Modelling the likelihood of levator avulsion in a urogynaecological population

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Background: Avulsion of the puborectalis muscle is a consequence of vaginal childbirth and associated with female pelvic organ prolapse. It can be palpated, although diagnosis by imaging seems more reliable.

Aims: To define the prior probability of avulsion based on history and gynaecological examination, in order to facilitate clinical diagnosis.

Methods: Over 3 years, 983 women had been assessed by 3D ultrasound at a tertiary urogynaecological unit. We analysed our database for predictors of puborectalis avulsion and designed a simplified predictive model with the help of backwards stepwise logistic regression.

Results: The following factors were strongly associated with the diagnosis of avulsion: age at first vaginal delivery, no stress incontinence, vaginal operative delivery, prolapse symptoms, cystocele, uterine prolapse, minimum Oxford grading of muscle strength and side differences in Oxford grading (all \( P < 0.001 \)). Multivariate logistic regression produced a model that had an adjusted \( r^2 \) of 37.2\%, predicting 81\% of cases correctly.

Conclusions: This study was undertaken to define the ‘typical’ patient suffering from avulsion of the puborectalis muscle, a common childbirth-related injury. Levator defects are most likely in women who had their first child by vaginal operative delivery over the age of 30 years, presenting with symptoms of prolapse without stress incontinence.

Key words: 3D ultrasound, avulsion, birth trauma, female pelvic organ prolapse, levator ani, translabial ultrasound.

Introduction

Avulsion of the puborectalis muscle from the pelvic sidewall is a common consequence of vaginal childbirth, and associated with abnormal muscle biometry and function as well as female pelvic organ prolapse. Avulsion increases the area of the levator hiatus, the largest potential hernial portal in the abdominal envelope. It has been described on magnetic resonance imaging, on ultrasound, intraoperatively, and in the cadaver. This form of birth trauma also seems to be a predictor of prolapse recurrence, implying that identification of women with avulsion may be of major importance for pelvic reconstructive surgery. While this condition can be diagnosed by palpation, this requires substantial training. Diagnosis by magnetic resonance imaging and pelvic floor ultrasound is highly repeatable, but these modalities are not always available, especially not in the surgeon’s office. The identification of levator trauma may be simplified if it was possible to describe the ‘typical patient’ – that is, the patient most likely to be found with levator avulsion on imaging. We therefore attempted to define the prior probability of such trauma based on patient history and simple gynaecological examination and to create a simple prognostic index, in order to alert the clinician to a high likelihood of trauma in a given patient and thereby to assist in the diagnosis of such trauma.

Materials and methods

This is a retrospective data review. Over a period of 3 years, 983 women had been seen at a tertiary urogynaecological unit, undergoing a standardised interview, a clinical examination, including ICS POP-Q (Prolapse quantification system of the International Continence Society) assessment, digital evaluation of the levator ani and pelvic floor ultrasound imaging. Symptoms of prolapse were defined as a vaginal lump or a ‘dragging sensation’ in the vagina. The assessment included pelvic floor imaging with 3D/4D translabial ultrasound as described previously, supine and after bladder emptying, using Voluson 730 expert ultrasound systems (GE Kretz Ultrasound, Zipf, Austria) with an 8–4 MHz volume transducer (acquisition angle of 85 degrees). For the assessment of muscle integrity, volumes were obtained on maximal pelvic floor contraction to maximise visibility of the muscle and its insertion on the inferior pubic ramus, or at rest in those patients unable to contract.

The puborectalis muscle was observed as a V-shaped loop surrounding the anorectum, vagina and urethra as documented previously, see Fig. 1. Tomographic ultrasound (TUI) (3) was used to confirm the diagnosis, with slices...
obtained in the axial plane at 2.5-mm slice intervals, from 5 mm below the plane of minimal hiatal dimensions (17) to 12.5 mm above that plane, in order to encompass the entire puborectalis muscle (see Fig. 1). A complete defect was diagnosed if the reference slice as well as the two slices cranial to the reference slice showed an avulsion (ie, slices 3–5 in Fig. 1).

The diagnosis of avulsion injury was only rated as positive if found on imaging, but digital palpation was used to grade muscle strength using the modified Oxford grading (MOS), and to confirm complete avulsion. In doubtful cases, the diagnosis was based on ultrasound findings. We reviewed records for the presence of a levator avulsion injury diagnosed on 3D ultrasound and analysed our database for predictors of trauma.

Initially, backwards stepwise logistic regression analysis was used to select the best model based on all parameters that were considered to be predictive. This model was then re-created using categorised versions of continuous predictors to allow the construction of a simple prognostic index. The risk points for the prognostic index were calculated by dividing the adjusted log odds ratios for each predictor from the multivariate model and rounding off to the nearest integer. The risk score for an individual was the sum of their risk points. Patients could then be categorised at being of low, medium, high or very high risk of presence of avulsion, based on their score.

Statistical analysis was conducted using Minitab V.13 (Minitab Inc., State College, PA, USA). All continuous parameters were tested for normality and found to be normally or near-normally distributed on Kolmogorov–Smirnov testing. Multivariate modelling was undertaken using SAS v9.1. This study is an extension of a project approved by the Institutional Human Research Ethics Committee (reference SWAHS HREC 05-029).

Results

Mean age was 54.5 (17–89) years, and mean age at first delivery was 23.7 (range 15–42) years. Patients presented with stress incontinence (74%), urge incontinence (70%) and symptoms of prolapse (40%). Levator defects were diagnosed on 3D ultrasound in 240 patients (24%). Table 1 shows basic demographic data. The following parameters were strongly associated with this diagnosis on simple logistic regression: age at first vaginal delivery, the absence of stress incontinence, forceps or vacuum delivery, symptoms of prolapse, cystocele grade, uterine prolapse grade, minimum Oxford grading of muscle strength and side differences in Oxford grading (all \( P < 0.001 \)).

The optimal model predicting levator avulsion from all available data had an adjusted \( r^2 \) of 37.2%, with most of the above parameters remaining significant, predicting 81% of cases correctly (see Table 2). The regression equation for this model is

\[
\log \text{odds (defect = 1)} = -2.304 + 0.690 \times \text{minimum Oxford grading} + 0.518 \times \text{difference in oxford grading} + 0.076 \times \text{age at p1} + 1.206 \times \text{if cystocele Grade 2} + 2.291 \times \text{if cystocele Grade 3} - 0.645 \times \text{if stress incontinent} + 0.509 \times \text{if vaginal operative deliveries} + 0.509 \times \text{if had hysterectomy}
\]

The probability of a defect can then be calculated as follows:

\[
\text{Probability (defect = 1)} = \frac{e^{\text{equationA}/\text{values}}}{(1 + e^{\text{equationA}/\text{values}})}
\]
Table 1 Demographic data (n = 983 unless otherwise indicated)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean (range) or number (%)</th>
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<tbody>
<tr>
<td>Age</td>
<td>54.5 (17–89)</td>
</tr>
<tr>
<td>Age at first vaginal delivery</td>
<td>23.7 (15–42)</td>
</tr>
<tr>
<td>Stress incontinence</td>
<td>724 (74)</td>
</tr>
<tr>
<td>Urge incontinence</td>
<td>684 (70)</td>
</tr>
<tr>
<td>Symptoms of prolapse</td>
<td>390 (40)</td>
</tr>
<tr>
<td>Vaginal delivery</td>
<td>2.4 (0–12)</td>
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<tr>
<td>Vaginal operative delivery</td>
<td>132/813 (16)</td>
</tr>
<tr>
<td>Previous hysterectomy</td>
<td>312 (31)</td>
</tr>
<tr>
<td>Significant cystocele (Grade 2+)</td>
<td>389 (40)</td>
</tr>
<tr>
<td>Significant uterine prolapse (Grade 2+)</td>
<td>64/671 (10)</td>
</tr>
<tr>
<td>Significant posterior compartment prolapse (Grade 2+)</td>
<td>285 (29)</td>
</tr>
<tr>
<td>Oxford grading</td>
<td>2.5 (0–5)</td>
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<tr>
<td>Avulsion</td>
<td>240 (24)</td>
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</table>

Table 2 The best model for predicting avulsion injury in a urological population (Nagelkerke $r^2 = 37.2$, correct prediction in 81% of patients), using all available data

<table>
<thead>
<tr>
<th>Factor</th>
<th>Adjusted OR (95% CI)</th>
<th>P-value</th>
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</thead>
<tbody>
<tr>
<td>Cystocele</td>
<td>1.00</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>2</td>
<td>3.94 (2.56, 6.09)</td>
<td>&lt;0.001</td>
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<tr>
<td>3</td>
<td>8.43 (5.36, 13.28)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Difference in Oxford grading (per Oxford Grade)</td>
<td>1.88 (1.29, 2.75)</td>
<td>0.001</td>
</tr>
<tr>
<td>Minimum Oxford grading (per Oxford Grade)</td>
<td>0.50 (0.42, 0.60)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age at first vaginal delivery (per year)</td>
<td>1.08 (1.04, 1.12)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Forceps/vacuum delivery</td>
<td>1.58 (1.06, 2.36)</td>
<td>0.03</td>
</tr>
<tr>
<td>History of hysterectomy</td>
<td>1.64 (1.12, 2.42)</td>
<td>0.01</td>
</tr>
<tr>
<td>Stress incontinence</td>
<td>0.51 (0.34, 0.76)</td>
<td>0.001</td>
</tr>
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</table>

Table 3 A simplified model for predicting avulsion injury in a urological population when relying on history and simple clinical examination only (Nagelkerke $r^2 = 30.05$, correct prediction in 79.3% of cases)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Adjusted OR (95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cystocele</td>
<td>1.00</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>2</td>
<td>3.54 (2.13, 5.89)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>3</td>
<td>10.3 (6.1, 17.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age at first vaginal delivery (per year)</td>
<td>1.08 (1.04, 1.13)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Incontinence or prolapse surgery</td>
<td>2.24 (1.25, 4.02)</td>
<td>0.007</td>
</tr>
<tr>
<td>Forceps/vacuum delivery (one or more)</td>
<td>2.09 (1.35, 3.25)</td>
<td>0.001</td>
</tr>
<tr>
<td>Stress incontinence</td>
<td>0.52 (0.32, 0.82)</td>
<td>0.006</td>
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Table 4 Multivariate Risk Factor model for avulsion injury

<table>
<thead>
<tr>
<th>Factor</th>
<th>OR</th>
<th>Risk points</th>
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<tbody>
<tr>
<td>Cystocele</td>
<td>1.00</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>3.34</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>8.68</td>
<td>5</td>
</tr>
<tr>
<td>Minimum Oxford grading</td>
<td>1.00</td>
<td>0</td>
</tr>
<tr>
<td>Per extra unit</td>
<td>0.53</td>
<td>1</td>
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<tr>
<td>Side difference in Oxford grading</td>
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<td>&lt;1</td>
<td>1.87</td>
<td>1</td>
</tr>
<tr>
<td>≥1.5</td>
<td>2.37</td>
<td>2</td>
</tr>
<tr>
<td>Age at first vaginal delivery</td>
<td>1.00</td>
<td>0</td>
</tr>
<tr>
<td>18 years</td>
<td>1.60</td>
<td>1</td>
</tr>
<tr>
<td>for each 6 extra</td>
<td>1.65</td>
<td>1</td>
</tr>
<tr>
<td>Hysterectomy</td>
<td>1.79</td>
<td>1</td>
</tr>
<tr>
<td>Forceps/vacuum delivery</td>
<td>0.49</td>
<td>2</td>
</tr>
<tr>
<td>Presence of stress incontinence</td>
<td>0.49</td>
<td>2</td>
</tr>
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</table>

Other models were constructed for history only, and history plus gynaecological examination (excluding levator assessment for strength, see Table 3).

The model and associated risk points for each predictor for the prognostic index are given in Table 4. Risk points are derived from the odds ratios obtained on multivariate regression. A woman who had her first vaginal delivery at 36 (3 points) with a grade 3 cystocele (5 points), no hysterectomy (0 points), stress incontinence (−2 points), a forceps delivery (1 point), and Oxford grading of 2 (−2 points) and an Oxford difference of 1 (1 point), would have a risk score of 6. Whereas, a woman who had her first vaginal delivery at 18 (0) with a grade 1 cystocele (0), no stress incontinence (0), no hysterectomy (0), a normal delivery (1) and Oxford grading of 4 (−4) and an Oxford difference of 0 (0) would have a risk score of −4. The prognostic scores have been grouped into different levels of risk, based on quartiles (Table 5). The first woman mentioned above has a score of 6, placing her in the high risk group, with the odds of having an avulsion being 32 times that of a woman in the low risk group. The second woman above has a score of −4, placing her in the lowest risk group.

The simplified model given in Table 3 was used to graphically demonstrate how different patterns of risk factors are associated with the probability of avulsion (Fig. 2a–c).

Table 5 Odds ratios of avulsion injury for four risk groups

<table>
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<tr>
<th>Risk group</th>
<th>Score range</th>
<th>Frequency</th>
<th>Odds ratio (95% CI)</th>
<th>P-value</th>
</tr>
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<tr>
<td>Very low</td>
<td>Score ≤ −3.5</td>
<td>224</td>
<td>2.9 (1.4–6.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Low</td>
<td>−3.5 &lt; score ≤ −1.5</td>
<td>171</td>
<td>6.5 (3.3–12.6)</td>
<td></td>
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<tr>
<td>Medium</td>
<td>−1.5 &lt; score ≤ 1.0</td>
<td>184</td>
<td>32.1 (17–62)</td>
<td></td>
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<tr>
<td>High</td>
<td>1.0 &lt; score</td>
<td>173</td>
<td></td>
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Discussion

While this fact still has to make its way into obstetric textbooks, it is now clear that traumatic alteration of the insertion of the puborectalis muscle on the inferior pubic ramus is a common form of maternal birth trauma,\(^1,^2\) which is very likely to occur at the time of crowning of the foetal head,\(^26\) and which may in fact occasionally be visible in Delivery suite.\(^15\) Such trauma seems associated with a major derangement of levator function and biomechanics,\(^8,^9\) and it may well be one of the main aetiological factors in the development of female pelvic organ prolapse.\(^8,^11\) From a clinical point of view, it is particularly relevant that avulsion of the puborectalis muscle seems to predict recurrence after prolapse surgery.\(^18–20\) This does not imply actual causation (which would be very difficult to prove), but clearly levator avulsion is a marker for prolapse and prolapse recurrence.

It is therefore likely that detection of avulsion injury will become part of the clinical assessment of women presenting with symptoms of female pelvic organ prolapse. While diagnosis by ultrasound or magnetic resonance imaging seems preferable, these modalities (and the skills necessary to employ them) are not generally available, not even in the developed world, and this situation will only change gradually. In the meantime, it may be more feasible to rely on clinical detection, which is eminently feasible and can be self-taught. For a review of a standardised methodology for the digital detection of levator trauma, please see Dietz and Chek.\(^21\)

To help clinicians identify patients who are highly likely to present with an avulsion injury and to assist in the detection of trauma by creating a high index of suspicion, we undertook this study to model the likelihood of avulsion in a large series of urogynaecological patients. The data used for the modelling of the likelihood of levator trauma are such that they can be obtained by any medical or nonmedical person dealing with patients presenting with symptoms of pelvic floor dysfunction.

Levator defects are most likely to be found on ultrasound in women who had their first child by vaginal operative delivery over the age of 30 years and who present with symptoms of prolapse without concomitant stress incontinence. Clinical findings that increase the likelihood of avulsion are cystocele and uterine prolapse as well as strength of a pelvic floor muscle contraction and side differences in contraction strength.

Several weaknesses of our study have to be acknowledged. First, the performance of our model will vary with patient populations. It is highly likely that inferior results would be obtained in populations of different ethnic composition or obstetric practice and of different age at presentation. The particular mix of clinical presentations is also likely to affect model performance: it is likely that different results would be obtained in a urological practice, or in the practice of a general obstetrician/gynaecologist elsewhere in Australia or the world.

Second, the diagnosis of avulsion injury was made by the staff who were not blinded against the data used in the construction of this model, and it is conceivable that this might have introduced bias. It is unlikely that such bias had a major impact; however, as all the major predictors of trauma, such as age at first delivery,\(^1,^2\) operative delivery,\(^2,^27,^28\) and pelvic organ prolapse,\(^2,^10,^11\) have been confirmed by other investigators and by different diagnostic methods, ie, by magnetic resonance imaging.

However, it also has to be pointed out that this model is not intended as a diagnostic tool in itself so that a high degree of accuracy is not required. We have created a prognostic index, which may be helpful to clinicians in identifying women who are at high risk of trauma, but which needs to be verified in an independent data set. Our model will likely be useful to clinicians in the development of diagnostic skills and possibly

Figure 2 The probability of avulsion versus patient age. (a) gives this relationship in women without significant cystocele and separately for vaginal operative delivery (yes/no), stress incontinence (yes/no) and previous incontinence or prolapse surgery (yes/no). (b) replicates these data for women with 2nd degree cystocele, and (c) gives the same relationships for patients with 3rd degree cystoceles.
also in helping determine the need for further diagnostic measures, such as ultrasound or magnetic resonance imaging. A simpler form of this model has already proven very useful in the interstate and overseas teaching programmes provided by the senior author because its use largely guarantees that locally organised courses can source patients with avulsion injury for demonstration purposes.

**Conclusion**

This study defines the ‘typical’ patient suffering from avulsion of the puborectalis muscle, a common childbirth-related injury. It is possible to predict the presence/absence of such trauma in a given urogynaecological patient with a high likelihood of success. This should help clinicians in evaluating their findings when starting to diagnose levator avulsion clinically, especially if confirmation by imaging is unavailable.

**Funding**

Nil.

**Disclosure**

H.P. Dietz has acted as a consultant for AMS and CCS, has received speaker’s honoraria from GE and Astellas, and has received equipment loans from GE, Toshiba and B+K.

**References**

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