE

Is the levator–urethra gap helpful for diagnosing avulsion?

Hans Peter Dietz [1] · Alejandro Pattillo Garnham [1,4] · Rodrigo Guzmán Rojas [1,2,3]

Received: 12 October 2015 / Accepted: 20 November 2015 / Published online: 9 December 2015

Abstract

Introduction and hypothesis Levator avulsion is a risk factor for female pelvic organ prolapse (POP) and recurrence after POP surgery. Imaging diagnosis requires the observation of an abnormal muscle insertion on tomographic ultrasound imaging (TUI). This study was designed to compare the diagnostic performance of the qualitative diagnosis (visual qualitative assessment) to measurement of the distance between muscle insertion and urethra [levator–urethra gap; (LUG)].

Methods This was a retrospective analysis of data obtained in a tertiary urogynecological unit. All patients presented with symptoms of pelvic floor dysfunction and underwent 4D translabial pelvic floor ultrasound (US), supine, and after voiding. Avulsion was defined qualitatively as abnormal muscle insertion and quantitatively as LUG ≥25 mm on at least three consecutive central axial plane slices, with one examiner using both methods. We examined the correlation between both methods and validated them against clinical prolapse, significant organ descent on US, and hiatal ballooning.

Results Between January and July 2013, 233 patients were seen, of whom 202 had complete volume data sets. The qualitative method diagnosed avulsion in 22 % and the quantitative method in 24.3 %. Agreement was good, with a kappa of 0.79 (0.70–0.87). Avulsion diagnosed by either method was associated with clinical and sonographic prolapse and hiatal ballooning, with odds ratios nonsignificantly higher for the quantitative method.

Conclusion Qualitative analysis of slices on TUI and a method using LUG measurement show good agreement for the diagnosis of avulsion. The LUG method is at least equally as valid in its capacity to predict significant prolapse on clinical examination and US, as well as ballooning of the levator hiatus.

Keywords Avulsion · Levator–urethra gap · Translabial ultrasound · Prolapse · Tomographic imaging

✉ Hans Peter Dietz
hpdietz@bigpond.com

[1] Sydney Medical School Nepean, Nepean Hospital, Penrith NSW 2750, Australia

[2] Departamento de Ginecología y Obstetricia, Clínica Alemana de Santiago-Universidad del Desarrollo, Concepción, Chile

[3] Departamento de Ginecología y Obstetricia, Hospital Clínico de la Universidad de Chile, Santiago, Chile

[4] División de obstetricia y ginecología, Escuela de medicina, Pontificia Universidad Católica de Chile, Santiago, Chile

Introduction

Levator avulsion is a risk factor for symptomatic female pelvic organ prolapse (POP) and recurrence after surgical correction of POP [1]. This condition can be diagnosed clinically on vaginal palpation [2, 3], using translabial ultrasound (US) [4] or with magnetic resonance imaging (MRI) [5]. Palpation is subjective and seems to be harder to teach than visual methods [2, 6, 7]; MRI is more expensive and less readily available than US. As the sonographic diagnosis of avulsion shows good agreement with MRI [8], US offers the least expensive, most available, and least bothersome option for real-time pelvic floor imaging.

Avulsion can be diagnosed on single slices and in rendered volumes, i.e., semitransparent representations of blocks of volume pixels, or voxels [4]. However, it is difficult to standardize such methods, and volume US allows the assessment of multiple tomographic slices placed anywhere in a volume data set, with both slice direction and interslice interval arbitrarily modifiable. A tomographic technique for diagnosing levator avulsion was first proposed in 2007 [9] and subsequently refined to optimize sensitivity and specificity of the avulsion diagnosis on multislice (tomographic) US imaging (TUI) [10]. This is usually performed on volumes obtained on pelvic floor muscle contraction (PFMC), as this tends to enhance tissue discrimination and muscle visibility, although it seems likely that avulsion diagnosed in volumes obtained at rest is also valid [11, 12].

Standard sonographic methodology requires observation of an abnormal insertion of the muscle on TUI [9]. The levator–urethra gap (LUG) is described as the distance between the center of the urethral lumen and insertion of the levator on the inferior pubic ramus, determined in axial plane slices [13]. An abnormal LUG has been associated with avulsion diagnosed by vaginal palpation [13], but it is not clear whether measurement of this parameter can improve detection of clinically significant levator trauma. Hence, this study was designed to compare the diagnostic performance of the qualitative visual diagnosis of avulsion (visual qualitative assessment) with LUG measurement by validating both methods against clinical and sonographic signs of prolapse.

Materials and methods

This study is a retrospective analysis of data obtained in routine clinical practice in a tertiary urogynecological unit between January 2013 and July 2013. All patients presented for urodynamic assessment complaining of various symptoms of pelvic floor dysfunction. There were no exclusions for the initial analysis , although women with previous POP surgery were excluded from validation of diagnostic methods against signs of POP. Patients underwent a standardized, nonvalidated, in-house interview; multichannel urodynamic testing; International Continence Society (ICS) POP Quantification (POP-Q) examination [14], and 4D translabial pelvic floor US supine and after voiding [4]. In short, translabial placement of a 4D curved-array transducer in the midsagittal plane allows recording of volume imaging data at an acquisition angle of 70–85°, encompassing the entire pelvic floor at a frequency of 1.5-4 Hz. At least one cine loop of volumes obtained during a Valsalva maneuver and a pelvic floor muscle contraction is saved.

US postprocessing was performed by the second author on a PC using proprietary software (4D View v 10.7) and blinded against all clinical data. This involved manipulating archived volume data to determine the axial plane of minimal hiatal dimensions [9], which was then used as a reference plane to construct a series of slices parallel to this plane. Avulsion of the puborectalis muscle was defined in a tomographic representation of volume data obtained on maximal PFMC or, if the patient was unable to contract, at rest. A qualitatively abnormal levator ani insertion in the plane of minimal dimensions and in the two slices immediately cranial to that plane, at an interslice interval of 2.5 mm, was defined as a full levator avulsion, as previously described, providing the qualitative diagnosis [10]. A quantitative diagnosis was defined as a LUG ≥25 mm visible on at least three consecutive axial plane slices (slices 3–5 or central-row slices) at and above the level of minimal hiatal dimensions (interslice interval of 2.5 mm) on pelvic floor muscle contraction (Fig. 1) [13], which is likely to encompass most of the puborectalis muscle [15]. Symptoms of prolapse were defined as a vaginal lump or bulge or a dragging sensation. Significant prolapse on clinical examination was defined as POP-Q stage 2 in the anterior and posterior compartments and/or stage 1 in the central compartment, as suggested by a recently published study conducted in our unit [16]. On imaging, prolapse was determined against the inferior symphyseal line [17]. Significant prolapse on US was defined as a cystocele to at least 10 mm below the symphysis and/or uterine descent to the symphysis or lower and/or rectal descent to at least 15 mm below the symphysis, as previously determined using receiver operator characteristic (ROC) curve statistics [18, 19]. Hiatal ballooning was diagnosed in volumes obtained on maximal Valsalva and measured in the midsagittal plane [20].

Volumes were first examined qualitatively (‘eyeballed’) to detect an abnormal insertion in the three central slices, as shown in Fig. 1. After determining the presence of avulsion by this method for all patients (that is, on both sides of three slices in 202 patients; i.e., 1212 times), the process of volume data review was repeated by the same operator, with LUG measured for each side in these slices, i.e., 1212 times. In other words, the operator completed all 202 qualitative assessments before starting LUG measurements and was blinded against qualitative diagnoses when determining LUG. To obtain a measure of agreement between methods, we examined the correlation of an abnormal LUG with qualitative assessment using Cohen’s kappa both for overall diagnosis of any avulsion (n=202) and for single slices (n=1212). Discordance was defined as the diagnosis of an abnormal muscle insertion in single slices or as the overall diagnosis of any avulsion by one method but normal findings for the respective criterion in the other method.

We then excluded patients with previous surgery for POP to determine the association of levator avulsion with significant POP (ICS Stage 2 in the anterior and/or posterior compartment, and/or stage 1 in the central compartment), significant organ descent on US, and hiatal ballooning, as diagnosed by either method. This was a retrospective pilot study; hence we did not perform power calculations.

This study was approved by the Nepean Blue Mountains Local Health District Human Research Ethics Committee (NBMLHD HREC reference no. 13–30). Statistical analysis was carried out with SPSS v12 (SPSS, Chicago, IL, USA) and

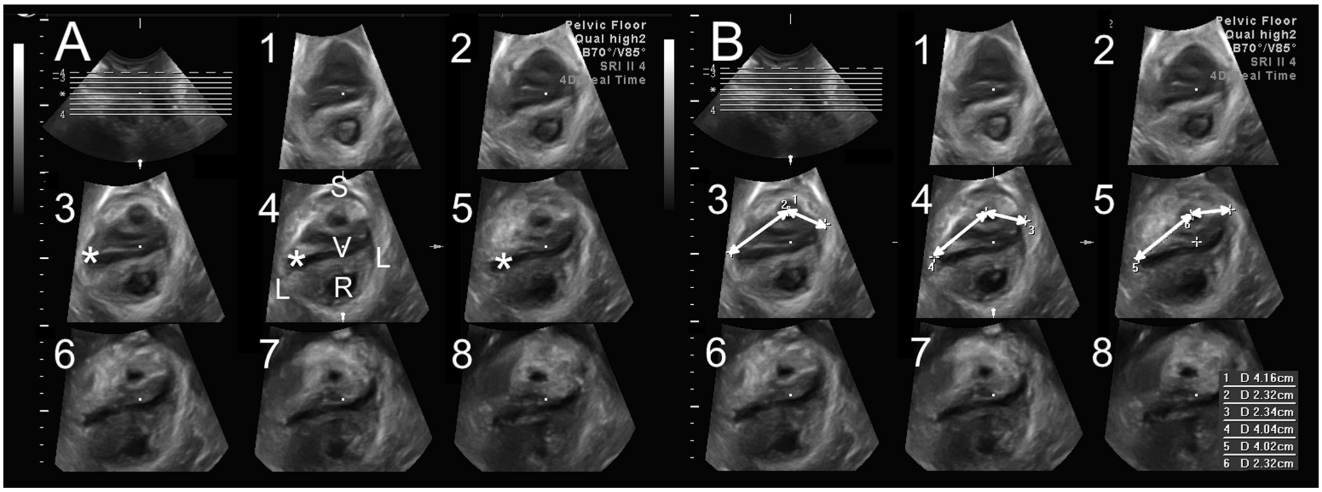

Fig. 1 Complete right-sided avulsion in patient with multicompartment prolapse. A patient is rated as positive for a full avulsion if the three slices of the central row are all abnormal. The native image is shown on the *left* (**a**), LUG measurements on the *right* (**b**). *S*symphysis pubis, *U*urethra, *V*vagina, *R*rectum, *L*levator ani. In (**a**), a vulsion is indicated by *. In (**b**), LUG measurements are given for slices 3–5, all of which are abnormal on the patient's right, i.e., on the *left side* of the images. Levator–urethra gap (LUG) indicated by arrows

Minitab v 10 (Minitab State College, PA, USA), using Student's *t* tests and Fisher's exact test. Cohen's kappa was used to test agreement of categorical diagnoses. A $p<0.05$ was considered statistically significant.

Results

Between January and July 2013, 233 patients were seen for assessment. Of them we were able to retrieve US volume data sets of 204, as 4D equipment had been unavailable on several days. Two patients were unable to contract their pelvic floor, and were excluded from the sample. The final study group included 202 patients, whose mean age was 53.9±14.5 years. and mean body mass index (BMI) 28.9±6.6 kg/m^2. Patients had a mean parity of 2.5±1.4, 171 (84.6 %) were vaginally parous, and 42 (20.8 %) had had a forceps assisted delivery. Thirty percent of patients (n=61) had a previous hysterectomy, and 32 (15.8 %) had previous surgery for female POP.

Fifty-three percent of patients (n=105) presented with symptoms of POP, 142 (71.7 %) had a history of stress urinary incontinence (SUI), and 137 (68.2 %) patients presented with urgency (UUI) incontinence. On clinical examination, 149 (73.8 %) patients had significant POP, i.e., stage 2, in the anterior and/or posterior and/or stage 1 in the central compartment [16]. Mean hiatal area on Valsalva was 28.5±10 cm^2. Sixty percent of patients had an abnormal hiatal area (ballooning)>25 cm^2 on Valsalva.

Two test–retest series were undertaken for qualitative avulsion diagnosis and quantitative LUG measurement. In both instances the second and third authors performed assessments on cine loops of multiple-volume data sets obtained in the same patients. The two operators selected individual volumes from amongst a large number of available volumes, then produced axial-plane slices from an infinite number of possible slices, then performed their assessments. Both parameters showed good repeatability, with a kappa of 0.88 and an Intraclass Correlation Coefficient (ICC) 0.76 [confidence interval (CI) 0.65-0.83].

On using visual qualitative assessment of the levator insertion on the inferior pubic ramus, we diagnosed avulsion in 44 women (22 %). This was right sided in 33 (16.3 %) and left sided in 26 (12.9 %). A bilateral avulsion was present in 15 (7.4 %) patients. On using LUG measurements, we detected avulsion in 49 (24.3 %) patients: right sided in 31 (15.3 %), left sided in 37 (18.3 %), and bilateral in 19 (9.4 %). Out of 404 diagnoses (left and right side for each patient), there was a discrepancy in 23 (5.7 %). Concordance was tested for single-side diagnoses in individual slices (n=1212) and for diagnosis of any avulsion, i.e., full avulsion on at least one side.

When evaluating single slices, the discrepancy rate was 8.3 % (101 of 1212 slices). Agreement for the diagnosis of any avulsion was good, with a kappa of 0.785 (0.701–0.869). Single-slice agreement was also good, with a kappa of 0.763 (0.72–0.807). There was no evidence of one diagnostic method yielding systematically different findings—e.g., greater bilateral avulsion with one of the two methods—compared with the other method.

Thirty-two patients had previous surgery for POP and were excluded from further analysis. Of the remaining 170, 18.8 % (n=32) had a complete avulsion. The odds ratios (OR) for significant POP, significant prolapse on US, and hiatal ballooning are shown in Table 1, which attempts to validate both diagnostic methods against measures known to be strongly associated with avulsion. ORs were statistically significant for both qualitative diagnosis of avulsion and LUG. All CIs overlapped widely, indicating that statistical relationships between diagnosis and associated outcomes were similar, suggesting similar validity of diagnoses.

Discussion

This retrospective study using 4D TUS imaging data shows that qualitative analysis of TUI slices and a method using LUG measurement have good agreement for avulsion diagnosis. The LUG method seems to be at least equally valid in its capacity to predict significant prolapse on clinical examination and US, as well as levator hiatus ballooning. In practice, LUG measurement is most likely to be useful in assessing doubtful cases.

Due to widespread availability and simplicity, tomographic imaging of the levator by means of translabial 3D/4D US is currently the most widespread method, and this is likely to remain so for the foreseeable future, until such time as technological advances make other modalities more attractive. Hence, it seems imperative to standardize and validate this diagnostic modality as much as possible, especially as regards the diagnosis of levator avulsion, i.e., traumatic disconnection of the puborectalis muscle from the pelvic sidewall. This form of trauma is consistently associated with a widening of the gap between muscle detected on the pelvic sidewall and the urethral body. Widening this gap defines avulsion on palpation and can be measured as the levator–urethra gap on US. A very similar parameter, the levator–symphysis gap (LSG), has been described on MRI [21, 22]. Increased LSG measurements are associated with POP [23]. To the authors' knowledge, the LSG has not been used in sonographic imaging due to the ease with which the center of the urethra can be identified on axial-plane US; as a result, direct comparisons are lacking.

The study reported here attempted to further standardize imaging diagnosis of avulsion while following the methodology set out for translabial US [10]. Qualitative analysis of slices on US without resorting to levator–urethra gap measurement and a method using LUG measurement shows high agreement for levator avulsion diagnosis, with a kappa of 0.785. Basing a diagnosis of avulsion on LUG measurement seems to result in greater validity of the resulting diagnosis, even if the effect size seems to be rather small. Hence, the authors suggest using LUG measurements in doubtful cases; if insertions are obviously intact, one would not expect any improvement in test performance from the addition of LUG.

The LUG method on its own, however, is at least equally valid in its capacity to predict significant prolapse on clinical examination and on TUS, as well as ballooning of the levator hiatus. This implies that a simple, 2D measurement may be substituted for the complex task of pattern recognition required for qualitative diagnosis. In principle, this may open up opportunities for automated detection of avulsion—a direction we have started to investigate [24].

While our results confirm the validity of current clinical and research practice, there are several weaknesses of this study that need to be acknowledged. First, it is a retrospective study using archived data sets analyzed by a junior trainee with limited experience in pelvic floor imaging. However, some may see this as an advantage, as results are more likely to be replicated by units with less extensive experience in the field. One operator (APG) scored avulsion using two methods, which may have introduced bias. However, the operator completed all 202 qualitative assessments before starting LUG measurements and was blinded against qualitative diagnoses when determining LUG.

In addition, our findings were obtained in symptomatic women who were largely Caucasian in origin. As there are substantial interethnic variations in pelvic floor functional anatomy [4, 25], one may well expect different findings in other ethnic groups, especially as regards the use of the levator–urethra gap as an adjunct in difficult cases. Given that LUG measurements are clearly lower in East Asians [8], it seems likely that a standard cutoff of 2.5 cm may not be appropriate in all individuals and ethnicities.

Finally, the role of individual biometry will have to be further evaluated in future studies. We are currently in the process of studying whether height is a confounder for the diagnostic performance of LUG measurements.

Table 1 Odds ratio (OR) of significant outcomes versus avulsion diagnosed by qualitative assessment and levator–urethra gap (LUG) measurement (n=202)

	Qualitative diagnosis of avulsion		LUG≥25 mm in all three central slices	
	OR (95 % CI)	*P* value	OR (95 % CI)	*P* value
Significant POP (≥ stage 2)	4.7 (1.4–16.2)	0.008	17.4 (2.3–131.4)	<0.0001
Significant organ descent on US	3.9 (1.5–10)	0.003	4.3 (1.6–11)	0.001
Ballooning (hiatal area≥25 cm^2)	5.2 (1.9–14.4)	0.001	7.7 (2.5–23.1)	<0.0001

POP pelvic organ prolapse, *US* ultrasound, *CI* confidence interval

Conclusion

Our findings support the use of LUG in addition to qualitative assessment of the levator muscle insertion to increase validity of a diagnosis of avulsion. In practice, this seems most useful in the evaluation of doubtful cases.

Compliance with ethical standards

Conflicts of interest None.

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