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Can pelvic floor trauma be predicted antenatally?

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Conflict of interest
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Abstract

Introduction. Levator trauma is a risk factor for the development of pelvic organ prolapse. We aimed to identify antenatal predictors for significant damage to the levator ani muscle during a first vaginal delivery. *Material and methods.* A retrospective observational study utilizing data from two studies with identical inclusion criteria and assessment protocols between 2005 and 2014. A total of 1148 primiparae with an uncomplicated singleton pregnancy were recruited and assessed with translabial ultrasound at 36 weeks antepartum and 871 (76%) returned for reassessment 3–6 months postpartum. The ultrasound data of vaginally parous women were analyzed for levator avulsion and microtrauma. The former was diagnosed if the muscle insertion at the inferior pubic ramus in the plane of minimal hiatal dimensions and within 5 mm above were abnormal on tomographic ultrasound imaging. Microtrauma was diagnosed in women with an intact levator and if there was a postpartum increase in hiatal area on Valsalva by >20% with the resultant area ≥25 cm^2. *Results.* The complete datasets of 844 women were analyzed. Among them, 609 delivered vaginally: by normal vaginal delivery in 452 (54%), a vacuum birth in 102 (12%) and a forceps delivery in 55 (6%). Levator avulsion was diagnosed in 98 and microtrauma in 97. On multivariate analysis, increasing maternal age, lower body mass index and lower bladder neck descent were associated with avulsion. Increased bladder neck descent and a family history of cesarean section (CS) were associcated with microtrauma. *Conclusions.* Maternal age, body mass index, bladder neck descent and family history of CS are antenatal predictors for levator trauma.

Abbreviations: BMI, body mass index; BND, bladder neck descent; POP, pelvic organ prolapse.

Introduction

Injury to the anal sphincter (OASI) is a well known complication of vaginal childbirth, with a quoted incidence of 4–6.6% (1). Apart from obstetric anal sphincter injury, however, pelvic floor trauma also includes levator ani muscle injury, which occurs more often and seems to be more strongly associated with future pelvic floor morbidity (2).

Key Message

Increased maternal age, lower body mass index and lower bladder neck descent are antenatal predictors for levator avulsion. A family history of cesarean section and higher bladder neck descent may predict microtrauma, i.e. hiatal overdistension.

Levator injury has a quoted incidence of 10–36% (3–6). It has been shown to be a strong risk factor for pelvic organ prolapse (POP) (6,7). The injury may take the form of avulsion (macrotrauma), where traumatic detachment of the puborectalis muscle from its insertion at the pubic rami, occurs at the time of crowning of the fetal head (8). It is commonly occult, although perineal and vaginal tears have recently been shown to be clinical markers of levator avulsion (9). Levator trauma may also take the form of irreversible overdistention of the levator ani complex, termed microtrauma. Microtrauma is defined as an increase in peripartum hiatal area on Valsalva >20% with a resulting area ≥25 cm^2 (4). It appears that both levator macro- and micro-trauma are most likely to occur with vaginal delivery of the first child (10,11). Both forms of levator injury are important risk factors in the development of POP and its recurrence (12,13).

Around 200 000 women undergo procedures for POP every year in the USA. The rate of surgery for POP is projected to rise by 46% by the year 2050 (14). A similar rise in the demand for POP surgeries is expected in Australia due to an aging population (15). Given these estimates and the significant association between levator trauma and POP, it becomes obvious that primary prevention of pelvic floor trauma should have a high research priority. Prevention may be more effective in high- risk patients, hence the identification of such individuals may be of potential value in clinical care and research. We therefore undertook a study aiming to identify antenatal risk factors for significant damage to the levator ani muscle in first-time mothers.

Material and methods

This is a reanalysis of the datasets of primiparous women seen in two prospective perinatal studies undertaken in two tertiary obstetric units in Sydney, Australia. One of the parental studies was an observational study designed to predict normal vaginal delivery. The other was a randomized controlled trial examining the effects of antepartum use of a birth trainer, the Epi-No® device, on the incidence of levator and anal sphincter injuries. Between 2005 and 2014, 1148 patients were recruited for the above two studies through the antenatal clinic at participating hospitals. Inclusion criteria for both studies were identical: (i) a nulliparous woman with no previous pregnancies ≥20 weeks' gestation, (ii) a planned vaginal delivery, (iii) an uncomplicated singleton pregnancy between 34 and 36 weeks' gestation and (iv) maternal age ≥18 years. All women underwent an identical assessment including a standardized interview, a clinical examination and a four-dimentional translabial ultrasound after written consent was obtained. Ultrasound imaging was performed in the supine position after bladder emptying using GE Voluson 730 Expert or E8 systems with an 8–4 MHz curved array volume transducer with an acquisition angle of 85° as previously described (16). Volumes were acquired at rest, on Valsalva and at maximum pelvic floor muscle contraction, with at least three Valsalva volumes acquired for each patient. All patients were invited back for repeat assessment 3–4 months postpartum, which was performed with the patient's abdomen covered to safeguard blinding to delivery mode. To avoid assessment bias, patients were requested not to divulge any information relating to their labor, delivery or outcome until after the completion of the examination.

Postprocessing of ultrasound volume data was performed on a desktop PC using proprietary software (GE Kretz 4D View 7.0–10.0, GE Kretz, Zipf, Austria) a minimum of 3 months after data acquisition, blinded to all clinical data. Levator avulsion was assessed on pelvic floor muscle contraction, or at rest if the patient failed to perform a pelvic floor muscle contraction, using tomographic ultrasound imaging in the axial plane. The levator ani muscle was imaged from 5 mm below to 12.5 mm above the plane of minimal hiatal dimensions with an interslice interval of 2.5 mm (17). The plane of minimal hiatal dimensions is identified as the shortest distance between the posterior symphysis pubis and the levator ani plate posterior to the anorectal muscularis in the mid-sagittal plane (18). Levator avulsion was diagnosed if the three central slices corresponding to the plane of minimal hiatal dimensions, 2.5 and 5 mm above this plane of reference (slices 3–5 in Figure 1), showed an abnormal insertion (avulsion) of the muscle at the inferior pubic ramus. The validity of this methodology has been demonstrated for symptoms and signs of POP (19).

Pelvic organ descent was assessed in volumes showing maximal organ displacement, against a reference line placed through the inferoposterior symphyseal margin (20). Bladder neck descent (BND) was used a marker for hiatal distensibility. Hiatal area was measured at the plane of minimal hiatal dimensions identified in the midsagittal plane (18). Irreversible overdistention of the levator hiatus ("microtrauma") was defined as a peripartum increase in a single individual of hiatal area on Valsalva >20%, provided this increase resulted in a postpartum hiatal area on Valsalva ≥25 cm^2. We have incorporated ≥25 cm^2 in the definition of microtrauma, as a hiatal area of <25 cm^2 can probably be regarded as nomal (18).

Obstetric and delivery data were collected from the hospital databases and patient records. This study was undertaken in the context of two parent studies approved by the Sydney West and Sydney South Area Health Service Human Research Ethics Committees (SWAHS HREC

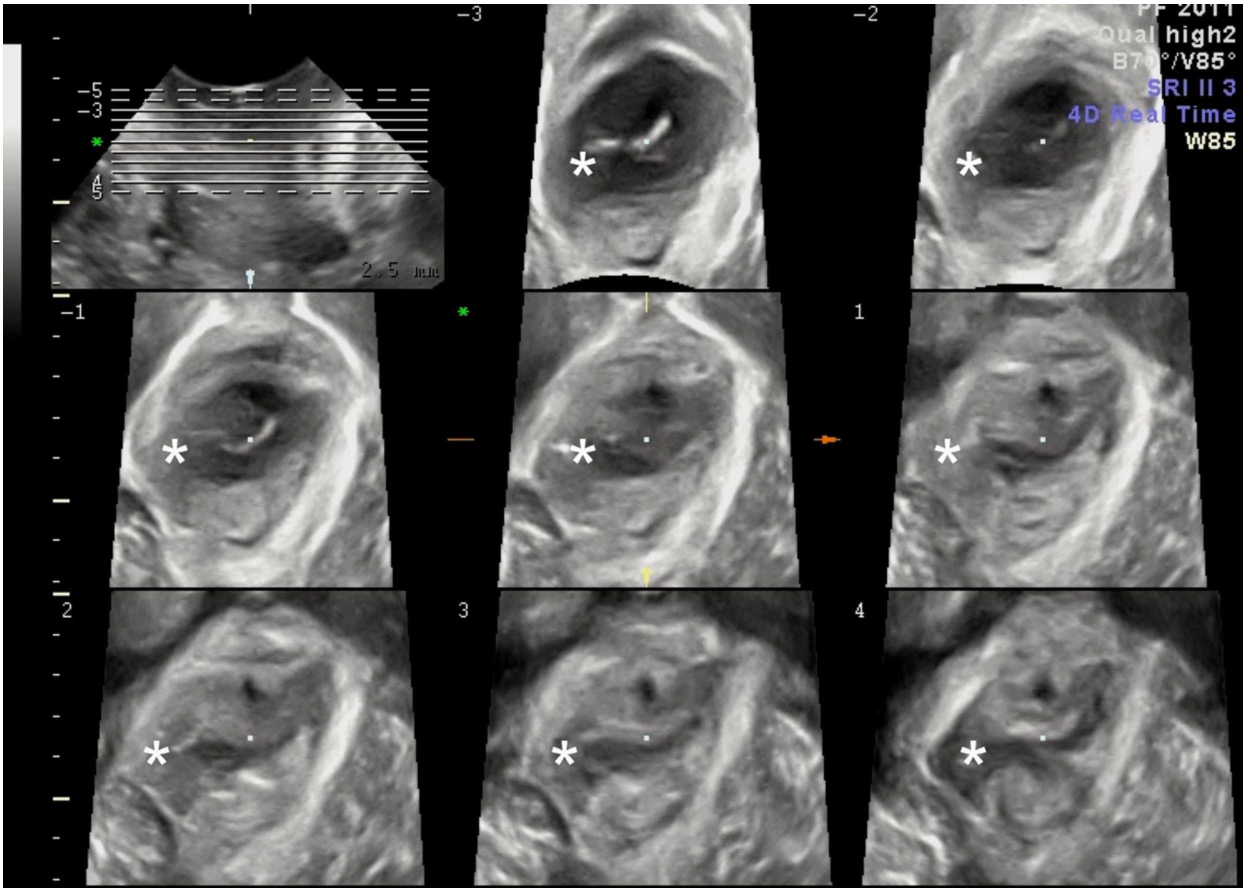

Figure 1. Tomographic image of a complete right-sided avulsion is indicated by (*) in slices 1–7. The volume was acquired on pelvic floor muscle contraction, during transperineal ultrasound with the probe in the midsagittal plane. The interslice interval is set at 2.5 mm. [Color figure can be viewed at wileyonlinelibrary.com].

07-022, SWAHS HREC 05/004 and SSAHS HREC X09-0384). One of the two studies was a randomized controlled perinatal intervention trial. The intervention arm of this trial was included in the analysis, as the intervention (i.e. use of the Epi-No birth trainer) was shown to have no effect on levator avulsion, irreversible overdistention (microtrauma), perineal tears or anal sphincter injuries (3). Power calculations were not undertaken, as this is a secondary analysis of the two trials for which sample size had been determined independently.

Subsequent analysis focused on the association between known potential antenatal risk factors and pelvic floor trauma diagnosed on ultrasound, using logistic regression to identify risk factors of interest. Statistical analysis was performed using MINITAB V13 (Minitab, State College, PA, USA) and SAS V9.2. Student's *t*-test and Mann–Whitney U-tests were used for normally distributed and non-normally distributed variables, respectively. Chi-square test was used for categorical variables. Any obstetric factors tested to be near significant, i.e. $p = 0.05$, on univariate analysis were included in a multivariable logistic regression model to control for confounding variables. A value of $p < 0.05$ was deemed statistically significant.

Results

Of 1148 participants recurited in the two peripartum studies, 871 (76%) returned for their postpartum assessment. Of these, 27 women were excluded from analysis due to missing or incomplete ultrasound data ($n = 18$), missing delivery data ($n = 6$) and ongoing pregnancy at the time of follow up ($n = 3$), leaving 844 complete datasets. Among them, 235 women (28%) delivered via cesarean section and 609 delivered vaginally. A normal vaginal delivery occurred in 452 women (54%), a vacuum extraction in 102 (12%) and a forceps delivery in 55 (6%).

The mean maternal age was 29 years (range 18.1–45.3) and the average antepartum body mass index (BMI) was 29.5 kg/m^2 (range 18–57). A total of 23% of women had a previous miscarriage. The mean gestational age at first presentation was 36.5 weeks (range 32.9–38.6) and the average gestation at delivery was 40.0 weeks (range 36.0–42.2). In all, 709 (83%) were white. An epidural was used in 374 (44%) and syntocinon in 372 (44%). The length of 2nd stage was recorded at a median of 45 min (interquartile range 12–101 min) and the mean birth-weight was 3472 g (range 2010–4996). Of those delivered vaginally, 159 had an episiotomy and 296 had a perineal tear (1st degree in 72, 2nd degree in 184, 3rd or 4th degree in 40).

On ultrasound postprocessing of stored volume imaging data, no levator avulsion was diagnosed in women delivered by cesarean section. In the vaginally parous group, levator avulsion was diagnosed in 98 (16%). On univariate analysis, increasing age, lower BMI and decreasing BND were associated with levator avulsion. On multivariate regression analysis, all three remained significant (see Table 1), although associations were weak.

For assessment of hiatal distensibility, women diagnosed with levator avulsion were excluded, leaving 511 datasets for analysis. Among the vaginally parous, 97 (19%) were diagnosed with irreversible overdistension of the levator hiatus, i.e. "microtrauma". On univariate analysis, family history (mother or sister) of cesarean section and increasing BND were associated with microtrauma. They remained significant on multivariate regression analysis (see Table 2).

Multivariate analyses were repeated after excluding patients in the intervention arm of the second parent study (the "EpiNo Trial"), yielding near-identical results.

Discussion

In this study of more than 800 women, we have confirmed findings of previous studies showing an association between maternal age and levator avulsion (see Figure 1) (21,22). It seems that advanced maternal age at the time of first delivery carries not only an increased risk of pregnancy complications, for example, gestational diabetes, preeclampsia and stillbirth, but also an increased risk of pelvic floor trauma (23,24). Changes in the biomechanical properties of pelvic floor connective tissues with age may explain the association, as connective tissue may become less elastic and more susceptible to trauma (25). Cadaver studies have shown an association between myogenic changes of the levator ani muscle and age (26). Furthermore, increasing age was found to be significantly associated with myopathic changes such as fibrosis, variations in fiber diameter and centralization of nuclei (27). Unfortunately, there is very little information in the world literature on the biomechanical properties of the levator ani muscle and its insertion on the inferior pubic ramus, apart from what has been obtained in cadavers (28).

Higher antenatal distensibility of supportive tissues, as evidenced by a higher BND, seems associated with a

Table 1. Predictors of levator ani avulsion (n = 609).

Predictors of avulsion n = 98	Univariate	p-value	Multivariate	p-value
Age	1.06 (95% CI 1.02–1.1)	p = 0.005	1.05 (95% CI 1.01–1.1)	p = 0.019
BMI	0.93 (95% CI 0.88–0.98)	p = 0.005	0.94 (95% CI 0.89–0.99)	p = 0.018
Ethnicity	0.58 (95% CI 0.29–1.16)	p = 0.125		
Family history of cesarean	1.09 (95% CI 1.83–0.65)	p = 0.747	1.05 (95% CI 0.62–1.78)	p = 0.864
Previous pregancy	1.36 (95% CI 0.81–2.28)	p = 0.251		
BND	0.97 (95% CI 0.95–0.99)	p = 0.0049	0.97 (95% CI 0.95–1)	p = 0.026

Table 2. Predictors of levator ani microtrauma (n = 609).

Predictors of microtrauma n = 97	Univariate	p-value	Multivariate	p-value
Age	1.03 (95% CI 0.99–1.08)	p = 0.158		
BMI	1.03 (95% CI 0.99–1.08)	p = 0.158		
Ethnicity	1.68 (95% CI 0.94–2.99)	p = 0.078		
Family history of cesarean	0.46 (95% CI 0.92–0.23)	p = 0.029	0.46 (95% CI 0.23–0.93)	p = 0.031
Previous pregnancy	1.22 (95% CI 0.71–2.11)	p = 0.473		
BND	1.02 (95% CI 1–1.05); p = 0.0571	p = 0.057	1.03 (95% CI 1–1.05)	p = 0.026

decreased risk of levator avulsion. Both BND and hiatal area on Valsalva are proxy measures for pelvic floor distensibility and they are strongly intercorrelated. Its weak positive association with irreversible overdistention is more difficult to explain. It is likely that tissues that are more prone to stretch, as opposed to rupture or avulse, may protect women from levator avulsion with vaginal delivery of the fetal head. It is also likely that individuals will vary in their vulnerability as regards trauma to the muscle itself and/or trauma to the insertion of the puborectalis. The latter is an unusual structure, as this muscle inserts directy into periost and bone, without intervening tendon or ligament (29).

Although a high BMI increases the risk of pregnancy complications (30), it seems to be protective of pelvic floor trauma, confirming previous findings (19). It is noteworthy that a similar protective effect of obesity has been shown for clinically diagnosed anal sphincter tears (31). Siafarikas et al. found no association between levator avulsion and BMI (32). However, that study had a smaller sample size (only 44 patients with defects compared with 98 patients in our series) and prepregnancy BMI was much lower (mean BMI 23.7 kg/m^2 vs. 29.5 kg/m^2) than in the study presented here. Of course, other factors such as a different ethnic mix and varying obstetric management may also play a role. It should be emphasized that the protective effect of BMI is not explained by the higher risk of CS in obese women, as it is also found when analyzing only women who delivered vaginally. It may be hypothesized that nutritional status may have an effect on the biomechanical properties of muscle and connective tissue (the "marbled steak" effect). This intriguing issue remains to be studied in future research.

To our knowledge, this is the largest study to date attempting to identify antepartum risk factors of levator trauma. Previous smaller studies have identified several possible risk factors for antenatal prediction of levator avulsion. In a study performed at our unit where 34 of 240 vaginally parous women were diagnosed with an avulsion, a lower BMI was found to be the only predictor of levator avulsion (19). This is likely due to the smaller study size. Other risk factors shown to be associated with levator trauma include increasing maternal age (24), smaller AP diameter at rest and on Valsalva on transperineal ultrasound (32,33) and increasing head circumference and birthweight of the newborn (34). However, findings have been inconsistent across studies and the clinical usefulness of these parameters is limited, especially in the case of estimated fetal weight using antenatal ultrasound. Our study has confirmed that decreasing BMI and increasing maternal age are associated with levator avulsion. Since the data relating to BMI and maternal age at the time of first delivery are both continuous and linear, we have not attempted to define a cut-off, as that would seem to be arbitrary and of very limited clinical utility. Although these risk factors are associated with levator avulsion, they are poor predictors when compared with intrapartum predictors of avulsion, especially forceps (35). However, this study has added to our knowledge that decreasing BND is positively associated with avulsion. The ultrasound methodology used in the study is inexpensive, simple and safe. It has been shown to be both highly reproducible and acceptable to patients (36). Lastly, ultrasound imaging provides an objective method for diagnosing occult trauma that may previously have gone undetected or ignored (37).

However, this study suffers from a number of weaknesses that must be acknowledged. First, the follow-up rate for our study was only 76%. It should also be mentioned that our study participants were largely white and younger than the Australian average for primiparae, hence the results may not be applicable to populations with different demographics. Addtionally, there were differences in age between attenders and non-attenders that could have affected our findings. Non-attenders were, on average, 2 years younger than attenders. Given that increasing age is a risk factor for both operative delivery and levator avulsion, this may have led to older women with pelvic floor damage returning for follow up while their younger, intact counterparts did not. Despite these factors, there were no significant differences in demographic and delivery data between attenders and non-attenders (Table 3).

Table 3. Demographics of attenders vs. non-attenders.

	Attenders (*n* = 871)	Non-attenders (*n* = 277)	*p*-value
Mean age, years (±SD)	29.0 (±5.5)	27.0 (±5.8)	<0.001
Mean BMI, (±SD)	29.5 (±5.3)	30.0 (±5.5)	0.20
Mean gestation at delivery, weeks (±SD)	40.0 (±1.25)	40.0 (±1.14)	0.58
Mean birthweight of baby, g (±SD)	3474 (±438)	3464 (±439)	0.76
Mean postpartum hospital stay, days (±SD)	3.5 (±1.7)	3.5 (±1.7)	0.99
Delivery mode*			
LSCS	240 (28%)	81 (29%)	0.056
Prelabor	59 (7%)	19 (7%)	
1st stage	133 (15%)	49 (18%)	
2nd stage	48 (6%)	13 (5%)	
NVD	462 (53%)	130 (47%)	
VE/FD	103 (12%)	47 (17%)	
	57 (7%)	9 (3%)	

BMI, body mass index; FD, forceps delivery LSCS, lower segment cesarean section; NVD, normal vaginal delivery; SD, standard deviation; VE, vacuum extraction.
*19 patients had missing data regarding mode of delivery.

Another issue of concern is that, to increase the power of the index project, some of the datasets used were collected as part of a prospective interventional study examining the effect of antepartum use of a birth device on pelvic floor trauma. Although use of this device could have potentially confounded the results, this seems unlikely, as the intervention was shown to have no effect on the incidence of levator trauma (3). A repeat analysis after excluding women in the intervention arm of the EpiNo Study yielded near-identical results.

Lastly, disparities in local obstetric practice may have affected outcomes. These patients were recruited from two tertiary units in Sydney, Australia, with somewhat disparate obstetric management. Forceps, which is a known risk factor for levator avulsion, is considerably less common in our unit than at most other tertiary units (38). The number of women diagnosed with avulsion and microtrauma may be higher in a unit with a high rate of complex vaginal deliveries (39).

In conclusion, increasing maternal age and decreasing BMI were associated with avulsion, whereas increasing BND, a measure that may reflect pelvic floor distensiblity, was protective against avulsion. However, all associations were weak. This implies that antenatal prediction of levator ani is unlikely to contribute to clinical care. This may be due partly to the fact that associations between tissue biomechanics and trauma are unlikely to be linear. Whereas very distensible tissues may protect from trauma, excessively stiff tissues may do the same – by preventing vaginal delivery in the first instance. Hence, it may be more practical to try and predict a nontraumatic normal vaginal delivery, the one outcome all obstetric caregivers and their patients are likely to aspire to.

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