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# Levator ani muscle avulsion during childbirth: a risk prediction model

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**Objective** To establish the incidence of levator ani muscle (LAM) avulsion in primiparous women and to develop a clinically applicable risk prediction model.

**Design** Observational longitudinal cohort study.

**Setting** District General University Hospital, United Kingdom.

**Sample** Nulliparous women at 36 weeks of gestation and 3 months postpartum.

**Methods** Four-dimensional transperineal ultrasound was performed during both visits. Tomographic ultrasound imaging at maximum contraction was used to diagnose no, minor or major LAM avulsion. A risk model was developed using multivariable ordinal logistic regression.

**Main outcome measures** Incidence of LAM avulsion and its risk factors.

**Results** Of 269 women with no antenatal LAM avulsion 71% ($n$ = 191) returned postpartum. No LAM avulsion was found after caesarean section ($n$ = 48). Following vaginal delivery the overall incidence of LAM avulsion was 21.0% ($n$ = 30, 95% confidence interval [95% CI] 15.1–28.4). Minor and major LAM avulsion were diagnosed in 4.9% ($n$ = 7, 95% CI 2.2–9.9) and 16.1% ($n$ = 23, 95% CI 10.9–23.0), respectively. Risk factors were obstetric anal sphincter injuries (odds ratio [OR] 4.4, 95% CI 1.6–12.1), prolonged active second stage of labour per hour (OR 2.2, 95% CI 1.4–3.3) and forceps delivery (OR 6.6, 95% CI 2.5–17.2). A risk model and nomogram were developed to estimate a woman's individual risk: three risk factors combined revealed a 75% chance of LAM avulsion.

**Conclusions** Twenty-one percent of women sustain LAM avulsion during their first vaginal delivery. Our risk model and nomogram are novel tools to estimate individual chances of LAM avulsion. We can now target postnatal women at risk of sustaining a LAM avulsion.

**Keywords** Childbirth, incidence, levator ani avulsion, pelvic organ prolapse, risk prediction model, transperineal ultrasound.

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## Introduction

Defects in pelvic floor muscles following childbirth were first described by Howard Gainey in 1943.[1] Subsequently, the main focus of trauma to the pelvic floor after vaginal delivery shifted to obstetric anal sphincter injuries (OASIS).[2] However, over the past decade, with the advent of modern imaging techniques, trauma to the pelvic floor muscles has gained a lot of interest. There is evidence that 36% of women with prolapse have an underlying levator ani muscle (LAM) avulsion.[3] This avulsion occurs in 13–36% of women mainly during the first vaginal delivery[4–11] by stretching and tearing of the muscle from the insertion on the inferior pubic ramus.[12]

A variety of childbirth-related risk factors for LAM avulsion have been described in the literature,[13] including operative vaginal delivery,[11] forceps delivery,[6,10,14] OASIS,[6] episiotomy,[6] prolonged second stage of labour,[6,8,10] increased fetal head circumference[8] and increased maternal age.[6] On the other hand, epidural analgesia is thought to be a protective factor.[10] In a prospective study, Shek and Dietz aimed to describe antepartum predictors of major LAM avulsion.[9] They found that a lower body mass index (28 versus 30 kg/m$^2$) was the only significant risk factor[9] and were therefore unable to develop an antepartum prediction model.

The primary aim of this study was to establish the incidence of LAM avulsion in primiparous women. Second,

we aimed to develop a clinically applicable risk prediction model for LAM avulsion.

## Methods

Between January 2011 and May 2012 nulliparous women were invited to participate in an observational longitudinal cohort study. This study was approved by the National Research Ethics Service South West London committee (REC 10/H0806/87). Women were recruited from the antenatal clinics and parent craft classes at Croydon University Hospital, London, UK. At the initial contact, they were informed about the project, an information leaflet was given and contact details were collected. At 34 weeks of gestation the researcher telephoned them to enquire if they were interested in participating in the study. The inclusion criteria were a singleton pregnancy, maternal age >18 years, no previous history of pregnancy of more than 20 weeks of gestation, and being able to read and understand English. We invited all nulliparous women to create a sample representative for the normal population. The recruitment process has previously been described in detail.[15] All women gave written informed consent during their first appointment at 36 weeks of gestation. Subsequently, participants were invited by telephone, postal mail and electronic mail to book a follow-up appointment 3 months following childbirth (Figure 1). Demographic and obstetric details were prospectively collected from the hospital confidential notes.

Women were asked to empty their bladder before the ultrasound assessment. Four-dimensional transperineal ultrasound (TPUS) was performed in the supine position with knees semi-flexed using a GE Voluson 730 system with a 4–8 MHz transabdominal curved array volume transducer, with an acquisition angle of 85 degrees. The midsagittal plane was used to identify the minimal anteroposterior diameter of the levator hiatus, from the posterior margin of the symphysis pubis to the anterior margin of LAM.[16,17] Tomographic ultrasound imaging (TUI) on maximum pelvic floor muscle contraction was used to assess the entire LAM and its attachment to the inferior pubic ramus.[18,19] Eight slices were created in the axial plane, from 5 mm below the plane of minimal hiatal dimensions to 12.5 mm above, at 2.5-mm slice intervals.[18,19] The central three slices were scored as positive or negative for LAM avulsion, using direct visualisation, scoring the left and right sides separately. The final unilateral score ranged from 0 (no avulsion) to 3 (complete LAM avulsion).[19] A summed total score for the left and right sides (0–6) was then assigned and classified as no LAM avulsion (summed score of 0), minor LAM avulsion (summed score of 1–3) or major LAM avulsion (summed score of 4–6, or a unilateral score of 3; Figure 2).[6,20] Blind offline analysis was performed using 4D VIEW version 10.2; GE Healthcare, London, UK. Two independent investigators (KvD and KK), blinded for mode of delivery and each other's results, analysed LAM avulsion on all postnatal

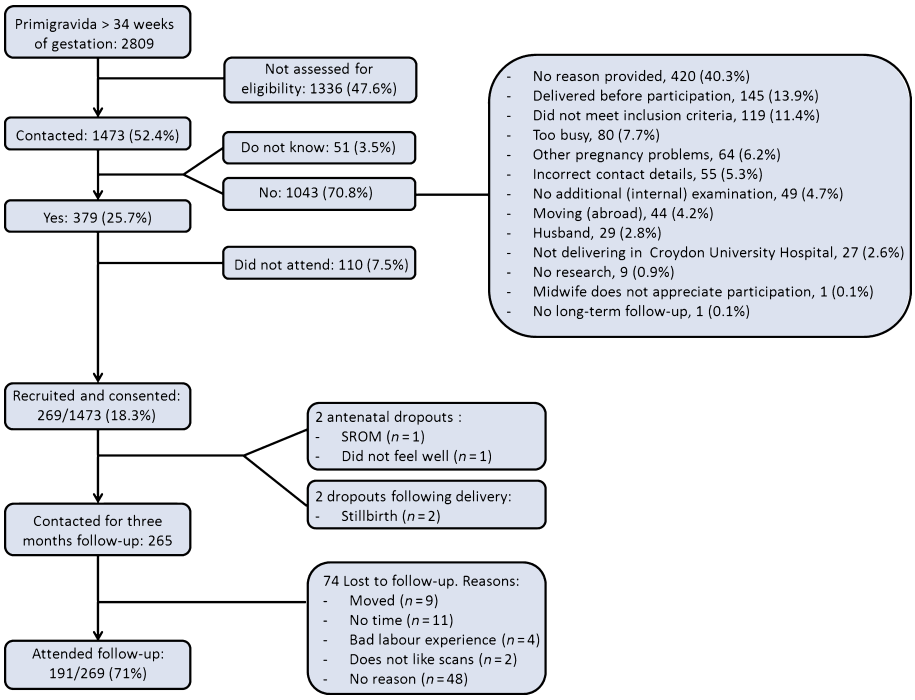


**Figure 1.** Flowchart of the recruitment process and the attendance of the 3-month postpartum visit. SROM, spontaneous rupture of membranes. (Partly reproduced from van Delft et al[15] with permission).

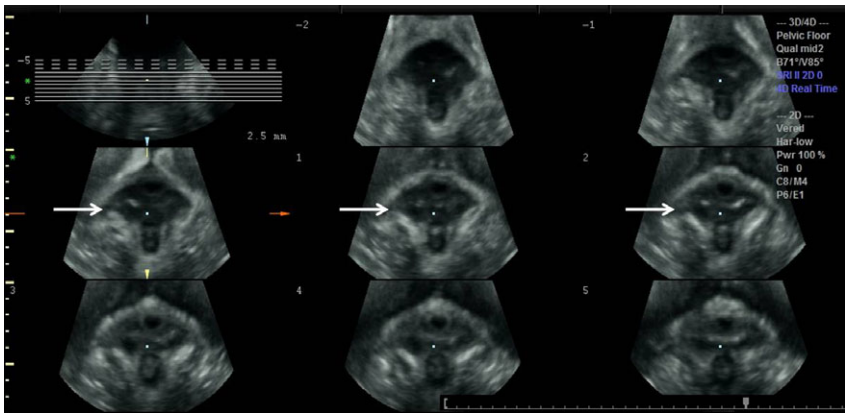


**Figure 2.** Tomographic ultrasound imaging: unilateral LAM avulsion on maximum contraction, 3 months postpartum. Arrows indicate right sided unilateral LAM avulsion.

scans. In presence of discrepancies, consensus was reached by a third investigator (RT). LAM avulsion can be diagnosed reliably using TUI on TPUS at maximum pelvic floor muscle contraction as excellent agreement was found between two raters [Cohen's $\kappa$ 0.83 (95% confidence interval [95% CI] 0.59–1.0)].[21]

### Statistical analysis

On the basis of previous studies on LAM avulsion following childbirth, we determined that we would need to enrol 186 women to detect 14% LAM avulsion with a precision (standard error) of 2.5%. A total sample size of 265 was calculated to allow a 30% dropout rate.

To analyse differences in women who attended 3 months postpartum and were lost to follow up, we used Student's *t*-test, Mann–Whitney *U*-test, chi-square test and Fisher's exact test where appropriate. Demographics and obstetric data to identify risk factors of LAM avulsion were analysed by definition of the three groups (no versus minor versus major LAM avulsion), using analysis of variance, applying post-hoc least significant difference procedure for inter-group comparison, Kruskal–Wallis test, chi-square test and Fisher's exact test where appropriate.

Subsequently, odds ratios (OR) were estimated by performing regression analysis on demographics and obstetric data. Ordinal logistic regression analysis was used instead of multinomial logistic regression to maintain the valuable information on ordering of LAM avulsion severity.[22] All variables with a $P < 0.20$ on univariable ordinal logistic regression were considered for multivariable ordinal logistic regression. The final selection procedure for the multivariable ordinal logistic regression was subsequently based on clinical relevance. Although individual risk prediction is often poor when based on only one factor,[23] it is important to avoid overfitting of the model especially with many predictive factors in a small dataset.[24] Accurate selection of predictive factors will result in models with less overfitting and greater generalisability.[24,25] Predictors should be as independent as possible and there should be a possibility to influence subsequent management based on these predictors. Furthermore, when performing regression analyses, the number of events (LAM avulsion) should be ten times the number of prognostic factors included in the model.[26]

Multivariable ordinal logistic regression was applied to estimate adjusted odds ratios for the most relevant variables, in models of all possible combinations of these most relevant variables (all subsets regression). The model with the highest $R^2$ was selected as the final model. The internal validity of this model was controlled for by performing bootstrap validation. Nomograms were created to estimate an individual woman's risk of LAM avulsion. All analyses were performed using SPSS (version 20.0 SPSS Inc, Chicago, IL, USA) and R (version 2.15.2).[27] Two-sided $P < 0.05$ were considered statistically significant.

## Results

1473 out of 2809 eligible women were invited to participate (Figure 1). Of these, 269 nulliparous women agreed to participate at a median of 36 weeks of gestation (range 34–41 weeks); 71% ($n = 191$) returned for follow up at a median of 13 weeks postnatal (range 10–26 weeks; Figure 1). Two antenatal women dropped out before the antenatal ultrasound assessment, all other ultrasound assessments were performed according to protocol. Demographics and obstetric data were compared to assess differences in the follow-up and lost-to-follow-up groups (see Supporting information, Table S1). Nonattenders were somewhat younger (mean age 29.1 versus 30.7 years, $P = 0.039$), more often delivered by caesarean section (43% versus 25%, $P = 0.043$), had fetuses with a significantly smaller birthweight (3185 g versus 3375 g, $P = 0.002$) and head circumference (33.8 cm versus 34.3 cm, $P = 0.045$) and more episiotomies (61% versus 43%, $P = 0.030$) were performed.

None of the antenatal women had LAM avulsion and no LAM avulsion was found after caesarean section ($n = 48$). The overall incidence of LAM avulsion following a vaginal delivery was 21.0% ($n = 30$, 95% CI 15.1–28.4). Minor and major LAM avulsion were diagnosed in 4.9% ($n = 7$, 95% CI 2.2–9.9) and 16.1% ($n = 23$, 95% CI 10.9–23.0), respectively.

Demographics were not notably different in the three groups (Table 1). Obstetric data revealed a significant association between LAM avulsion and age, duration of active second stage, mode of delivery (forceps delivery) and perineal laceration (OASIS; Table 1). Six women had forceps deliveries and OASIS. One of them had no LAM avulsion and five had major LAM avulsion.

### Ordinal logistic regression analysis

Women who underwent caesarean sections were excluded from the ordinal logistic regression analysis, because they had not sustained LAM avulsion. The following variables had a $P < 0.20$ on univariable ordinal logistic regression analysis and were considered for multivariable ordinal logistic regression analysis: body mass index (OR 0.95, 95% CI 0.87–1.03), mode of delivery (forceps delivery as a risk factor: OR 6.6, 95% CI 2.5–17.2), second stage of labour (per hour; OR 1.82, 95% CI 1.00–1.82), active second stage of labour (per hour) (OR 2.17, 95% CI 1.35–3.28), perineal laceration/OASIS (OR 4.4, 95% CI 1.6–12.1), second degree tear (OR 2.6, 95% CI 1.15–5.87) and episiotomy (OR 0.5, 95% CI 0.21–1.07; see Supporting information, Table S2).

Multivariable ordinal logistic regression analysis applying all subsets analyses was performed for three variables, to avoid overfitting in a relatively small number of women with any form of LAM avulsion ($n = 30$),[24] as the ratio of number of events to number of prognostic values should be 10 : 1.[26] The selection procedure for the multivariable analysis was based on clinical relevance of the predictors as explained in the Methods. Therefore OASIS, duration of active second stage of labour and forceps delivery were selected from the candidate list of predictors. This resulted in four combined models with crude and adjusted odds ratios (Table 2). Model 1 consisted of: OASIS and active second stage of labour, model 2: OASIS and forceps delivery, model 3: active second stage and forceps delivery, model 4: OASIS, active second stage of labour and forceps delivery.

The odds ratios indicate that (higher values of) these variables increase the likelihood of more severe LAM avulsion. Furthermore, using multivariable ordinal logistic regression analysis, we estimated cumulative odds for the observation of LAM avulsion severity. For example, if two women were identical except for the variable OASIS, the odds for a major LAM avulsion (versus minor or no LAM avulsion) were 3.1 in the case of OASIS. Likewise, the odds for a LAM avulsion (either minor or major) versus no LAM avulsion were 3.1 times greater than for the woman without OASIS. The three predictive factors used for the prediction model are independent factors. Although OASIS and forceps delivery have previously been related,[2] they have a cumulative effect on the chance of sustaining LAM avulsion, which make them independent factors.

Model 4, consisting of all three variables, resulted in the most reliable risk prediction of having sustained LAM avulsion. This model has an $R^2$ of 19.2%, which suggests how much of LAM avulsion can (19.2%) and how much cannot (80.8%) be explained by the model. The internal validity of the model was evaluated by performing bootstrap validation. The concordance-index (c-index) indicating discrimination for the proposed model (similar to the area under the receiver operator curve in logistic regression) was 0.672. After correction for optimism in the original model the c-index was 0.647 (>0.70 corresponds to a reasonable model), which implies that you can predict better with this risk model than if you had no model at all. The nomogram based on model 4, can be used to estimate a woman's individual risk of having sustained LAM avulsion (Figure 3).

## Discussion

### Main findings

This observational longitudinal cohort study reveals a 21% incidence of LAM avulsion in primiparous women 3 months following vaginal delivery. The risk factors for LAM avulsion were OASIS, active second stage of labour and forceps delivery. The risk model and nomogram we have described are novel tools to estimate an individual woman's risk of having sustained LAM avulsion.

### Strengths and limitations

The strengths of the study were the prospective design and power calculation to establish the incidence of LAM avulsion. Furthermore, the loss to follow-up group was similar in demographics and obstetric outcomes to the group that attended both visits. The prospective study design makes the results of the prediction model more reliable.[24] However, we acknowledge the limitations because this study was not powered to develop a prediction model.[24,26] Second, the list of predictors was not defined a priori, which would have made the risk of overfitting even smaller. Another limitation is the relatively small number of women with LAM avulsion, allowing us to only enter three variables in the multivariable ordinal logistic regression analysis.[22,26] Although with small group sizes the risk of overfitting exists,[24,25] we have controlled for that by performing bootstrapping to internally validate the discriminatory performance of the model.[24] However, the major

**Table 1.** Demographics and obstetric details in women with no, minor or major LAM avulsion

| | No avulsion ($n$ = 161) | Minor avulsion ($n$ = 7) | Major avulsion ($n$ = 23) | $P$ value |
|---|---|---|---|---|
| **Demographic variables** | | | | |
| Age (years) | 30.7 (SD 5.3) | 25.0 (SD 6.0) | 32.9 (SD 5.3) | **0.003**[B,C] |
| Body mass index (kg/m$^2$) | 25.6 (SD 5.7) | 25.4 (SD 6.3) | 23.3 (SD 2.7) | 0.18 |
| Ethnicity | | | | |
| White | 91 (57%) | 5 (71%) | 10 (43%) | 0.10 |
| Asian | 24 (15%) | | 5 (22%) | |
| Mixed | 6 (4%) | 2 (29%) | 2 (9%) | |
| Black | 37 (23%) | | 5 (22%) | |
| Other | 3 (2%) | | 1 (4%) | |
| **Delivery variables** | | | | |
| Gestational age at delivery (weeks) | 40.1 (SD 1.2) | 40.0 (SD 1.3) | 40.4 (SD 1.0) | 0.40 |
| Induction | | | | |
| No | 111 (69%) | 4 (57%) | 20 (87%) | 0.15 |
| Yes | 50 (31%) | 3 (43%) | 3 (13%) | |
| Use of oxytocin | | | | |
| No | 99 (61%) | 5 (71%) | 13 (57%) | 0.77 |
| Yes | 62 (389%) | 2 (29%) | 10 (43%) | |
| Epidural analgesia | | | | |
| No | 105 (65%) | 5 (71%) | 16 (70%) | 0.88 |
| Yes | 56 (35%) | 2 (29%) | 7 (30%) | |
| First stage (minutes)* | 415 (range 35–1271) | 310 (range 90–756) | 420 (range 62–985) | 0.24 |
| Second stage (minutes)* | 60 (range 4–269) | 45 (range 27–267) | 130 (range 4–260) | 0.10 |
| Active second stage (minutes)* | 37 (range 2–209) | 45 (range 22–183) | 75 (range 2–200) | **0.018**[A] |
| Mode of delivery | | | | |
| Normal vaginal | 77 (48%) | 6 (86%) | 9 (39%) | **<0.001** |
| Forceps | 10 (6%) | 1 (14%) | 10 (43%) | |
| Ventouse | 26 (16%) | | 4 (17%) | |
| Elective caesarean | 10 (6%) | | | |
| Emergency caesarean | 38 (24%) | | | |
| Perineal laceration* | | | | |
| No | 11 (10%) | | 1 (4%) | **0.001** |
| First-degree | 14 (12%) | 4 (57%) | 3 (13%) | |
| Second-degree | 80 (70%) | 3 (43%) | 11 (48%) | |
| OASIS | 10 (9%) | | 8 (35%) | |
| Episiotomy* | | | | |
| No | 70 (61%) | 5 (71) | 8 (35%) | 0.05 |
| Yes | 45 (39%) | 2 (29%) | 15 (65%) | |
| Birthweight (g) | 3362 (SD 413) | 3451 (SD 428) | 3450 (SD 441) | 0.57 |
| Head circumference (cm)** | 34.2 (SD 14.4) | 34.0 (SD 12.6) | 34.4 (SD 18.8) | 0.78 |
| Occipito-anterior*** | | | | |
| No | 20 (13%) | 0 | 4 (17%) | 0.48 |
| Yes | 136 (87%) | 7 (100%) | 19 (83%) | |
| Shoulder dystocia**** | | | | |
| No | 155 (99%) | 7 (100%) | 23 (100%) | 0.82 |
| Yes | 2 (1%) | 0 | 0 | |

Analysis of variance applying least significant difference if $P < 0.05$, Kruskal–Wallis applying Mann–Whitney $U$-test if $P < 0.05$, and chi-square test. Continuous variables are given as means with standard deviations (SDs) or medians with ranges (range); categorical variables are given as numbers with percentages (%). All $P$-values are two-sided.

[A–C]Statistically significant difference between no and major avulsion (A), minor and major avulsion (B) and no and minor avulsion (C), respectively.

*Not applicable in women that delivered by caesarean section.

**Missing data in six women without LAM avulsion, in one woman with minor LAM avulsion and in one woman with major LAM avulsion.

***Missing data in five women without LAM avulsion.

****Missing data in four women without LAM avulsion.

Bold values are statistically significant values.

**Table 2.** Multivariable ordinal logistic regression analysis: crude and adjusted odds ratios for LAM avulsion severity in three categories for primiparous women following vaginal delivery ($n$ = 143)

| Variables | Crude odds ratio (95% CI) | *P* value | Adjusted odds ratio (95% CI) | | | |
|---|---|---|---|---|---|---|
| | | | Model 1, $R^2$ = 0.145 | Model 2, $R^2$ = 0.167 | Model 3, $R^2$ = 0.161 | Model 4, $R^2$ = 0.191 |
| Forceps delivery | 6.6 (2.5–17.2) $R^2$ = 0.128 | <0.001 | | 5.6 (2.1–15.0) | 4.2 (1.5–12.1) | 3.8 (1.3–11.1) |
| OASIS | 4.4 (1.6–12.1) $R^2$ = 0.069 | 0.007 | 3.5 (1.2–10.1) | 3.4 (1.2–9.9) | – | 3.1 (1.01–9.2) |
| Active second stage (hour) | 2.17 (1.35–3.28) $R^2$ = 0.102 | 0.001 | 2.05 (1.27–3.09) | | 1.61 (1.0–2.75) | 1.61 (1.06–2.59) |
| Estimates for the intercepts of the lower and middle categories respectively | | | 1.02–1.39 | −1.08 to −0.70 | 0.72–1.10 | −0.20 to 0.19 |

Model 1, OASIS and Active second stage of labour; Model 2, OASIS and Forceps delivery; Model 3, Active second stage and Forceps delivery; Model 4, all variables combined in one model.
The crude and adjusted odds ratios were estimated using univariable and multivariable ordinal logistic regression analyses, respectively.

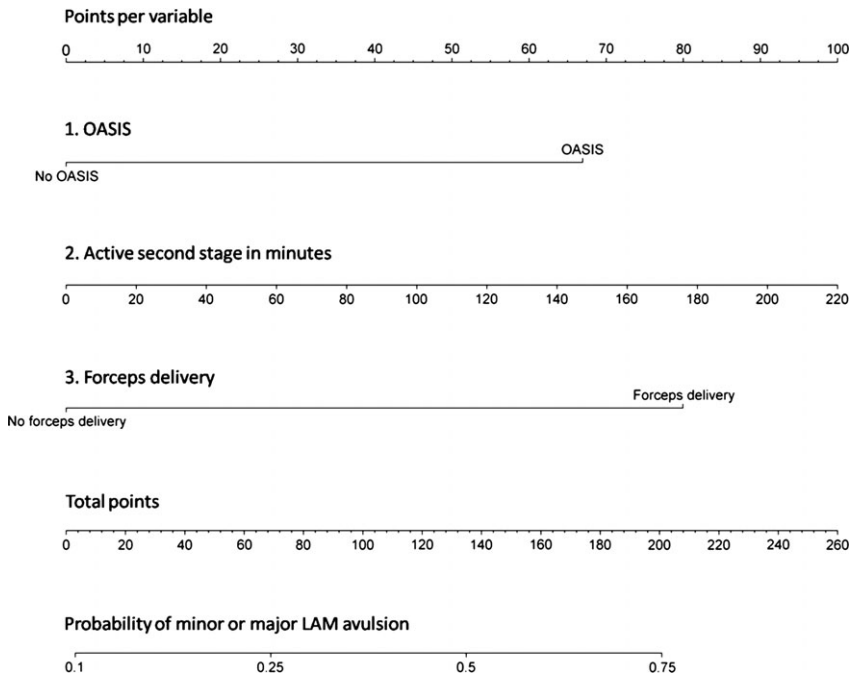


**Figure 3.** Nomogram to estimate an individual woman's risk of having sustained LAM avulsion (minor or major LAM avulsion). For each level of predictive factors, a number of points are allocated at the point scale above. The total points can be calculated by adding the points of each separate parameter. This number represents the chance of having sustained LAM avulsion during the first vaginal delivery. For example, a woman with OASIS (67 points), an active second stage of labour of 120 minutes (55 points) and forceps delivery (79 points) has a total score of 201 points; probability of having sustained minor or major LAM avulsion is 75%. On the other hand, a woman who has been in active second stage of labour for 1 hour (28 points), without OASIS and without forceps delivery, has a 15% chance of having sustained minor or major LAM avulsion.

limitation of our study is its external validity[24] and we acknowledge that our model needs further evaluation and validation in an external model in a different population. Further work could be done on the prediction model in a study that is adequately powered to develop a risk prediction model. However, for such analysis, risk prediction models as ours can help to establish which risk factors to evaluate in a large sample. Furthermore, the $R^2$ remains low even for the best model, and consequently most cases of avulsion are not currently predictable.

### Interpretation

The incidence of LAM avulsion following vaginal delivery found in our study is in keeping with, and adds credence to, other studies revealing a 13–22% incidence using TPUS[7–11] and 18–20% incidence using magnetic resonance imaging[4,6] a few months after delivery. Our incidence of 21% in vaginally parous women seems to be a little higher, which is probably because we incorporated minor LAM avulsion, whereas others only reported major LAM avulsion.[9,10] A higher incidence rate of 36% was found by Dietz and Lanzarone.[5] However, the definition they used was 'a loss of continuity between muscle and pelvic side wall in all volume data sets (rest, squeeze, Valsalva)',[5] which is different from a more recent suggested definition in which TUI at maximum pelvic floor muscle contraction is used to diagnose LAM avulsion.[21] This might explain why later studies[7–11] using the same definition on TPUS as in our study, have found similar incidence rates of LAM avulsion. This highlights the importance of using standardising terms when research is conducted.

Prediction models for LAM avulsion have been developed for women presenting to tertiary urogynaecology clinics with pelvic floor dysfunction.[20,28] The variables they identified cannot be used for comparison in our study population, because our women are much younger and do not have a history of previous prolapse surgery. We therefore sought to create a prediction model related to childbirth only. Ideally, a prediction model should consist of modifiable factors present before childbirth, such as mother's age or body mass index, to allow prevention of LAM avulsion. However, similar to the findings of Shek and Dietz[9] we were unable to demonstrate any influence of the mentioned antenatal variables on the incidence of LAM avulsion. We therefore developed our model to identify women at risk of having sustained LAM avulsion during their first vaginal delivery. Women delivered by caesarean section were excluded, because none sustained LAM avulsion. Our model cannot explain 80% of LAM avulsion. This implies that there must be other factors that contribute to LAM avulsion, which we could not identify in our population. However, this can possibly be explained by our relatively small numbers. Nevertheless, OASIS, prolonged second stage of labour and forceps delivery will certainly put women at a high risk of LAM avulsion, which is in keeping with the literature.[6,8,10,14]

It has been suggested that prediction models should only be presented when they can be clinically applicable.[24] We therefore developed clinically applicable nomograms based on our risk model, to estimate a woman's individual risk of having sustained LAM avulsion, which can be used in a clinical setting. The presented tools will help to target women at high risk of having sustained LAM avulsion. These women can be offered pelvic floor imaging to confirm or exclude a diagnosis of LAM avulsion. If this is confirmed, or if imaging is not available but women are at high risk, they could be advised to initiate intensive lifestyle modification and pelvic floor education to increase pelvic floor muscle strength. As we know, these women are at risk of developing pelvic organ prolapse in the long term[3] and it has been shown that supervised pelvic floor muscle training increases pelvic floor muscle strength in women with pelvic organ prolapse.[29] We speculate that pelvic floor muscle training might prevent or at least delay the onset of symptomatic pelvic organ prolapse in women following childbirth.

Our model can also help focus on obstetric care with a view to minimising the risk of LAM avulsion as repair of the damage soon after delivery has not been shown to be beneficial.[30] The latest NICE guidelines on Intrapartum Care suggest that birth would be expected to take place within 3 hours of the start of active second stage of labour.[31] However, our model shows that an active second stage of labour of 180 minutes could increase the chance of sustaining LAM avulsion. Furthermore, we could aim to reduce the need for instrumental delivery. The RCOG Green-top guideline on operative vaginal delivery provides level one evidence on such a strategy, including continuous support in labour, upright position, minimised use of epidural analgesia and to start oxytocin in second stage of labour.[32] Hands-on training in the choice and technique of vacuum extraction will enhance the risk of success and minimise the use of forceps[32], the main risk factor for LAM avulsion.[6,10,14] However, we acknowledge that, although the length of the second stage is a proxy marker for fetal–maternal disproportion and obstruction, it is not clear that measures to shorten the second stage would reduce the rate of LAM avulsion. Furthermore, the mode of vaginal delivery is likely to be strongly influenced by unmeasured factors relating to obstructed labour. Therefore, the association between forceps and avulsion may be a result of confounding by indication, and may perhaps not be a true causal relationship.

## Conclusion

Twenty-one percent of women sustain LAM avulsion during their first vaginal delivery. Our risk model shows that OASIS, active second stage of labour and forceps delivery are risk factors. We have developed a nomogram that is a novel tool to estimate an individual woman's risk of having sustained LAM avulsion. This nomogram can help us to target postnatal women at risk and offer them pelvic floor education.

### Disclosure of interest

All authors declare no conflicts of interest.

### Contribution to authorship

KWM van Delft contributed to project development, recruitment, data management, data analysis and manuscript writ-

ing. R Thakar contributed to protocol development, project development, data analysis and manuscript editing. AH Sultan contributed to protocol development, project development and manuscript editing. N Schwertner-Tiepelmann contributed to protocol development and recruitment. KB Kluivers contributed to data analysis and manuscript editing. All authors approved the final manuscript.

### Details of ethics approval

This study was approved by the National Research Ethics Service South West London committee (REC 10/H0806/87) on 17 November 2010.

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## Supporting Information

Additional Supporting Information may be found in the online version of this article:

**Table S1.** Demographics and obstetric details in women who have and who have not attended the follow-up visit.

**Table S2.** Univariable ordinal logistic regression analysis, excluding women who delivered via caesarean section ($n = 48$). ■

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# Levator muscle injuries: prediction does not enable prevention

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*Editor's Commentary on 'Levator ani muscle avulsion during childbirth: a risk prediction model'*

Levator muscle injuries at childbirth have been widely researched in recent years with the use of transperineal three-dimensional and four-dimensional ultrasound and magnetic resonance imaging techniques. The current literature presents a variation in the definitions used for levator avulsion resulting in a variation in the reported incidence.

Although several risk factors for levator avulsion have been identified, their predictive role has been unclear.

This is a well-designed prospective cohort study that adds to the body of evidence on levator avulsions at childbirth. The authors aimed to establish the incidence of avulsion in primiparas and subsequently to develop a risk prediction model for such injuries. This has previously been attempted, but it was deemed impossible to achieve antepartum prediction of the risk for avulsion injury (Shek KL et al. *Am J Obstet Gynecol* 2010;202:586 e1–6).

The authors of the current study state that 'there should be a possibility to influence subsequent management based on these predictors' and in agreement with previous research (Shek KL et al. *BJOG* 2010;117:1485–92), they confirmed associations between levator avulsion and intrapartum factors, specifically duration of active second stage, mode of delivery (forceps delivery) and perineal trauma obstetric anal sphincter injuries (OASIS). These have been considered as independent risk factors, although there are well documented associations between them.

The authors of this study admit that prevention of levator injury based on their model is not possible because the predictors were not modifiable variables before childbirth and therefore, based on these results, it is not feasible to recommend interventions to prevent such injuries. Of note, 80% of avulsions cannot be explained by this model, which could be admittedly due to the small size of the study or to other variables that were not included in the model. This raises a question on the calibration of this model and its potential applicability in different populations requires further research.

More recently, it has been shown using magnetic resonance imaging, that bony pelvis dimensions may have a predictive role, because they are also associated with levator injuries (Berger MB et al. *Int Urogynecol J* 2013;24:1377–83). However, the causal direction in this case is not clear, i.e. it is unknown if levator ani avulsions result in changes to the bony pelvis, or if a shorter anterior-to-posterior dimension of the bony pelvis predisposes women to birth trauma resulting in severe levator defects.

A risk prediction model with or without antenatally modifiable factors may indeed allow screening and identification of women who are at high risk of levator injuries and therefore further investigations and interventions can be undertaken postnatally, including pelvic floor rehabilitation.

Risk prediction models have been used in several areas of clinical practice and their role in clinical management algorithms has often been the subject of debate, as to whether they effectively assist in prevention or merely in clinical decision-making. Nevertheless, a robust risk prediction model may assist in clinical management. However, in considering introduction of such tools into clinical practice, the critical issue is how we determine the clinical utility of a model. Validation is essential and statistical measures to evaluate robustness and performance in different populations, such as discrimination and calibration, are recommended.

## Disclosure of interests

The author is a Scientific Editor for *BJOG* and has received honoraria for attendance in scientific meetings by Astellas, Pfizer and Boston Scientific, and an Ethicon Travel Award by the RCOG to visit the University of Michigan, where he participated in research projects with the Pelvic Floor Research Group.