Příloha 1:

Rusavy et al. BMC Pregnancy and Childbirth (2019) 19:207
https://doi.org/10.1186/s12884-019-2359-7

BMC Pregnancy and Childbirth

RESEARCH ARTICLE Open Access

Timing of cesarean and its impact on labor duration and genital tract trauma at the first subsequent vaginal birth: a retrospective cohort study

Zdenek Rusavy[1,2*], Erika Francova[3], Lenka Paymova[1], Khaled M. Ismail[1,2] and Vladimir Kalis[1,2]

Abstract

Background: The objectives of this study were to explore the course of labor and the risk of obstetric anal sphincter injury at the first vaginal birth after cesarean section (fVBAC) in comparison to primiparous vaginal birth (PVB) in women without epidural analgesia and to assess if laboring before the previous cesarean affected these outcomes.

Methods: All fVBACs without epidural analgesia and the subsequent PVBs (controls) between 2012 and 2016 were included in this retrospective cohort study. Data were collected from health records and included maternal demographics, gestational age, and labor details (duration of 1st and 2nd stages, labor induction or augmentation, birthweight, operative vaginal birth, estimated blood loss, extent of childbirth trauma) in both groups as well as cervical dilation at the time of previous cesarean in the fVBAC group. Wilcoxon and Chi-square tests were used for data analyses.

Results: The study comprised 510 women; 255 fVBACs and 255 controls. The majority of fVBACs were after a pre-labor cesarean section – 177 (69.4%). There was a statistically significant difference in the recorded duration of first stage between the fVBACs and controls (289 vs. 347 min respectively, $p < .001$). Women were less likely to have an intact perineum in the fVBAC group (29.8 vs. 43.1%, $p < 0.01$), however, there was no statistically significant difference in anal sphincter injury rates between both groups (2.3 vs. 1.9%, $p = 0.76$). The groups differed in rates of cervical tears requiring suturing (21.2 vs. 12.9%, $p = 0.01$). On further subgroup analysis, the duration of first stage of labor was shorter in women who previously had a caesarean section late in labor (≥ 8 cm cervical dilatation) compared to a pre-labor cesarean section, however, there were no differences in other outcomes.

Conclusion: Compared to primiparous women having a vaginal birth, women having their first vaginal birth after a cesarean section have a shorter 1st stage of labor (particularly if the cesarean was performed in advanced labor), a higher risk of sustaining cervical lacerations and perineal trauma. However, there was no difference in the risk of sustaining obstetric anal sphincter injuries between the study groups.

Keywords: Vaginal birth after cesarean, Cervical laceration, Childbirth trauma, OASI, Perineal tear

* Correspondence: rusavyz@fnplzen.cz
[1]Department of Gynecology and Obstetrics, Faculty of Medicine in Pilsen, Charles University, Prague, Czech Republic
[2]Biomedical Center, Faculty of Medicine in Pilsen, Charles University, Alej Svobody 80, 304 60 Plzen, Czech Republic
Full list of author information is available at the end of the article

Background

Cesarean delivery rates are gradually increasing worldwide both in developed and undeveloped countries [1]. Reduction of Cesarean Section (CS) rates has become a priority for several health authorities globally, which might have contributed to the recently observed plateauing of this rate in some countries [2, 3]. Previous uterine scar is the most common single indication for repeat cesarean section contributing to almost a third of all cesarean deliveries in the USA [4]. Vaginal birth after cesarean section (VBAC) represents one of the effective interventions to reduce CS rates [5]. Moreover, it has been demonstrated that the use of standardized and effective protocols to inform intrapartum care and decision making in VBACs is associated with low complications and acceptable success rates [6]. However, some authors warn about the association of such practice with low success rates and relatively high risk of adverse events [7].

Although an extensively studied subject, a limited number of studies focused on pelvic floor trauma after fVBAC [8–11]. Since childbirth trauma may lead to a number of pelvic floor disorders with severe consequences, women considering a VBAC should be aware of the risk of injury during their vaginal birth. Additionally, data regarding risk of pelvic floor damage in relation to a VBAC are conflicting. While some authors reported increased obstetric anal sphincter injuries (OASIs) rates in women having their first vaginal birth after cesarean (fVBAC) [8, 10], more recent studies reported rates that are comparable to those reported in primiparous vaginal births (PVBs) [9, 11, 12] with higher rates only after previous emergency cesarean section [13]. It has been suggested that the higher risk of pelvic floor trauma is secondary to higher rates of operative vaginal birth [8].

Another possible explanation is related to the reduced cervical resistance to dilatation, and hence faster progress in labor, in parous women [14], which when coupled with a nulliparous pelvic floor may lead to higher risk of pelvic floor damage, nevertheless, this has not been properly studied [8, 15]. Therefore, the main aim of this study was to compare our primary endpoint of OASIs rate and the secondary endpoints of duration of labor and other genital tract tears in women having their fVBAC to primiparous controls who had a vaginal birth. As a secondary matter, we hypothesized that labor would be shorter and the risk of childbirth trauma would be higher in women, in whom the previous cesarean section was performed in advanced labor rather than pre-labor. Hence, we wanted to explore if laboring prior to the previous CS impacted on these outcomes.

Methods

This is a retrospective cohort study comparing the duration of labor and genital tract trauma in women after their fVBAC compared to primiparous women who had a vaginal birth. All singleton, term (≥37th week of gestation) fVBAC who delivered at the Department of Gynecology and Obstetrics, Medical Faculty and University Hospital in Pilsen, Charles University from January 2012 till December 2016 were included in the study (Additional file 1: Figure S1). The singleton term PVB subsequent to each of the included fVBAC formed the control cohort. The controls were selected on a one-to-one ratio to the VBAC patients. Women who had a vaginal birth prior to the index cesarean section, and pregnancy complicated by intrauterine fetal death, fetal anomalies, stillbirth and those who had intrapartum epidural analgesia were excluded from the study. Since the main aim of the study was to assess the influence of the previous labor process, women with epidural analgesia were excluded as it is considered a major confounding factor for labor duration and perineal trauma [16–18]. The use of oxytocin for labor induction or augmentation or any form of pharmacologic or mechanical cervical ripening was not considered as exclusion criteria. Prostaglandins were never used for this purpose in fVBAC. The hospital clinical database was used to identify eligible women and their individual health records were used for data collection.

In our unit, the perineum is always assessed by a doctor after any type of vaginal birth and any identified trauma is classified in line with the RCOG guideline [19]. Bidigital vaginorectal examination of the anal sphincter is performed routinely in case of a suspected second degree or higher tear and episiotomy. All episiotomies were either mediolateral or lateral and cut on the woman's right side [20] Manual perineal protection is routinely performed in our hospital for all vaginal births as previously reported [21, 22]. According to the routine practice at our institution, all women having a vaginal birth have a speculum examination immediately after the delivery of the placenta and any cervical lacerations and vaginal tears ≥5 cm in length were recorded. A vaginal tear was defined as any tear in the vaginal wall, regardless of its location or whether it was isolated or concomitant with a 1st degree perineal tear. Minimal perineal trauma was defined as non-bleeding laceration of the skin, not requiring a suture. The beginning of the first stage of labor was defined as the onset of regular contractions leading to cervical effacement or dilatation. The beginning of the second stage was defined as full dilation of the cervix. The durations of the first and the second stage of labor are recorded in minutes. Additionally, the maximum cervical dilation reached at the time of the previous cesarean section was investigated in the fVBAC group. Other institutions were asked to provide this information had the woman had her cesarean birth elsewhere. Women were excluded from the subgroup analysis if such information was not available. A subanalysis within the fVBAC group was performed based on whether the previous CS was performed pre-labor (fVBAC-PL) or in advanced labor (fVBAC-AL). This stratification was based on whether the cervix was not effaced or ≥ 8 cm at the time the decision was made to perform the CS respectively. Data were de-identified upon data collection and statistical analyses were performed using SAS 9.4 (SAS Institute Inc., Cary, NC, USA) statistical software. The comparison of variables between the two study groups with respect to their distribution of normality was performed using non-parametric ANOVA (2-sample Wilcoxon test). Categorical variables were analyzed using the χ^2 test and described by contingency tables, $p < 0.05$ was considered statistically significant. Multivariate regression controlling for age and BMI was additionally performed for all statistically significant differences. The study was approved by the University Hospital Pilsen, Charles University ethics committee (Date of approval: 12-03-2015). Since this study was a retrospective review of electronic medical records, informed consent from the individual patients was not required.

Results

A total of 1565 (9.7%) women with a history of CS were admitted for delivery at our referral center during the study period. A repeat CS was performed in 1189 women (76.0%) and 376 (24.0%) had a VBAC. Of these, 255 (67.8%) women were included in the study based on the *a priori* inclusion and exclusion criteria (177 (69.4%) fVBAC-PL, 31 (12.2%) fVBAC-AL) (Additional file 1: Figure S1). The control group comprised 255 PVBs who fulfilled the inclusion and exclusion criteria. The mean interval between the cesarean section in women from the VBAC group was 3.6 years.

Apart from age at the time of birth, there were no differences between the two groups in their demographic characteristics, gestational age or birthweight (Table 1). The first stage of labor was significantly shorter in the fVBAC group compared to controls (289 vs. 347 min, $p < .001$) (Table 1). A statistically significantly shorter first stage of labor in fVBAC-AL subgroup compared to fVBAC-PL (230 vs. 296 min, $p = .007$) was observed (Table 2). There were no differences in the duration of the second stage of labor, oxytocin use for labor augmentation or operative vaginal birth rates between the study groups or in the within group subanalysis, however, there were more induced labors in our control cohort (Table 1 and Table 2).

Women in the fVBAC group were less likely to have an intact perineum compared to PVBs (29.8 vs. 43.1%, $p = .002$), but no statistically significant difference in OASIs rates were observed (2.4% vs. 1.9%, $p = .761$) (Table 3). When comparing the fVBAC subgroups with controls for rates of 1st and 2nd degree perineal tears, the difference was only significant between fVBAC-PL and controls (15.8% vs. 9.0%, $p = .019$ and 14.7% vs. 7.8%, $p = .022$ respectively). While, the only significant difference between the two fVBAC subgroups was in episiotomy rate with it being higher in the fVBAC-AL one (61.3% vs. 38.4%, $p = .017$) (Table 4).

There were no statistically significant differences in rates of vaginal tears in any of the between or within group analysis, however, cervical lacerations ≥1 cm were more frequent in the fVBAC group compared to controls (21.2% vs. 13.0%, $p = .014$). When comparing fVBAC subgroups with controls, a similar pattern was only observed between the fVBAC-PL vs control but not the fVBAC-AL vs control subanalysis (21.5% vs. 13.0%, $p = .027$ and 9.7% vs. 13.0%, $p = .779$ respectively). Nonetheless, the difference between cervical tears between the two fVBAC subgroups did not reach statistical

Table 1 Delivery characteristics

Variable	PVB (Controls) *n* = 255	fVBAC *n* = 255	*p*-value
Age [years]; mean ± SD	28.6 ± 4.8	31.7 ± 4.0	<.001[a]
BMI; mean ± SD	28.5 ± 4.8	29.1 ± 5.1	.215[a]
Gestational age [weeks]; mean ± SD	39.8 ± 1.4	39.7 ± 1.3	.107[a]
Birthweight [g]; mean ± SD	3260.6 ± 424.9	3295.6 ± 429.8	.369[a]
1st stage duration [min]; mean ± SD	347.0 ± 150.5	289.1 ± 128.1	<.001[a]
2nd stage duration [min]; mean ± SD	23.8 ± 20.6	20.8 ± 15.7	.146[a]
Instrumental delivery; n (%)	10 (3.9)	12.0 (4.7)	.663[b]
Estimated blood loss [ml]; mean ± SD	387.3 ± 185.9	391.0 ± 158.8	.039[a]
Labor induction; n (%)	34 (13.3)	3 (1.2)	<.001[b]
Oxytocin use for labor augmentation; n(%)	111 (43.5)	110 (43.1)	.929[b]

fVBAC First vaginal birth after cesarean
PVB Primiparous vaginal birth
[a]non-parametric ANOVA (2-sample Wilcoxon test)
[b]Chi-square Test

Table 2 fVBAC subgroups - delivery characteristics

Variable	fVBAC-PL *n* = 177	fVBAC-AL *n* = 31	*p*-value
Age [years]; mean ± SD	31.8 ± 4.1	31.9 ± 3.3	.988[a]
BMI; mean ± SD	29.5 ± 5.7	28.2 ± 3.0	.570[a]
Gestational age [weeks]; mean ± SD	39.7 ± 1.3	39.4 ± 1.3	.218[a]
Birthweight [g]; mean ± SD	3295.5 ± 408.4	3258.7 ± 269.3	.637[a]
1st stage duration [min]; mean ± SD	296.0 ± 132.7	230.0 ± 104.2	.007[a]
2nd stage duration [min]; mean ± SD	20.9 ± 15.8	22.5 ± 18.3	.806[a]
Instrumental delivery; n (%)	6 (3.4)	2 (6.5)	.340[b]
Estimated blood loss [ml]; mean ± SD	388.7 ± 166.0	433.9 ± 194.7	.077[a]
Labor induction; n (%)	1 (0.6)	1 (3.2)	.277[b]
Oxytocin use for labor augmentation; n(%)	76 (42.9)	11 (35.5)	.555[b]

fVBAC-PL first vaginal birth after pre-labor cesarean
fVBAC-AL first vaginal birth after advanced labor cesarean
a non-parametric ANOVA (2-sample Wilcoxon test)
[b]Fisher's exact test

significance, which could be a reflection of the relatively small sample size of the fVBAC-AL subgroup. All observed differences remained statistically significant on multivariate analysis controlling for maternal age and BMI.

Discussion

The findings of this study demonstrate that women having their fVBAC are not similar to PVBs with regards to several labor and birth outcomes. Indeed, our hypothesis, that women having the fVBAC would have a shorter first stage of labor compared to PVBs was confirmed. Furthermore, this difference was more striking in women who were advanced in labor prior to having their CS. In spite of identifying a higher risk of spontaneous perineal tears and episiotomy in general in the fVBAC cohort compared to controls, there were no differences in OASIs between the two groups. Finally, on subgroup analysis the risk of cervical laceration was almost doubled in the subgroup of fVBACs who did not labor before compared to PVBs. Contrary to previous studies, we did not find increased OASIs rate [8, 10]. It is possible that the reason for this is that, unlike other studies, the birthweight and operative vaginal birth rates, which are known risk factors for OASIs, were comparable between our two study groups [8, 15]. Another possible reason for the low OASIs rate could be related to the strong research focus in our department on reducing the risk childbirth-related pelvic floor trauma and the staff receive regular training related to intrapartum interventions for the primary prevention of OASIs. The method of assessment of perineal trauma is not fully described in most articles that have suggested a higher OASIs rate following VBAC and it is possible that after VBAC women were subject to a more systematic assessment or the examination was performed by a more experienced accoucher and either could have enhanced the detection rate [23]. In our unit, the perineum is always inspected using the recommended bidigital vaginorectal examination by an experienced obstetrician or midwife [19]. Finally, it is important to highlight that operative vaginal

Table 3 Childbirth trauma

Variable	PVB (Controls) *n* = 255	fVBAC *n* = 255	*p*-value
Intact / minimal perineal trauma; n (%)	110 (43.1)	76 (29.8)	.002[a]
1st degree perineal rupture; n (%)	23 (9.0)	35 (13.7)	.122[a]
2nd degree perineal rupture; n (%)	20 (7.8)	33 (12.9)	.059[a]
3rd degree perineal rupture; n (%)	5 (1.9)	6 (2.4)	.761[a]
Episiotomy; n (%)	102 (40.0)	109 (42.8)	.579[a]
Important vaginal tear ≥5 cm; n (%)	32 (12.5)	45 (17.3)	.136[a]
Cervical laceration ≥1 cm; n (%)	33 (12.9)	54 (21.2)	.014[a]

fVBAC First vaginal birth after cesarean
PVB Primiparous vaginal birth
[a]Chi-square Test

Table 4 fVBAC subgroups - childbirth trauma

Variable	fVBAC-PL $n = 177$	fVBAC-AL $n = 31$	*p*-value
Intact / minimal perineal trauma; n (%)	53 (29.9)	5 (16.1)	.132[b]
1st degree perineal rupture; n (%)	28 (15.8)	3 (9.7)	.584[b]
2nd degree perineal rupture; n (%)	26 (14.7)	4 (13.0)	1.00[b]
3rd degree perineal rupture; n (%)	4 (2.3)	1 (3.2)	.558[b]
Episiotomy; n (%)	68 (38.4)	19 (61.3)	.017[a]
Important vaginal tear ≥5 cm; n (%)	32 (18.1)	4 (13.0)	.612[b]
Cervical laceration ≥1 cm; n (%)	38 (21.5)	3 (9.7)	.149[b]

fVBAC-PL first vaginal birth after pre-labor cesarean
fVBAC-AL first vaginal birth after advanced labor cesarean
[a]Chi-square Test
[b]Fisher's exact test

birth rates are generally very low in the Czech Republic with a preference towards the use of ventouse because of its associated lower risk of OASIs compared to forceps [24].

Intrapartum cervical lacerations are relatively common with an overall incidence widely ranging from 25 to 90% [25], most of these are detectable only on routine cervical examination after a vaginal birth. Although a routine policy in our unit, this practice is not adopted in the majority of maternity units globally either because it is considered an uncomfortable intervention for the women or because of the perceived lack of association between small cervical laceration and poor outcomes. We appreciate that the cervical laceration rates described in the present study are high in comparison to previously published data [25–27], however, this might be a reflection of the severity of reported lacerations where other studies focused on more severe cervical lacerations that were associated with severe postpartum hemorrhage or involvement of other structures like the lower uterine segment or the vaginal wall [25]. Cervical lacerations of 1 cm and more are considered clinically significant and sutured at our institution. This threshold was therefore selected for comparison. Investigating the reason for the observed high cervical tear rates was beyond the scope of our study and hence our proposed reasoning for this finding is only speculative. It is plausible that the higher risk of cervical laceration in the VBAC group could be linked to non uniform reduction in cervical tissue resistance up to the degree to which the cervix has previously dilated causing a mismatch between the strength of uterine contractions and cervical resistance resulting in its traumatization. However, this explanation does not support the finding that on subgroup analysis the difference in laceration was only significant when the PVB versus fVBAC-PL comparison.

Our results regarding the difference in labor duration are in contradiction with previously published studies. A secondary analysis of data from a Consortium on Safe Labor [4] study has shown that labor duration for a trial of labor after cesarean was slower compared to nulliparous labor [28]. Other studies described comparable first stage and shorter second stage of labor duration in VBAC [12, 15]. We do not have a clear explanation for these inconsistencies and we can only speculate that the difference could be a result of the exclusion of women who had epidural analgesia or the relatively low operative vaginal birth rates in our study. We identified a higher episiotomy rate in our fVBAC-AL compared to fVBAC-PL group. There is no clear explanation of this observation because the majority of episiotomies are performed at the accoucher's discretion and the indication for the episiotomy is not routinely documented. On detailed review of the hospital notes of women who had an episiotomy in both subgroups, 21/68 episiotomies in fVBAC PL group and 5/19 episiotomies in the fVBAC-AL had evidence of suspected fetal distress, which might have been the indication for the episiotomy, nevertheless this does not explain the findings. It is possible that this difference is a reflection of a faster progressing labor and "nulliparous" perineum. Interestingly, a recent study reported an increased risk of OASIs in women delivering vaginally after emergency compared to elective caesarean sections and episiotomy appeared to be protective [13]. The increased rate of episiotomy in our fVBAC-AL group might explain the comparable OASIs rates in our study.

The major strength of the present study lies in its design. Unlike most previous studies on this topic, this is not a registry analysis. Hand abstracting of the results allowed for looking at individual health records to obtain more precise and detailed data. Additionally, since all women had their fVBAC in the same institution, the variation in obstetric practice and perineal management during labor would have been minimal. Another strength of the study is that the study groups were well defined where we did not include any women with previous vaginal deliveries or those who used epidural analgesia, both are established confounders to the outcomes of interest. Moreover, we were able to perform some preliminary analyses on the impact of the type of CS performed on the course of subsequent VBAC. In this context, we intentionally only included women who had a planned CS with a non-effaced cervix and those who had an emergency CS after being advanced in labor because we hypothesized that if there was a difference in any of these outcomes it will be more evident between these two distinct clinical categories. The major limitation of the study is certainly the number of women in the fVBAC-AL group, however, the size still allowed a proper statistical analysis. Another limitation is the absence of ultrasound assessment in the follow-up. The assessment of the perineal trauma was performed clinically after the delivery. It was suggested that more than a half of OASIs may remain undiagnosed by the attending obstetrician or midwife, providing rectal examination is not performed after the delivery [23]. However, this examination is part of our routine practice. Nonetheless, in this retrospective analysis we were unable to objectively assess and quantify anal sphincter and levator ani injuries using ultrasound in follow-up. This remains an objective for future studies. Finally, although the exclusion of women who used an epidural allowed a more robust evaluation of our hypotheses, it limits extrapolating our study findings to women opting to use epidural analgesia for their fVBAC.

Conclusions

In conclusion, compared to primiparous women having a vaginal birth, women having their first vaginal birth after a cesarean section without epidural analgesia have a shorter 1st stage of labor. This difference is more pronounced if the woman's previous cesarean was performed in advanced labour. Women having their fVBAC seem to have a higher risk of sustaining cervical lacerations and perineal trauma. However, the risk of anal sphincter injuries does not seem to be increased which is reassuring for women considering a trial of VBAC.

Additional file

Additional file 1: Figure S1. Identification of fVBAC study participants. (DOCX 26 kb)

Abbreviations

CS: cesarean section; fVBAC: first vaginal birth after cesarean; fVBAC-AL: first vaginal birth after advanced labor cesarean; fVBAC-PL: first vaginal birth after pre-labor cesarean; OASI: obstetric anal sphincter injury; PVB: primiparous vaginal birth; VBAC: vaginal birth after cesarean

Acknowledgements

Not applicable.

Authors' contributions

ZR designed the study, participated on data interpretation and wrote the manuscript. EF performed the chart review and hand abstracted the data, she participated on manuscript editing. LP participated on data collection, analysis and interpretation. KMI participated in data interpretation and manuscript writing and editing. VK helped with the study design, data interpretation and edited the manuscript. All authors read and approved the final manuscript.

Funding

The study was funded by National Sustainability Program I (NPU I) Nr. LO1503 provided by the Ministry of Education Youth and Sports of the Czech Republic and Charles University Research Fund (Progres Q39). The funders were not directly involved in the study design, collection, analysis and interpretation of the data and writing of the manuscript.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available in the Figshare online open access repository, https://doi.org/10.6084/m9.figshare.7732898

Ethics approval and consent to participate

The study was approved by the University Hospital Pilsen, Charles University ethics committee (Date of approval: 12-03-2015). Since this study was a retrospective review of electronic medical records, informed consent from the individual patients was not required by the ethics committee.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Department of Gynecology and Obstetrics, Faculty of Medicine in Pilsen, Charles University, Prague, Czech Republic. [2]Biomedical Center, Faculty of Medicine in Pilsen, Charles University, Alej Svobody 80, 304 60 Plzen, Czech Republic. [3]Department of Obstetrics and Gynecology, Ceske Budejovice Regional Hospital, Ceske Budejovice, Czech Republic.

Received: 19 February 2019 Accepted: 12 June 2019
Published online: 20 June 2019

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Příloha 2:

Mají ženy rodící vaginálně po předchozím císařském řezu větší riziko avulzního poranění musculus levator ani?

Vaginal birth after cesarean section and levator ani avulsion

Paymová L.[1, 2], Kališ V.[1, 2], Šperlová T.[2], Nová V.[3], Rušavý Z.[1, 2]

[1] Gynekologicko-porodnická klinika FN a LF UK, Plzeň, přednosta doc. MUDr. Z. Novotný CSc.
[2] Lékařská fakulta Univerzity Karlovy, Plzeň
[3] Gynekologické oddělení Nemocnice Hořovice, NH Hospital a.s., primář MUDr. L. Teslík, I.F.E.P.A.G.

ABSTRACT

Objective: The aim of the study was to assess the risk of levator ani avulsion in vaginal birth after cesarean section (VBAC).
Design: Observational cohort study.
Settings: Department of Gynecology and Obstetrics, Medical Faculty, Charles University and University Hospital Pilsen.
Methodology: In this observational study we included every secundiparous woman after her first VBAC at term from 2012 till 2016 at our tertiary center. Women after repeated VBAC, delivering preterm or women after stillbirth were excluded. In addition, we enrolled random primiparous women as a control group. The women were invited for a 4D pelvic floor ultrasound for acquisition of a 4D volume of their pelvic floor at rest and during Valsalva. The levator avulsion was diagnosed off-line from the volumes of the pelvic floor during contraction, area of the urogenital hiatus was measured at rest and Valsalva. The laterality of the avulsion was additionally noted. The cohorts were then compared using Chi-square test and Wilcoxon two-sample test according to the distribution of normality, p-value < 0.05 was considered statistically significant.
Results: Total of 255 women after VBAC in the study period were enrolled in the study based on the inclusion and exclusion criteria. All of them were contacted, 98 (38.4%) came for the examination. The main reason for additional exclusion was another pregnancy or delivery and lack of interest in the study. In addition, 69 random women after first vaginal delivery were examined as a control group. No statistically significant differences in group characteristics apart from the age at the time of birth (32.7 vs. 30.0 years, $p < 0.05$) were found between VBAC and the Controls. The difference in levator avulsion and ballooning rate did not reach statistical significance. The variance of area of the urogenital hiatus in rest and during Valsalva was similar in both groups.
Conclusion: VBAC is not associated with an increased risk of levator ani avulsion compared to primaparous women.

KEYWORDS

4D transperineal ultrasound, musculus levator ani, avulsion injury, VBAC, pelvic floor

SOUHRN

Cíl: Srovnat incidenci avulzního poranění m. levator ani (MLA) u žen po prvním vaginálním porodu po předchozím císařském řezu (VBAC) a u prvorodiček.
Typ studie: Observační studie.
Název a sídlo pracoviště: Gynekologicko-porodnická klinika Fakultní nemocnice Plzeň.
Metodika: Do studie byly zahrnuty všechny druhorodičky po termínovém VBAC, které porodily mezi roky 2012 a 2016. Ženy po opakovaném VBAC, po předčasnému porodu a po porodu mrtvého plodu byly vyřazeny. Z náhodně vybraných prvorodiček byla vytvořena kontrolní skupina. Všechny ženy byly pozvány k vyšetření 4D transperineálním ultrazvukem. V případě jejich souhlasu jim byl nasnímán 4D volum pánevního dna při kontrakci a při Valsalvově manévru. Ten byl následně off-line zhodnocen k vyšetření avulze MLA a plochy urogenitálního hiátu. Byla zaznamenána lateralita případného avulzního poranění. Obě skupiny byly mezi sebou porovnány pomocí $\chi 2$ testu a Wilcoxonova two-sample testu, hodnota $p < 0{,}05$ byla stanovena jako statisticky významná.

Výsledky: V daném časovém období vaginálně porodilo a vstupní kritéria splnilo celkem 255 žen po císařském řezu. Všechny z nich byly kontaktovány, k vyšetření se dostavilo 98 žen. Hlavním důvodem pro neúčast ve studii bylo další těhotenství a porod po VBAC. Kontrolní skupinu prvorodiček tvořilo 69 žen. Kromě věku rodiček v době porodu (32,7 vs. 30 roků, p < 0,05) nebyl zaznamenán žádný statisticky významný rozdíl v charakteristice obou skupin. Rozdíl v četnosti avulzního poranění i balooningu ani v jedné z obou skupin nedosáhl statistické významnosti. Změna plochy urogenitálního hiátu při Valsalvově manévru a v klidu byla pro obě skupiny rodiček srovnatelná.
Závěr: Ženy s císařským řezem v anamnéze rodící poprvé vaginálně nemají zvýšené riziko avulzního poranění MLA proti prvorodičkám.

KLÍČOVÁ SLOVA

4D transperineální ultrazvuk, musculus levator ani, avulzní poranění, VBAC, pánevní dno

MUDr. Lenka Paymová, e-mail: paymoval@fnplzen.cz
Čes. Gynek., 2020, 85, č. 5, s. 296–301

ÚVOD

Incidence císařských řezů celosvětově stoupá a znepokojuje porodníky vyspělých států [1], kteří se pomocí různých strategií a postupů snaží tento fakt zvrátit [4]. Až jedna třetina z celkového počtu prováděných císařských řezů v USA je indikována pro předchozí císařský řez v anamnéze [28], a proto se jeví vaginálně vedený porod po předchozím císařském řezu (VBAC) jako efektivní způsob vedoucí ke snížení incidence císařských řezů [13].

Poranění musculus levator ani (MLA) je relativně častou komplikací vaginálně vedeného porodu. Jeho incidence se pohybuje mezi 13–36 % [5, 9]. Jde o poranění, které je velmi obtížně diagnostikovatelné a zároveň prakticky neošetřitelné. Vede ke snížené kontraktilitě pánevního dna a rozšíření urogenitální hiátu – balooningu [7]. Je spojeno se zvýšeným rizikem sestupu pánevních orgánů [8] se všemi jeho důsledky a negativním vlivem na kvalitu života ženy, včetně její sexuality [24]. Poranění navíc zvyšuje riziko selhání rekonstrukčních operací sestupu pánevních orgánů [20]. Mezi hlavní rizikové faktory avulzního poranění MLA patří věk rodičky, primiparita [17], porodní váha novorozence [23], obvod jeho hlavičky, délka druhé doby porodní [26] a klešťový porod [25]. Vaginální porod po předchozím císařském řezu je podle některých autorů spojen se zvýšeným rizikem poranění perinea [14, 19] a děložního hrdla [21]. Tento fenomén bývá vysvětlován kombinací rychleji progredujícího porodu, většího plodu a silnější kontraktility dělohy u vícerodičky ve spojení s pánevním dnem nerodivší ženy [15, 21].

Ve světové literatuře existuje řada odborných studií, které se zabývají hodnocením avulzního poranění MLA po vaginálním porodu [2, 12], srovnávají jeho incidenci s incidencí u nerodivších žen [3, 27] nebo u žen po primárním i urgentním císařském řezu [18]. Incidence poranění MLA při vaginálním porodu po císařském řezu studována nebyla. Cílem předkládané studie bylo zhodnotit četnost avulzního poranění MLA u žen po VBAC.

MATERIÁL A METODIKA

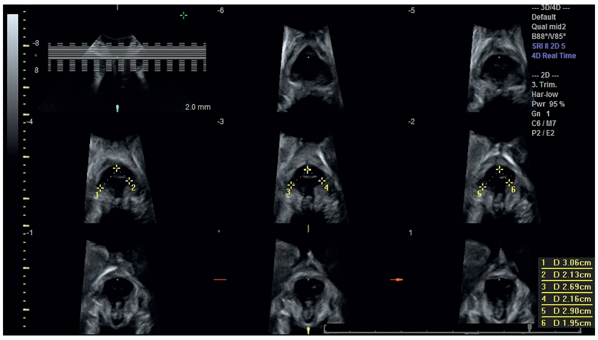
Do naší observační studie jsme zahrnuli všechny druhorodičky s císařským řezem v anamnéze, které porodily poprvé vaginálně v termínu mezi roky 2012 až 2016 na Gynekologicko-porodnické klinice FN Plzeň. Ženy po opakovaném VBAC, po porodu mrtvého plodu nebo plodu s fetálními anomáliemi byly ze studie vyřazeny. Z náhodně vybraných prvorodiček jsme vytvořili kontrolní skupinu splňující výše uvedená kritéria. Použití oxytocinu, ať už v rámci indukce porodu, nebo augmentace slabých kontrakcí děložních, nebylo vyřazujícím kritériem. Stejně jako použití prostaglandinů nebo jiných mechanických metod zrání děložního hrdla. Na našem pracovišti v případě VBAC prostaglandiny nepoužíváme.

Vybrané ženy byly telefonicky kontaktovány a byla jim navržena spolupráce ve studii. Před zařazením do studie ženy podepsaly informovaný souhlas a poté jim bylo vyšetřeno pánevní dno pomocí 4D transperineálního ultrazvuku. Ženy byly vyšetřovány v supinační poloze, s prázdným močovým měchýřem, pomocí přístroje GE Voluson E8 (GE Kretz Medizintechnik Zipf, Rakousko) s ultrazvukovým paprskem 4–8 MHz s akvizičním úhlem 85 stupňů. Volumy pánevního dna byly snímány v rovině minimálního rozměru urogenitálního hiátu, která je ve střední sagitální rovině ohraničena hyperechogenitou zadní stěny spony stydké a hyperechogenitou přední hranice MLA.

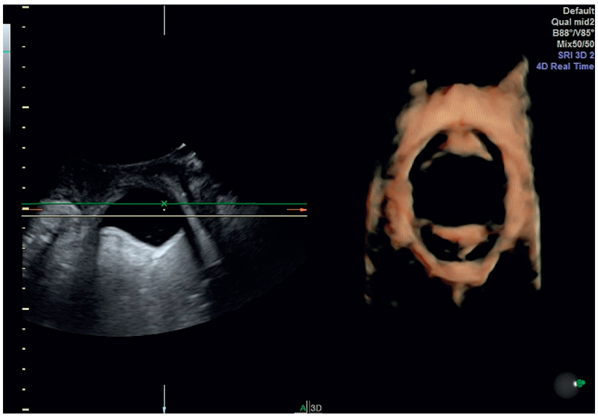
Vyhodnocení přítomnosti avulze MLA za kontrakce a měření plochy urogenitálního hiátu v klidu a při Valsalvově manévru z nasnímaných volumů bylo provedeno off-line pomocí software 4D View (obr. 1). Nasnímané 4D volumy při maximální kontrakci svalů pánevního dna byly použity k hodnocení avulze MLA. Pomocí tomografických řezů v intervalu 2,5 mm byla vyšetřena oblast 5 mm pod a 12,5 mm nad rovinou minimální plochy urogenitálního hiátu tak, aby byl zahrnut kompletně i m. puborectalis. Avulze MLA byla diagnostikována v případě potvrzení abnormální inzerce MLA ve třech centrálních řezech [11], což odpovídá vzdálenosti úponu levátoru ke stydké kosti od středu uretry větší než 25 mm (obr. 2). Hodnotili jsme také 4D volum pánevního dna při maximálním Valsalvově manévru, protože velikost jeho plochy velmi úzce koreluje s rizikem vzniku poklesu pánevních orgánů [10]. Balooning byl definován jako plocha hiátu při maximálním Valsalvově manévru nad 25 mm^2 (obr. 3).

Obecné charakteristiky pacientek (věk, BMI, gestační stáří) stejně jako informace o průběhu porodů (indukce, augmentace, trvání jednotlivých dob porodních, porodní váha novorozence) byly vyhledány v nemocniční databázi. V nepo-

Obr. 1 3D rekonstrukce svalů pánevního dna se zobrazením urogenitální hiátu



Obr. 2 Sonografická tomografie (TUI) a hodnocení avulze MLA ve třech centrálních snímcích pomocí vzdálenosti levator-urethra gap



Obr. 3 3D rekonstrukce svalů pánevního dna při Valsalvově manévru a rozšíření urogenitální hiátu (balooning)

slední řadě nás zajímalo, v jaké fázi porodu byl proveden předcházející císařský řez. Za účelem dalšího hodnocení jsme rodičky rozdělili do následujících tří skupin. Skupina A byla skupina po elektivním císařském řezu, skupina B měla císařský řez během probíhajícího vaginální porodu do branky 8 cm, skupina C na nálezu branky 8 cm a vyšším.

Získaná data byla zpracována pomocí statistického softwaru SAS 9.4 (SAS Institute Inc., Cary, NC, USA). Srovnání proměnných mezi skupinami bylo provedeno pomocí Wilcoxonova testu (neparametrická ANOVA) či Fisherovým exaktním testem podle rozložení normality. Kategorické proměnné byly porovnány pomocí kontingenčních tabulek. Hladina statistické významnosti byla určena jako hodnota $p < 0,05$. Studie byla schválena etickou komisí FN a LF UK v Plzni (číslo 92/2017).

VÝSLEDKY

V daném časovém období porodilo a vstupní kritéria do studie splnilo celkem 255 žen po VBAC. Všechny byly telefonicky kontaktovány a k vyšetření se dostavilo 98 (38,4 %) z nich. Hlavním důvodem pro dodatečné vyloučení pacientky ze studie bylo právě probíhající těhotenství či již dříve proběhlý další porod, dále pak nesouhlas se zařazením do studie. Kontrolní skupinu náhodně vybraných prvorodiček tvořilo 69 (41 %) žen. Časový odstup ultrazvukového vyšetření od vaginálního porodu činil v průměru 33 měsíců. Charakteristiku obou hlavních skupin vyšetřovaných pacientek shrnuje tabulka 1. Ženy v obou skupinách rodily průměrně ve 39. týdnu gravidity. Ženy po VBAC byly v době porodu starší (32,7 let vs. 29,9 let, $p < 0,0001$) a měly statisticky významně kratší trvání první (279,6 min. vs. 344,8 min, $p = 0,007$) i druhé doby porodní (21,2 min. vs. 35,3 min., $p = 0,004$). Ve skupině rodiček po

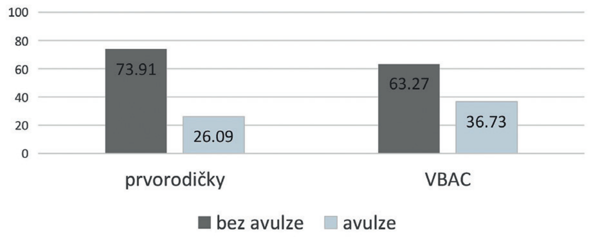
Tab. 1 Charakteristika porovnávaných skupin pacientek v souboru

Charakteristika	Prvorodičky	VBAC	p-value
	n = 69	n = 98	
Věk; průměr ± SD	**29,9 ± 4,6**	**32,7 ± 3,5**	**<0,0001***
BMI; průměr ± SD	29,7 ± 5,7	28,9 ± 4,2	NS*
Gestační stáří [týdny]; průměr ± SD	39,5 ± 1,2	39,6 ± 1,2	NS*
Porodní hmotnost [g]; průměr ± SD	3329,4 ± 433,9	3345,3 ± 402,1	NS*
Trvání I. DP [min]; průměr ± SD	**344,8 ± 153,0**	**279,6 ± 116,1**	**0,007***
Trvání II. DP [min]; průměr ± SD	**35,3 ± 34,0**	**21,2 ± 16,5**	**0,004***
Operativní porod; n (%)	3 (4,4)	2 (2,1)	NS**
Indukovaný porod;n (%)	**11 (15,9)**	**0 (0)**	**<0,0001****
Medikamentózní porod; n (%)	32 (46,4)	39 (39,8)	NS**

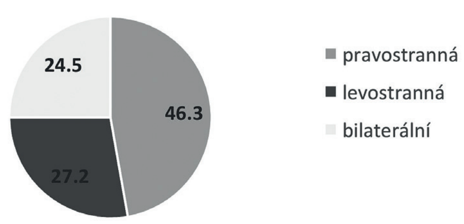
* Wilcoxon Two Sample test, ** Fisher´s Exact Test, SD směrodatná odchylka, NS statisticky nevýznamná hodnota

předchozím císařském řezu nebyla zaznamenána žádná indukce porodu. V ostatních parametrech (BMI rodičky, porodní hmotnost novorozence, frekvence operativního ukončení porodu, augmentace děložních kontrakcí užitím oxytocinu) uvedených v tabulce nebyly mezi skupinami zaznamenány významné rozdíly.

Četnost avulzního poranění jsme sledovali v obou hlavních skupinách jak celkově, tak i s ohledem na lateralitu poranění MLA (tab. 2, graf 1, 2 a 3). Ve skupině žen po VBAC bylo poranění MLA diagnostikováno v 36,7 % porodů, častěji unilaterálně, vpravo. V kontrolní skupině prvorodiček bylo diagnostikováno poranění MLA v 26,1 % případů. Častěji šlo o poranění bilaterální.



Graf 1 Avulzní poranění MLA (%) v souboru



Graf 2 Avulze MLA u VBAC (%)

Graf 3 Avulze MLA u provorodiček (%)

Tab. 2 Hodnocení sonografických parametrů při vyšetření pacientek v souboru

	Prvorodičky	VBAC	p-value
	n = 69	n = 98	
avulze MLA celkem; n (%)	18 (26,1)	36 (36,7)	NS**
avulze MLA pravostranná; n (%)	6 (8,7)	17 (17,4)	NS**
avulze MLA levostranná; n (%)	2 (2,9)	10 (10,2)	NS**
avulze MLA bilaterální; n (%)	10 (14,5)	9 (9,2)	NS**
balooning; n (%)	13 (18,8)	10 (10,2)	NS**
rozdíl plochy hiátu v klidu a při Valsalvově manévru [cm^2]; ± SD	18,5 ± 6,4	17,7 ± 6,9	NS*

* Wilcoxon Two Sample test, ** Fisher´s Exact Test, NS statisticky nevýznamná hodnota

Nepozorovali jsme žádný statisticky významný rozdíl mezi skupinami rodiček v četnostech jednotlivých typů poranění MLA. Ballooning, tedy rozšíření urogenitálního hiátu při Valsalvově manévru na plochu 25 cm² a větší, byl zaznamenán v obou dvou hlavních skupinách s obdobnou četností. Statisticky významný rozdíl nebyl zaznamenán v obou zmíněných skupinách ani v rozdílu plochy urogenitálního hiátu v klidu a při Valsalvově manévru (tab. 2). Dále bylo provedeno porovnání mezi podskupinami VBAC (A, B a C) ke zhodnocení významu fáze předchozího porodu, ve které byl proveden císařský řez. Skupina A byla tvořena 75 (44,9 %) ženami, skupina B 14 (8,4 %) ženami. Nejméně početnou skupinu C v našem souboru tvořilo 9 (5,39 %) žen. Zejména z důvodu malé četnosti skupin B a C jsme nepozorovali žádné statisticky významné rozdíly. Výsledky shrnuje tabulka 3 (tab. 3). V souboru žen jsme sledovali rizikové faktory pro vznik avulzního poranění MLA. Hodnocení proběhlo pomocí statistické deskripce a testu o rozdílu. Neprokázali jsme souvislost avulze MLA s poraněním análního svěrače pochvy ani epiziotomií. Skupina rodiček, u které bylo avulzní poranění MLA prokázáno, zahrnovala starší rodičky a měla kratší trvání druhé doby porodní proti skupině žen bez poranění. Bohužel OR ani zde nedosahuje statisticky významného rozdílu.

Tab. 3 Hodnocení sonografických parametrů při vyšetření VBAC podskupin

	VBAC (A) n = 75	VBAC (B) n = 14	VBAC (C) n = 9	p-value
avulze MLA celkem; n (%)	27 (36)	5 (35,7)	4 (44,4)	NS*
avulze MLA pravostranná; n (%)	11 (14,7)	3 (21,4)	3 (33,3)	NS*
avulze MLA levostranná; n (%)	9 (12)	1 (7,1)	0 (0)	NS *
avulze MLA bilaterální; n (%)	7 (9,3)	1 (7,1)	1 (11,1)	NS*
balooning; n (%)	8 (10,7)	1 (7,1)	1 (11,1)	NS*
rozdíl plochy hiatu v klidu a při Valsalvově manévru [cm²]; ± SD	17,4 ± 7,2	18,9 ± 4,9	18,5 ± 7,2	NS**

* Chi- square test, ** Wilcoxon Two Sample Test, NS statisticky nevýznamná hodnota

DISKUSE

Na základě sofistikovaného sonografického vyšetření pánevního dna jsme prokázali, že přes vyšší věk a kratší trvání druhé doby porodní, ženy rodící poprvé vaginálně po předchozím císařském řezu nemají statisticky významnější riziko vzniku avulzního poranění MLA než prvorodičky. A to ani v případě, že předchozí císařský řez byl proveden na pokročilejším vaginálním nálezu v průběhu předchozího porodu. Frekvence avulzního poranění MLA v našem souboru odpovídala obecně udávané incidenci tohoto poranění. Vyjma vyššího věku a kratší první a druhé doby porodní u žen po VBAC nebyl zaznamenán žádný statisticky významný rozdíl v charakteristikách porodů obou hlavních skupin rodiček.

Diagnostika avulzního poranění MLA probíhala sonograficky, tak jako ve většině odborných studií zabývajících se hodnocením pánevního dna. Metodika vyšetření vycházela z mezinárodně uznávaných doporučených postupů [9]. Jen menšina odborných studií hodnotí poranění svalů pánevního dna pomocí magnetické rezonance [2, 5, 17, 22]. Ta umožňuje diagnostiku mikrotraumat a parciálních avulzí MLA. Metoda počítačové tomografie není v této oblasti prakticky využitelná [6].

Časový odstup v diagnostice avulzního poranění v naší studii byl průměrně 33 měsíců. Ve většině odborných studií je to v rozmezí 3–12 měsíců po porodu [16, 27]. Citované odborné práce hodnotí také perzistenci avulzního poranění MLA. Vyšetření žen v těchto studiích bylo provedeno opakovaně s různě dlouhým časovým odstupem. Zdá se, že v časném poporodním období (do měsíce po porodu) je udávaná incidence avulzního poranění MLA vyšší, s delším odstupem se již významněji nemění.

Naše studie se zaměřila na téma v odborné světové literatuře dosud opomíjené. Žádná z prací zabývajících se poraněním pánevního dna při vaginální porodu nehodnotila ženy po VBAC. Vzhledem k narůstající incidenci prováděných císařských řezů v populaci jde přitom o téma vysoce aktuální. Naší snahou bylo získat data, která by sloužila k informování lékařů i jejich pacientek. S vědomím toho, že způsob porodu po císařském řezu může do značné míry ovlivnit kvalitu života ženy. Limitací naší studie je relativně malý soubor dat z jednoho pracoviště, který omezuje možnosti zhodnocení se statistickou významností. To také znemožnilo validní vyhodnocení rizikových faktorů souvisejících se vznikem avulzního poranění MLA.

V současné době probíhá ve spolupráci s Gynekologicko-porodnickou klinikou VFN a 1. LF v Praze multicentrická studie zahrnující rodičky z obou pracovišť. Věříme, že rozšíření souboru povede k zisku většího množství dat a dále k lepší informovanosti lékařů i jejich pacientek.

ZÁVĚR

Ženy rodící vaginálně po předchozím císařském řezu nemají významnější riziko vzniku avulzního poranění MLA proti prvorodičkám, přestože jsou starší a mají zkrácené trvání první i druhé doby porodní. Rozsah poranění hráze včetně epiziotomie nijak nekoreloval s rizikem poranění MLA. Průběh porodu před provedením císařského řezu nejspíše nemá vliv na riziko poranění při následném vaginálním porodu.

Tato studie vznikla na základě finanční podpory Grantové agentury Univerzity Karlovy, projekt č. 12077.

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MUDr. Lenka Paymová
Gynekologicko-porodnická klinika
FN a LF UK
Alej Svobody 80
304 60 Plzeň
e-mail: paymoval@fnplzen.cz

Příloha 3:

Ultrasound Obstet Gynecol 2021
Published online in Wiley Online Library (wileyonlinelibrary.com). **DOI:** 10.1002/uog.23629

Vaginal birth after Cesarean section and levator ani avulsion: a case–control study

L. PAYMOVA[1], K. SVABIK[2], A. NEUMANN[2], V. KALIS[1,3], K. M. ISMAIL[1,3] and Z. RUSAVY[1,3]

[1]*Department of Obstetrics and Gynecology, Faculty of Medicine in Plzen, Charles University, Plzen, Czech Republic;* [2]*Department of Obstetrics and Gynecology, 1st Faculty of Medicine, Charles University, Prague, Czech Republic;* [3]*Biomedical Center, Faculty of Medicine in Plzen, Charles University, Plzen, Czech Republic*

KEYWORDS: ballooning; childbirth trauma; levator ani avulsion; levator hiatus; transperineal ultrasound; urogenital hiatus; vaginal birth after Cesarean; VBAC

CONTRIBUTION

What are the novel findings of this work?
This is the first study to report on the incidence of levator ani muscle avulsion following vaginal birth after Cesarean section. Our data showed that vaginal birth after Cesarean section is associated with an increased risk of levator ani muscle avulsion.

What are the clinical implications of this work?
Levator ani muscle avulsion increases the risk of developing pelvic organ prolapse later in life and the risk of its recurrence after reconstructive surgery. The findings of our study show that women who delivered vaginally after a Cesarean section are at an increased risk of having levator ani muscle avulsion compared with primiparous women who had a vaginal delivery.

ABSTRACT

Objective *The aim of this study was to explore the risk of levator ani muscle (LAM) avulsion and enlargement of the levator hiatus following vaginal birth after Cesarean section (VBAC) in comparison with vaginal delivery in primiparous women.*

Methods *In this two-center observational case–control study, we identified all women who had a term VBAC for their second delivery at the Departments of Gynecology and Obstetrics, Faculty of Medicine in Pilsen and the 1st Faculty of Medicine in Prague, Charles University, Czech Republic between 2012 and 2016. Women with a repeat VBAC, preterm birth or stillbirth were excluded from the study. As a control group, we enrolled a cohort of primiparous women who delivered vaginally during the study period. To increase our control sample, we also invited all primiparous women who delivered vaginally in both participating units between May and June 2019 to participate. All participants were invited for a four-dimensional pelvic floor ultrasound scan to assess LAM trauma. LAM avulsion and the area of the levator hiatus were assessed offline from the stored pelvic floor volumes obtained at rest, during maximum contraction and during Valsalva maneuver. The laterality of the avulsion was also noted. The cohorts were then compared using the* χ^2 *test and Wilcoxon's two-sample test according to the normality of the distribution;* $P < 0.05$ *was considered statistically significant. Multivariate regression analysis, controlling for age and body mass index (BMI), was also performed.*

Results *A total of 356 women had a VBAC for their second delivery during the study period. Of these, 152 (42.7%) attended the ultrasound examination and full data were available for statistical analysis for 141 women. The control group comprised 113 primiparous women. A significant difference was observed between the VBAC group and the control group in age (32.7* vs *30.1 years;* $P < 0.05$*), BMI (28.4 kg/m*^{2} vs *27.4 kg/m*^{2}*;* $P < 0.05$*) and duration of the first and second stages of labor (293.1* vs *345.9 min;* $P < 0.05$ *and 27.6* vs *35.3 min;* $P < 0.05$*, respectively) at the time of the index birth. The LAM avulsion rate was significantly higher in the VBAC than in the control group (32.6%* vs *18.6%;* $P = 0.01$*). The difference between the groups was observed predominantly in the rate of unilateral avulsion and remained significant after controlling for age and BMI (adjusted odds ratio 2.061 (95% CI, 1.103–3.852)). There was no statistically significant difference in the area of the levator hiatus at rest (12.0* vs *12.6 cm*^{2}*;* $P = 0.28$*)*

Correspondence to: Dr Z. Rusavy, Department of Gynecology and Obstetrics, University Hospital Plzen, Alej Svobody 80, 304 60 Plzen, Czech Republic (e-mail: rusavyz@fnplzen.cz)

Accepted: 3 March 2021

or on maximum Valsalva maneuver (18.6 vs *18.7 cm*^{2}*;* P = *0.55) between the VBAC and control groups. The incidence of levator hiatal ballooning was comparable between the groups (17.7% and 18.6%;* P = *0.86).*

Conclusions *VBAC is associated with a significantly higher rate of LAM avulsion than is vaginal birth in nulliparous women. The difference was significant even after controlling for age and BMI.* *© 2021 International Society of Ultrasound in Obstetrics and Gynecology.*

INTRODUCTION

After a first delivery by Cesarean section (CS), many women choose to attempt a vaginal delivery for their second child[1]. In the USA, a uterine scar contributes to almost a third of Cesarean delivery indications[2]. Hence, vaginal birth after CS (VBAC) is currently an important and effective intervention for curtailing the rising CS rate[3–5]. Opponents of VBAC point out that the policy of trial of labor after CS is associated with a low success rate, an increased risk of uterine rupture and potential adverse events[6]. However, serious complications associated with the trial of labor after CS are rare, and the success rate is acceptable provided that a standardized evidence-based labor management protocol facilitates intrapartum care and decisions[7].

Childbirth trauma and its possible consequences should be taken into account when counseling women about their second delivery after CS. Although VBAC is an extensively studied subject, to date, few studies have focused on pelvic floor trauma after this mode of birth[8–12] and none of them studied the risk of levator ani muscle (LAM) avulsion. LAM avulsion is a relatively frequent complication following a vaginal delivery, with a reported prevalence ranging from 13% to 36%[13,14]. It leads to reduced contractility of the pelvic floor and increased vaginal laxity[15,16]. The trauma plays an important role in the pathophysiology of pelvic organ prolapse, increasing its lifetime risk 4-fold and hence negatively impacting on the woman's quality of life and sexuality[17–19].

VBAC has been associated with an increased risk of perineal[8,10] and cervical trauma[11]. It has been postulated that the combination of a vaginally nulliparous pelvic floor, a larger fetus and more powerful uterine contractility may result in an increased likelihood of pelvic floor trauma[11,20]. Therefore, we hypothesized that the risk of LAM avulsion at the time of the first vaginal delivery is higher in women having a VBAC compared with that in nulliparous women. Consequently, the magnitude of enlargement of the levator hiatus was expected to be greater in women after VBAC. The aim of the study was to test these hypotheses.

METHODS

In this observational case–control study, we identified all women who had a term VBAC for their second delivery at the Department of Gynecology and Obstetrics, Faculty of Medicine in Pilsen and the Department of Gynecology and Obstetrics, 1st Faculty of Medicine in Prague, Charles University, between 2012 and 2016. Women with a repeat VBAC, preterm birth or stillbirth were excluded from the study. We aimed to recruit primiparous women who delivered vaginally as our control group. We initially attempted to recruit controls with a length of follow-up comparable with that of the cases. This was achieved by approaching every primiparous woman who had a singleton vaginal birth subsequent to each of the included VBAC cases. However, this approach yielded a small number of women who had not had a further delivery in the meantime. Therefore, to increase the number of controls, we invited all women who had their first vaginal delivery in both participating units between May and June 2019 for an ultrasound examination at least 2 months postpartum. The hospital electronic clinical databases of the two participating units were used to identify eligible women, and their individual health records were used for data collection (age, body mass index (BMI), gestational age, birth weight, duration of the first and second stages of labor, perineal trauma, episiotomy, vaginal laceration, operative vaginal delivery). Women who were eligible were contacted and invited to participate in the study.

Women were assessed in the supine position after bladder emptying using four-dimensional (4D) ultrasound (GE Voluson E8, GE Healthcare, Zipf, Austria) with 8–4-MHz curved array volume transducer with an 85° angle of acquisition. Volume acquisition was performed on maximum Valsalva maneuver for the assessment of the dimensions of the levator hiatus and on maximum pelvic floor muscle contraction for diagnosis of LAM avulsion. The acquired volumes were analyzed offline on a desktop PC using the proprietary software 4D View version 18.0 (GE Healthcare). The assessors who performed the ultrasound analysis were blinded to all the patients' data.

Tomographic ultrasound imaging (TUI) was used for the diagnosis of LAM avulsion, with slices obtained in the axial plane at 2.5-mm slice intervals using the plane of minimal hiatal dimensions and the two slices immediately above that plane. The plane of minimal hiatal dimensions was defined in the mid-sagittal plane as the minimal distance between the hyperechogenic posterior aspect of the symphysis pubis and the hyperechogenic anterior border of the LAM just posterior to the anorectal muscle. LAM avulsion was diagnosed if the distance between the center of the urethra and the LAM insertion (levator–urethra gap) was ≥ 25 mm in all three central slices[21,22] (Figure 1). The laterality of the avulsion was also recorded. Hiatal dimensions were measured in an axial cross-section at the plane of minimal hiatal dimensions[23]. Hiatal area at rest and during the third maximum Valsalva maneuver was measured. The distensibility of the levator hiatus was described by the difference in its area at rest and on maximum Valsalva and the frequency of ballooning, which was defined as area of the levator hiatus > 25 cm^2 during maximum Valsalva[24]. The volumes were analyzed offline by

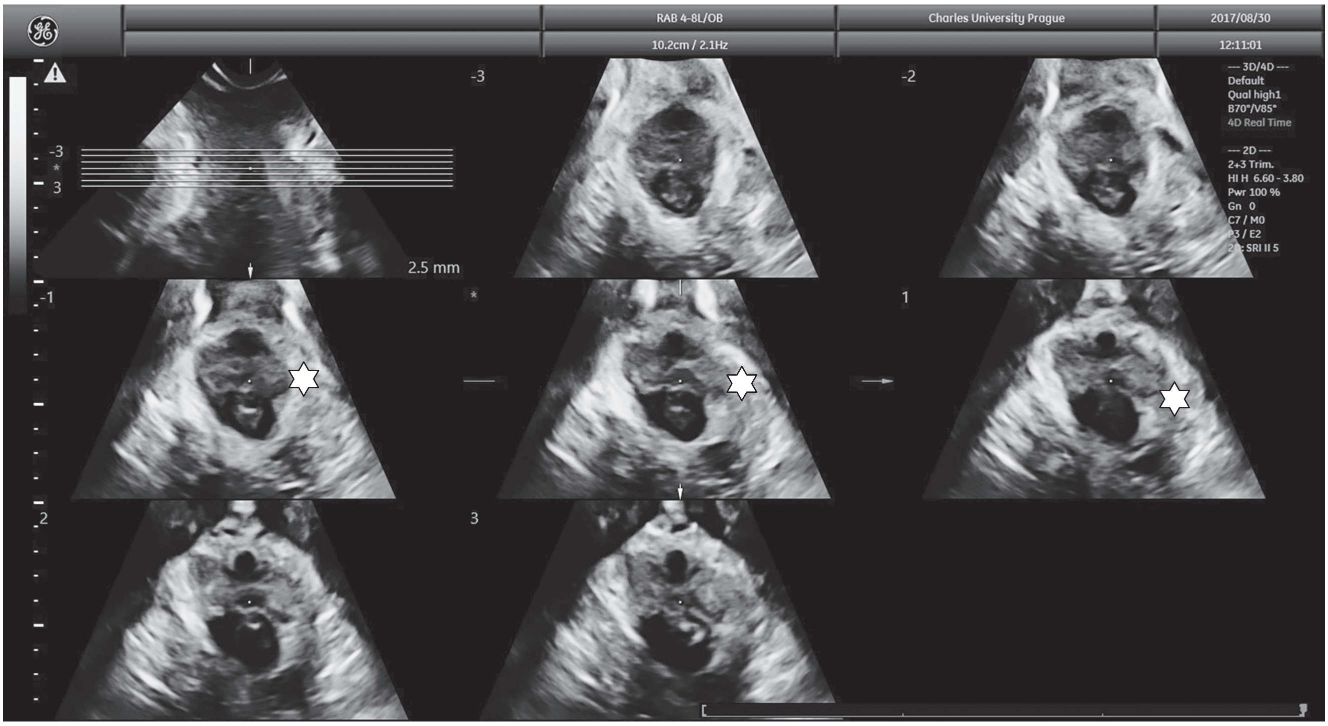

Figure 1 Left-sided levator ani muscle avulsion (✡) diagnosed by tomographic ultrasound imaging.

an assessor blinded to any childbirth trauma information using TUI to identify unrecognized anal sphincter injury[25].

Statistical analysis was performed using SAS 9.4 statistical software (SAS Institute Inc., Cary, NC, USA). Comparison of variables between the two study groups with respect to the normality of their distribution was performed using the non-parametric two-sample Wilcoxon test. Categorical variables were analyzed using the χ^2 test or Fisher's exact test, as appropriate, and described by contingency tables; $P < 0.05$ was considered to indicate statistical significance. Additional multivariate logistic regression analysis was performed to control for age and BMI.

The study was approved by the local ethics committees of both participating units (ethics committee of the University Hospital in Pilsen and Faculty of Medicine in Pilsen, Charles University – number 92/2017, date of approval 2nd March 2017, and ethics committee of the General University Hospital in Prague – number 100/17, date of approval 19th October 2017). Prior to enrollment, all women provided signed informed consent. The study was registered at ClinicalTrials.gov (NCT03420001) prior to its commencement.

RESULTS

The database search identified 356 women who had a first VBAC during the study period and who met the *a-priori* set inclusion criteria. Of these, 54 were excluded owing to an ongoing pregnancy or another delivery, 149 were uncontactable or declined to participate in the study and one woman had had perineal surgery since her delivery. The remaining 152/356 (42.7%) women were recruited into the study as cases, and all attended for the ultrasound assessment. Eleven women were additionally excluded owing to incomplete or missing ultrasound data (Figure 2). In addition, 113 primiparous women delivering vaginally were enrolled as a control group. The group comprised 25 case-matched women with the same length of follow-up as the VBAC group, as well as a cohort of women who delivered consecutively in a 2-month period who attended for pelvic floor ultrasound examination. In total, 88/355 (24.8%) women who delivered in this period agreed to participate and attended for the ultrasound assessment (Figure 2). The mean follow-up was 3.5 years in the VBAC group and 1 year in the control group.

The demographic details and birth outcomes of the groups are summarized in Table 1. There was a statistically significant difference in age (32.7 *vs* 30.1 years; $P < 0.05$) and BMI (28.4 *vs* 27.4 kg/m^2; $P < 0.05$) between the VBAC and control groups. Furthermore, compared with controls, the VBAC cohort had significantly shorter duration of the first and second stages of labor (293.1 *vs* 345.9 min; $P < 0.05$ and 27.6 *vs* 35.3 min; $P < 0.05$, respectively). Obstetric anal sphincter injury (OASI) was observed in six women in the VBAC group, while none of the controls was affected ($P = 0.03$). The groups did not differ in the frequency of other degrees of perineal or vaginal trauma (Table 1). Very few women ($n = 4$ per group) had an operative vaginal delivery, which was by vacuum extraction in all cases.

LAM avulsion occurred in 32.6% of women in the VBAC group (Table 2) and was more frequent on the right side, however, the difference in laterality did not reach statistical significance (right-sided, 14.9%; left-sided, 9.2%; bilateral, 8.5%; $P = 0.2$). The LAM avulsion rate was significantly higher in the VBAC group than in controls (32.6% *vs* 18.6%; $P = 0.01$), and this difference remained significant even after controlling for age and BMI. The adjusted odds ratio (OR) was 2.1 (95% CI, 1.1–3.9) and did not differ substantially from the crude OR. The relative risk of LAM in the VBAC group was 1.35 (95% CI, 1.1–1.7). The observed difference between the VBAC and control groups was present only in the rate of unilateral, but not bilateral, avulsion (Table 2). No statistically significant difference in the area of the levator hiatus at rest (12.0 *vs* 12.6 cm^2; $P = 0.28$) or on maximum Valsalva maneuver (18.6 *vs* 18.7 cm^2; $P = 0.55$) was observed. Similarly, the incidence of levator hiatal ballooning was comparable in the VBAC and control groups (17.7% and 18.6%; $P = 0.86$) (Table 2).

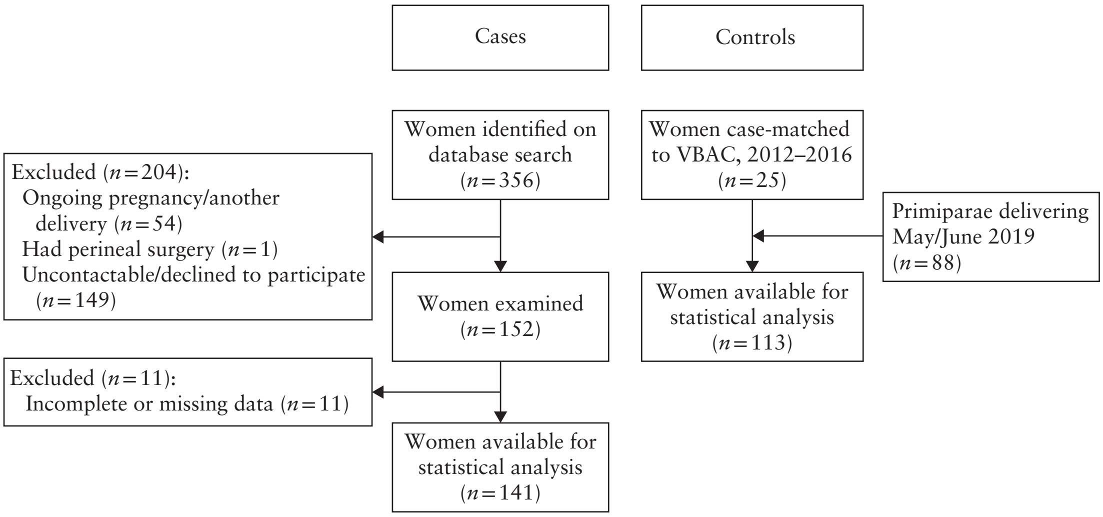

Figure 2 Flowchart summarizing study population.

Table 1 Demographic characteristics and birth outcomes of women with vaginal birth after Cesarean section (VBAC) and primiparous women with vaginal delivery (controls)

Parameter	*VBAC (n = 141)*	*Controls (n = 113)*	P
Age (years)	32.7 ± 3.6	30.1 ± 4.6	0.0001*
BMI (kg/m^2)	28.4 ± 4.3	27.4 ± 6.0	0.0236*
Gestational age at delivery (weeks)	39.6 ± 1.2	39.4 ± 1.2	0.45*
Birth weight (g)	3372.2 ± 401.9	3307.9 ± 467.5	0.28*
Duration of first stage of labor (min)	293.1 ± 139.3	345.9 ± 129.0	0.0004*
Duration of second stage of labor (min)	27.6 ± 19.3	35.3 ± 28.1	0.02*
Operative vaginal delivery	4 (2.8)	4 (3.5)	1.00†
Intact or minimal perineal trauma	29 (20.6)	24 (21.2)	0.91‡
First-degree tear	15 (10.6)	11 (9.7)	0.80‡
Second-degree tear	16 (11.3)	14 (12.4)	0.81‡
Obstetric anal sphincter injury	6 (4.3)	0 (0)	0.03†
Mediolateral episiotomy	74 (52.5)	51 (45.1)	0.23‡
Vaginal tear ≥ 5 cm	24 (17.0)	18 (15.9)	0.80‡

Data are presented as mean ± SD or *n* (%). *Wilcoxon two-sample test. †Fisher's exact test. ‡χ^2 test. BMI, body mass index.

Table 2 Findings on pelvic floor ultrasound in women with vaginal birth after Cesarean section (VBAC) and primiparous women with vaginal delivery (controls)

Parameter	*VBAC (n = 141)*	*Controls (n = 113)*	P
Any LAM avulsion	46 (32.6)	21 (18.6)	0.01*
Unilateral LAM avulsion	34 (24.1)	11 (9.7)	0.003*
Bilateral LAM avulsion	12 (8.5)	10 (8.8)	0.92*
Levator hiatal area (cm^2)			
At rest	12.0 ± 3.4	12.6 ± 3.7	0.28†
On maximum Valsalva maneuver	18.6 ± 7.3	18.7 ± 6.3	0.55†
Increase from rest to maximum Valsalva maneuver	6.6 ± 6.2	6.1 ± 4.5	0.83†
Hiatal ballooning	25 (17.7)	21 (18.6)	0.86*

Data are presented as *n* (%) or mean ± SD. *χ^2 test. †Wilcoxon two-sample test. LAM, levator ani muscle.

DISCUSSION

In this case–control ultrasound study of LAM trauma after VBAC, we found that women who had VBAC are at an increased risk of LAM injury than are primiparous women after a vaginal birth. Women with VBAC were older at the time of delivery and had a higher BMI, but their LAM avulsion rate was higher when compared with controls, even after controlling for these confounders. The size of the levator hiatus and the ballooning rate were comparable between the VBAC and control groups despite the difference in the avulsion rate. Urogenital hiatus enlargement probably occurs later in life[26]. Furthermore, only a small proportion of ballooning of the levator hiatus can be explained by LAM injury at the time of childbirth[27].

The main risk factors for LAM avulsion include age, primiparity, birth weight, head circumference, length of the second stage of labor and forceps delivery[28–30]. Although most of these risk factors are commonly associated with VBAC, the difference between the groups in this study remained significant even after controlling for age and BMI, suggesting that VBAC represents an additional risk factor. Although only speculative, the faster progression of labor in the VBAC cases, allowing less time for adaptation of the pelvic floor, could lead to an increased risk of its injury.

It has been suggested that LAM injury is more frequent in women sustaining OASI[31,32]. In agreement with other studies, we observed more OASI in our VBAC cohort[8–10,12]. However, our study was not designed or powered to test this outcome, nor was this one of our objectives.

To our knowledge, there are no other published studies designed to evaluate LAM avulsion rate after VBAC that could be compared with our study. Only one study indicated a possible increased avulsion rate after VBAC and suggested further investigation[20]. The authors hypothesized that 'the combination of a vaginally nulliparous pelvic floor, a larger baby and more powerful uterine contractility may result in an increased likelihood of pelvic floor trauma'. Although women in the VBAC group did not deliver a larger baby in our study, more powerful uterine contractility reflected by shorter first and second stages of labor, when compared with the control group, was observed. The relative shortening of labor could also have been caused by the fact that trial of labor after CS is more likely to be terminated by an iterative CS. However, this approach would be more protective towards the pelvic floor and would not explain the higher avulsion rate.

A review of the literature revealed that 13–36% of women undergoing their first vaginal delivery sustain LAM avulsion[14]; the LAM avulsion rates reported in both groups in our study fall within this range. A very recent review showed an incidence of LAM avulsion after the first spontaneous vaginal delivery of 15%[33]. Caudwell-Hall *et al.*[34] published a large study on the incidence of LAM injury after vaginal delivery, and in their series of 609 women who delivered vaginally, they reported an avulsion rate of 16%. Interestingly, they identified a family history of CS (mother, sister) as a risk factor for LAM avulsion. In our study, a past history of CS was identified as another risk factor for LAM avulsion. The slightly higher avulsion rate in the control group compared with that in the abovementioned studies could be explained by selection bias, since only a quarter of the women in the control group attended the examination. Symptomatic women were more prone to attend in previous studies[35].

The increased rate of LAM trauma after VBAC cannot be explained by a higher operative vaginal delivery rate, as this was comparable between the VBAC and control groups. The slightly higher avulsion rate in the control group compared with the data of the abovementioned studies could be explained by the inclusion of cases with operative vaginal delivery in the analysis. However, this is rather improbable given the negligible proportion of women with an operative vaginal delivery (2.8 *vs* 3.5%; $P = 1.0$). These low numbers are a reflection of Czech obstetric practice, in which the rate of operative vaginal birth is generally very low, with a preference towards the use of vacuum extraction because of the associated lower risk of OASIs and LAM avulsion. The latter was also reported by Friedman *et al.*[13] in their meta-analysis, in which a substantial association between mode of delivery and LAM avulsion was demonstrated.

We acknowledge that our study has some limitations. In spite of the inclusion of women from two tertiary referral centers over a relatively long study period, the number of women with VBAC was still limited. Several women became pregnant or had another delivery after the first VBAC and hence were not included in our analysis. The same issues made it impossible to include enough controls with the same length of follow-up. The retrospective nature of the study is another limitation because it did not allow us to report on the VBAC success rate, as information on trial of labor after CS was not collected in our databases. Similarly, comparison of the area of the levator hiatus before and after delivery was not possible. In contrast, the methodology of the ultrasound assessment is a major strength of the study. The analysis was performed offline by two expert sonographers specializing in pelvic floor ultrasound (K.S., Z.R.), who were blinded to the patients' data, according to the standardized internationally accepted methodology[22]. Furthermore, the inclusion of more than one center increases the external validity of our findings. It eliminates local variations in the management of labor and perineal care provided in the second stage of labor. Comparison of the VBAC cohort with a control group of primiparous women delivering in the same institution constitutes another strength of the study. This design allowed us to study the effects of VBAC because women in the two groups delivered under comparable conditions.

In conclusion, VBAC appears to be associated with an increased risk of LAM avulsion, which remained significant after controlling for age and BMI. Our findings confirm the hypothesis that the combination of a vaginally nulliparous pelvic floor and more powerful uterine contractility in VBAC may result in an increased likelihood of pelvic floor trauma. Based on our observations, women after a CS could be informed about an increased probability of LAM trauma following vaginal delivery, but our results should be validated in a study with a larger cohort.

ACKNOWLEDGMENTS

This study was funded by the GA UK (Charles University Grant Agency, project No. 918119). K.I. is part-funded by project No. CZ.02.1.01/0.0/0.0/16_019/0000787 ‘Fighting INfectious Diseases’, awarded by the Ministry of Education, Youth and Sports of the Czech Republic, financed from The European Regional Development Fund. Funders were not involved in the design, analysis or the reporting of this work.

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Příloha 4:

doi: 10.48095/cccg2022173

Průběh porodu před císařským řezem a incidence avulze *musculus levator ani* při prvním následném vaginálním porodu – pilotní studie

Timing of caesarean section and its impact on *levator ani musle* avulsion at the first subsequent vaginal birth – a pilot study

L. Paymová[1], K. Švabík[2], V. Kališ[1], K. M. Ismail[3], Z. Rušavý[1]

[1] Gynekologicko-porodnická klinika LF UK a FN Plzeň
[2] Gynekologicko-porodnická klinika 1. LF UK a VFN v Praze
[3] Biomedicínské centrum, LF UK Plzeň

Souhrn: Cíl: Cílem této multicentrické observační kohortové studie bylo objasnit vliv indikace císařského řezu (SC – cesarean section) na riziko vzniku avulze levátoru (MLA – *musculus levator ani*) při následném vaginálním porodu. **Metodika:** Do studie byly zařazeny ženy, které porodily poprvé vaginálně po předchozím císařském řezu (VBAC – vaginal birth after cesarean section) v období 2012–2016 na Gynekologicko-porodnické klinice LF UK a FN v Plzni a na Gynekologicko-porodnické klinice 1. LF UK a VFN v Praze. Rodičky byly rozděleny do dvou skupin – po elektivním a akutním císařském řezu – a následně vyšetřeny pomocí 4D transperineálního ultrazvuku. Z 66 nasnímaných volumů pánevního dna byla offline vyhodnocena přítomnost avulzního poranění a velikost urogenitálního hiátu. Data byla statisticky zhodnocena. **Výsledky:** V obou centrech porodilo celkem 356 žen po předchozím SC. Ultrazvukové vyšetření podstoupilo 152 z nich (42,7 %), kompletní data byla dostupná u 141 rodiček. Po akutním SC bylo 80 žen, 61 žen po elektivním SC. Incidence avulzního poranění byla vyšší ve skupině rodiček po elektivním SC, avšak bez průkazu statistické významnosti (26,3 vs. 41 %, p = 0,0645). Při vyšetření urogenitálního hiátu a přítomnosti balloningu nebyl prokázán signifikantní rozdíl. **Závěr:** VBAC je asociován se signifikantně vyšší incidencí avulzního poranění MLA ve srovnání s prvním vaginálním porodem. Zdá se, že riziko avulze MLA nezávisí na průběhu porodu před předchozím císařským řezem. K potvrzení výsledků bude jistě třeba studií s větší kohortou pacientek.

Klíčová slova: 4D transperineální ultrazvuk – *musculus levator ani* – avulzní poranění – vaginální porod po císařském řezu – pánevní dno

Summary: Objective: The aim of this multicentric observational study was to explore the impact of the timing of cesarean section (SC) on levator (MLA – *levator ani musle*) avulsion at the first subsequent vaginal birth. **Methods:** All women after term vaginal birth following a cesarean section (VBAC) for their second delivery at the Departments of Gynecology and Obstetrics, Faculty of Medicine, Charles University and University Hospital in Pilsen and the 1st Faculty of Medicine, Charles University and General Hospital in Prague, between 2012 and 2016 were identified. Hospital database and surgical notes were used to collect basic characteristics of the patients including the indication and course of their previous delivery. These women were divided into two groups according to indication of prior SC in the previous delivery to women with elective SC and acute SC. All participants were invited for a 4D pelvic floor ultrasound to assess levator trauma. Levator avulsion and the levator hiatus area were assessed off-line from the stored pelvic floor volumes. Data were statistically assessed. **Results:** A total of 356 women had a VBAC for their second delivery during the study period. Of these, 152 (42.7%) attended the ultrasound examination and full data were available for 141 women for statistical analyses. These were further divided into 80 women after acute SC and 61 women after elective SC. The levator avulsion rate was higher in the elective SC subgroup, but the difference was not significant (26.3 vs. 41.0%, P = 0.0645). No statistical differences in urogenital hiatus enlargement and ballooning were observed. **Conclusion**: VBAC is associated with a significantly higher rate of levator ani avulsion compared to the first vaginal birth in nulliparous women. However, it seems that risk of levator ani avulsion doesn't depend on the timing of SC in previous labor. More studies are needed to confirm the results of this pilot study.

Key words: 4D transperineal ultrasound – *levator ani muscle* – avulsion injury – vaginal birth after cesarean section – pelvic floor

Úvod

Vaginální porod po předchozím císařském řezu (VBAC – vaginal birth after cesarean section) je jedním z efektivních způsobů, jak snížit celosvětově se zvyšující incidenci císařských řezů [1–3]. Až jednu třetinu všech indikací k císařskému řezu v USA tvoří právě předchozí císařský řez v anamnéze rodičky [4]. Oponenti vedení porodu touto cestou upozorňují na relativně nízkou úspěšnost dokončení porodu vaginální cestou (TOLAC – trial of labor after cesarean) a na zvýšené riziko ruptury děložní se všemi svými nepříznivými důsledky [5]. Nicméně tyto komplikace se vyskytují jen zřídka a procento úspěšnosti dokončení porodu vaginální cestou je akceptovatelné. To vše pod podmínkou dodržení evidence-based doporučených postupů [6].

Přestože je VBAC velmi dobře prostudovanou problematikou, jen málo vědeckých prací se zaměřilo na zkoumání poranění pánevního dna po tomto způsobu porodu. Avulzní poranění *musculus levator ani* (MLA) je relativně častou komplikací vaginálně vedeného porodu. Vede ke snížení kontraktility svalstva pánevního dna, zvyšuje vaginální laxitu [7,8] a hraje zásadní roli v patofyziologii rozvoje sestupu pánevních orgánů se všemi svými negativními důsledky na život ženy vč. její sexuality [9–11]. Metaanalýza prací ukázala, že incidence avulzního poranění po prvním spontánním vaginálním porodu je 15 % [12]. Z jiné observační studie vyplývá, že incidence avulzního poranění MLA u sekundipar po císařském řezu je 33 % [13]. Zvýšené riziko u VBAC bylo přičítáno kombinaci rychleji progredujícího porodu, většího plodu a silnější kontraktility dělohy u vícerodičky ve spojení s pánevním dnem nerodivší ženy [14]. Vliv délky expozice porodnímu ději před provedením císařského řezu na porodní poranění MLA při následném vaginálním porodu zatím studován nebyl.

Cílem studie bylo zjistit, jaký vliv na vznik avulzního poranění MLA má fakt, že předchozí císařský řez byl proveden elektivně nebo akutně v průběhu předchozího porodu ženy.

Metodika

Jedná se o sekundární zhodnocení dat multicentrické observační kohortové studie hodnotící incidenci avulzního poranění MLA u rodiček po prvním VBAC ve srovnání s kontrolní skupinou běžných primipar [13]. Do studie byly zařazeny všechny termínové sekundipary s císařským řezem v anamnéze, které porodily na Gynekologicko-porodnické klinice LF UK a FN v Plzni a Gynekologicko-porodnické klinice 1. LF UK a VFN v Praze v období 2012–2016. Ženy po opakovaném VBAC, předčasném porodu nebo porodu mrtvého plodu byly vyřazeny. S použitím nemocničního informačního systému byla zaznamenána data charakterizující obě skupiny žen (věk při porodu, BMI, gestační stáří, porodní hmotnost novorozence, trvání I. a II. doby porodní, event. operativní ukončení porodu, porodní poranění). Dokumentace ohledně porodu před předchozím císařským řezem byla využita k rozdělení VBAC do dvou podskupin – po elektivním a akutním císařském řezu. „Akutní císařský řez“ byl proveden v aktivní fázi porodu, tedy při vaginálním nálezu branky > 4 cm. V případě, že předchozí císařský řez probíhal v jiném zdravotnickém zařízení, byla ve spolupráci s ním tato data získána dodatečně.

Ženy po podepsání informovaného souhlasu byly vyšetřeny v supinační poloze, po vyprázdnění močového měchýře pomocí 4D transperineální sonografie (GE Voluson E8-GE Kretz Medizintechnik, Zipf, Austria). Konvexní 4D sonda s frekvencí 4–8 MHz a akvizičním úhlem 85° byla využita k nasnímání volumů pánevního dna. Volumy byly vyhodnoceny offline dvěma zkušenými nezávislými hodnotícími pomocí software 4D View, a to bez znalosti dalších dat. Rozměry plochy urogenitálního hiátu v klidu a při Valsalvově manévru byly měřeny v rovině jeho minimálních rozměrů, která je ve střední sagitální rovině ohraničena hyperechogenitou zadní stěny spony stydké a hyperechogenitou přední hranice MLA. Vyhodnocení přítomnosti avulze MLA za kontrakce svalů pánevního dna z nasnímaných volumů bylo provedeno z tomografických řezů (TUI – tomographic ultrasound imaging) šíře 2,5 mm v oblasti 5 mm pod a 12,5 mm nad rovinou minimální plochy urogenitálního hiátu, tak aby byl zahrnut kompletně *musculus puborectalis*. Avulze MLA byla diagnostikována v případě potvrzení abnormální inzerce MLA ve třech centrálních řezech [15,16], což odpovídá vzdálenosti úponu levátoru ke stydké kosti od středu uretry > 25 mm. Zároveň jsme využili TUI k hodnocení skrytého porodního poranění análního sfinkteru.

Získaná data byla zpracována pomocí statistického softwaru SAS 9.4 (SAS Institute Inc., Cary, NC, USA). Srovnání proměnných mezi skupinami bylo provedeno pomocí Wilcoxonova testu (neparametrická ANOVA) či Fisherovým exaktním testem dle rozložení normality. Kategorické proměnné byly porovnány pomocí kontingenčních tabulek. Hladina statistické významnosti byla určena jako hodnota $p < 0,05$.

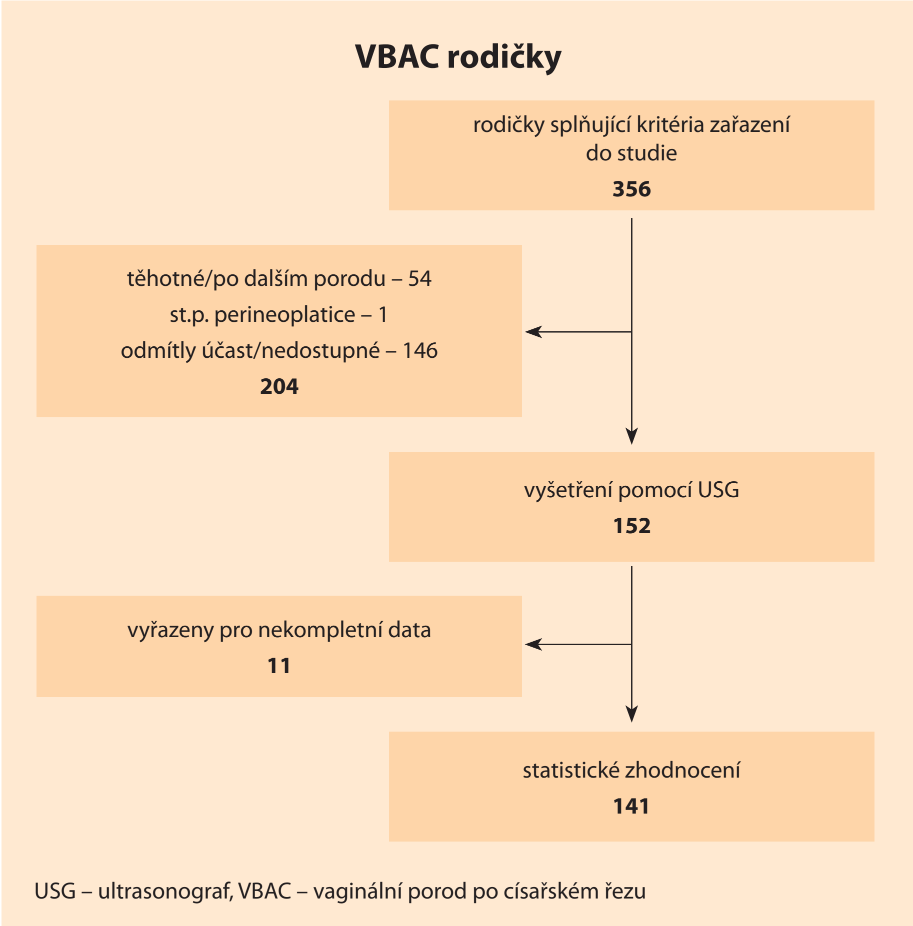
Studie byla schválena etickou komisí LF UK a FN v Plzni (číslo 92/2017) a etickou komisí VFN v Praze (číslo 100/17).

Výsledky

Za studované období porodilo vaginálně po předchozím císařském řezu a kritéria pro zařazení do studie splnilo celkem 356 žen. Z nich bylo 54 vyřazeno pro další právě probíhající těhotenství nebo stav po dalším porodu, 149 žen nebylo možné telefonicky kontaktovat, případně nesouhlasily s účastí ve studii. Jedna žena od svého porodu podstoupila perineoplastiku. Zbylých 152 žen (42,7 %) podstoupilo ultrazvukové vyšetření. Dodatečně bylo vyloučeno 11 žen pro inkompletní nebo chybějící data z vyšetření (obr. 1). Studovaná skupina žen byla dále rozdělena do podskupin po elektivním (61) a akutním císařském řezu (80) na základě posouzení průběhu porodu před císařským řezem – jako cut-off byla stanovena aktivní vs. pasivní fáze I. doby porodní, tedy porodnická branka > 4 cm. Tyto podskupiny byly mezi sebou porovnány.

Demografické charakteristiky a charakteristiky porodu jsou shrnuty v tab. 1. Ve věku rodiček při porodu (32,5 vs. 33,1 let; p = 0,4346) a BMI (28,9 vs. 27,9 kg/m^2; p = 0,2477), gestačním stáří a hmotnosti novorozence nebyl shledán statisticky významný rozdíl mezi oběma skupinami. Trvání I. a II. doby porodní bylo srovnatelné, stejně tak počty případů, ve kterých bylo nutné ukončit porod instrumentálně. Vždy se jednalo o použití vakuumextraktoru. Porodní poranění análního sfinkteru (OASIS – obstetric anal sphincter injuries) bylo zaznamenáno u pěti rodiček po akutním císařském řezu, u rodiček po elektivním císařském řezu bylo zaznamenáno jen v jednom případě. Vzhledem k malému počtu pozorování nebyl rozdíl statisticky významný (5/79 vs. 1/60; p = 0,235). Skupiny se nelišily ani v dalších kategoriích porodního poranění.

Incidence avulzního poranění MLA po prvním VBAC byla ve skupině obecně 32,6 %. S přihlédnutím k průběhu předchozího porodu, který skončil císařským řezem, byla incidence avulzního poranění MLA vyšší u žen po elektivním císařském řezu (26,3 vs. 41,0 %; p = 0,06). Na první pohled nápadný rozdíl bohužel nenabyl statistické významnosti, snad s ohledem na malou četnost žen v obou skupinách. V případě jednostranné avulze při hodnocení její laterality jsme



Obr. 1. Schéma rodičky po předchozím císařském řezu zařazené ve studii.
Fig. 1. Scheme of the mother after the previous caesarean section included in the study.

Tab. 1. Charakteristika porovnávaných skupin rodiček v souboru.
Tab. 1. Characteristics of compared groups of mothers in the group.

	VBAC po akutním SC	SD/%	VBAC po elektivním SC	SD/%	p-hodnota
avulze	21/80	26,3 %	25/61	41,0 %	0,0645[3]
pravostranná	5/80	6,3 %	16/61	26,2 %	0,0015[2]
levostranná	8/80	10,0 %	5/61	8,2 %	0,7769[2]
bilaterální	8/80	10,0 %	4/61	6,6 %	0,5533[2]
plocha hiatu v klidu (cm^2)	11,99	3,65	12,04	3,0	0,5109[1]
plocha hiatu při Valsalva (cm^2)	18,67	7,75	18,49	6,8	0,9023[1]
rozdíl plochy hiátu při valsalva a v klidu (cm^2)	6,68	6,28	6,46	6,2	0,995[1]
ballooning	17/80	21,3 %	8/61	13,1 %	0,2102[3]

[1] Wilcoxonův dvouvýběrový test
[2] Fisherův exaktní test
[3] Chí-kvadrát test
SC – císařský řez, SD – směrodatná odchylka, VBAC – vaginální porod po císařském řezu

Tab. 2. Zhodnocení pánevního dna u VBAC rodiček.
Tab. 2. Pelvic floor evaluation in VBAC mothers.

	VBAC po akutním SC	SD/%	VBAC po elektivním SC	SD/%	p-hodnota
věk (roky)	32,5	3,9	33,1	3,20	0,4346 [1]
BMI	27,9	3,5	28,9	4,38	0,2477 [1]
gestační stáří při porodu (týden)	39,5	1,2	39,6	1,18	0,7264 [1]
porodní hmotnost (g)	3 349,9	387,9	3 401,7	424,39	0,6972 [1]
I. doba porodní (min)	283,8	139,9	305,3	140,07	0,2371 [1]
II. doba porodní (min)	29,5	20,0	25,0	18,32	0,1674 [1]
operativní ukončení porodu	2	2,5 %	2	3,33 %	1 [2]
perineum intaktní/s minimálním poraněním	16	20,3 %	13	21,67 %	0,839 [3]
ruptura perinea I. st.	6	7,6 %	9	15,00 %	0,1634 [3]
ruptura perinea II. st.	9	11,4 %	7	11,67 %	0,96 [3]
OASIS	5	6,3 %	1	1,67 %	0,2352 [2]
episiotomie	44	55,7 %	30	50,00 %	0,505 [3]
ruptura pariet. vaginae nad 5 cm	16	20,3 %	8	13,33 %	0,285 [3]
ruptura cervixu	12	15,2 %	12	20,00 %	0,4574 [3]

[1] Wilcoxonův dvouvýběrový test
[2] Fisherův exaktní test
[3] Chí-kvadrát test
OASIS – porodní poranění análního sfinkteru, SC – císařský řez, SD – směrodatná odchylka, VBAC – vaginální porod po císařském řezu

zjistili statisticky významný rozdíl v incidenci pravostranného avulzního poranění MLA. Opět ve skupině rodiček po elektivním císařském řezu (26,2 vs. 6,3 %; p = 0,0015). Při hodnocení levostranné a bilaterální avulze statisticky významný rozdíl pozorován nebyl. Ani v ostatních ultrasonografických markerech (plocha urogenitálního hiátu v klidu, při Valsavově manévru a incidence ballooningu) nebyly zjištěny signifikantní rozdíly v obou skupinách rodiček (tab. 2).

Diskuze

Dle dosud publikované literatury mají ženy rodící po předchozím císařském řezu větší riziko avulzního poranění MLA oproti prvorodičkám obecně. Ze sekundární analýzy našich dat přitom vyplývá, že pokročilost porodu před císařským řezem toto riziko statisticky významně nemění. Stejně tak nemá fáze předchozího porodu vliv na velikost urogenitálního hiátu a incidenci ballooningu. Velikost plochy urogenitálního hiátu při maximálním Valsalvově manévru přitom velmi úzce koreluje s rizikem vzniku poklesu pánevních orgánů [17]. Tyto změny pravděpodobně vznikají až později po porodu [18]. Kromě toho z dostupných studií víme, že jen u malé skupiny žen s nálezem ballooningu je současně přítomno poporodní avulzní poranění MLA [19].

Při srovnání skupin rodiček po elektivním a akutním císařském řezu jsme měli k dispozici sice malé, ale prakticky shodné skupiny. Rodičky se nelišily demografickými údaji ani charakteristikami porodu, porodily novorozence s obdobnou porodní hmotností. Přesto rozdíl v incidenci avulze MLA nebyl statisticky významný. Power analýza na základě našich dat ukázala, že pro průkaz statisticky signifikantního rozdílu na hladině alfa 5 % a při požadované 80% síle testu by při zjištěných četnostech bylo třeba v každém rameni studie právě 161 pacientek.

Pokud je nám známo, v tuto chvíli neexistuje jiná publikovaná odborná studie zabývající se incidencí avulzního poranění MLA u VBAC rodiček, která současně hodnotí vliv průběhu předchozího porodu, který vedl k císařskému řezu. Z nedávno publikované přehledové práce víme, že incidence avulze MLA po prvním vaginálním porodu je v rozmezí 15–52 % (15 % po spontánním vaginálním porodu, 21 % při použití vakuumextraktoru, 52 % při ukončení porodu *per forcipem*) [12]. Incidence uváděná v obou skupinách VBAC rodiček v naší sekundární analýze spadá do uvedeného rozmezí. Caudwell-Hall et al publikovali rozsáhlou odbornou práci, kde sledovali 609 žen, které porodily vaginálně, a avulzi MLA zjistili u 16 % z nich. Zajímavé bylo zjištění, že císařský řez v rodinné anamnéze (u matky, sestry) patří mezi rizikové faktory avulzního poranění MLA. I z jiné odborné práce vyplývá, že samotný VBAC se zdá být rizikovým faktorem pro vznik avulzního poranění MLA [13]. Poznamenejme ještě, že vyšší incidenci avulzního poranění ve skupině VBAC rodiček nelze vysvětlit vyšší četností operativního ukončení porodu. Z našich dat vyplývá, že šlo pouze o jednotky procent. Tato nízká čísla reflektují českou porodnickou školu, kde je obecně procento operativních porodů velmi nízké, s preferencí vakuumextrakce před forcepsem pro nižší riziko poranění análního sfinkteru a avulze MLA [20].

Naše studie má jistě své limitace. Navzdory tomu, že jsme zahrnuli ženy ze dvou perinatologických center v ČR a že studie probíhala relativně dlouhou dobu, počet žen rodících po předchozím císařském řezu byl omezený. Zároveň několik žen mezitím znovu otěhotnělo nebo porodilo, a proto musely být ze studie vyřazeny. Na základě výsledku výše zmíněné power analýzy bude jistě možné sestavit studii s větší kohortou žen k ověření námi zjištěných výsledků. Další limitací je retrospektivní design studie, neznáme úspěšnost vedení porodu po předchozím císařském řezu. Chybí údaj o počtu porodů, které nakonec skončily iterativním císařským řezem (TOLAC). Obdobně nebylo možné porovnat velikost urogenitálního hiátu u ženy před porodem a po něm.

Mezi silné stránky studie patří metodika použitá při vedení této studie. Analýza nasnímaných volumů dle mezinárodně uznávané metodiky [16] byla prováděna offline dvěma nezávislými expertními sonografisty, bez přístupu k ostatním charakteristikám rodiček a datům o porodu. Zahrnutí více než jednoho centra do studie eliminuje lokální odlišnosti ve vedení porodu a chránění hráze prováděném na konci II. doby porodní.

Závěr

Po zhodnocení našich dat potvrzujeme, že ženy rodící vaginálně po předchozím císařském řezu mají vyšší riziko poranění MLA ve srovnání se ženami při jejich prvním spontánním vaginálním porodu. Z našich dat dále vyplývá, že není statisticky významný rozdíl v incidenci avulzního poranění MLA s ohledem na průběh předchozího porodu před císařským řezem. Vzhledem k malé četnosti žen ve skupinách je ale nutné tato data ověřit ve studii s větší kohortou žen. Ženy po císařském řezu by měly být informovány o riziku poranění svalů pánevního dna při následujícím vaginálním porodu. Po porodu by pak následně měly být vyšetřeny, aby se vhodnou rehabilitací a omezením působení dalších rizikových faktorů mohlo zabránit rozvoji sestupu pánevních orgánů se všemi důsledky.

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Publikační etika: Redakční rada potvrzuje, že rukopis práce splnil ICMJE kritéria pro publikace zasílané do biomedicínských časopisů.

Publication ethics: The Editorial Board declares that the manuscript met the ICMJE uniform requirements for biomedical papers.

Konflikt zájmů: Autoři deklarují, že v souvislosti s předmětem studie/práce nemají žádný konflikt zájmů.

Conflict of interests: The authors declare they have no potential conflicts of interest concerning the drugs, products or services used in the study.

Dedikace: Tato studie vznikla na základě finanční podpory Grantové agentury University Karlovy v Praze (GAUK, projekt č. 918119).

Dedication: This study was created with the financial support of the Grant Agency of Charles University in Prague (GAUK, project no. 918119).

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ORCID autorů

L. Paymová 0000-0002-6112-3624
K. Švabík 0000-0003-1778-2101
V. Kališ 0000-0001-7003-6795
K. M. Ismail 0000-0001-9449-0706
Z. Rušavý 0000-0001-7125-9819

Doručeno/Submitted: 2. 3. 2022
Přijato/Accepted: 4. 4. 2022

MUDr. Lenka Paymová
Gynekologicko-porodnická klinika
LF UK a FN Plzeň
Alej Svobody 80
304 60 Plzeň
paymoval@fnplzen.cz

Příloha 5:

BJOG An International Journal of Obstetrics and Gynaecology

Royal College of Obstetricians & Gynaecologists

DOI: 10.1111/1471-0528.16837
www.bjog.org

Systematic review

Levator ani avulsion: a Systematic evidence review (LASER)

Z Rusavy,[a,b,c] **L Paymova,**[a,c] **M Kozerovsky,**[c] **A Veverkova,**[c] **V Kalis,**[a,b,c] **RA Kamel,**[d] **KM Ismail**[a,b]

[a] Department of Obstetrics and Gynaecology, Faculty of Medicine in Pilsen, Charles University, Pilsen, Czech Republic [b] Biomedical Centre, Faculty of Medicine in Pilsen, Charles University, Pilsen, Czech Republic [c] Department of Obstetrics and Gynaecology, University Hospital, Pilsen, Czech Republic [d] Maternal-Fetal Medicine Unit, Department of Obstetrics and Gynaecology, Cairo University, Cairo, Egypt
Correspondence: KM Ismail, Department of Gynecology and Obstetrics, Faculty of Medicine in Pilsen, Charles University, Alej Svobody 80, 304 60 Pilsen, Czech Republic. Email: khaled.ismail@lfp.cuni.cz

Accepted 10 April 2021.

This article includes Author Insights, a video abstract available at: https://vimeo.com/bjog/authorinsights16837

Background There is variation in the reported incidence rates of levator avulsion (LA) and paucity of research into its risk factors.

Objective To explore the incidence rate of LA by mode of birth, imaging modality, timing of diagnosis and laterality of avulsion.

Search strategy We searched MEDLINE, EMBASE, CINAHL, AMED and MIDIRS with no language restriction from inception to April 2019.

Study eligibility criteria A study was included if LA was assessed by an imaging modality after the first vaginal birth or caesarean section. Case series and reports were not included.

Data collection and analysis RevMan v5.3 was used for the meta-analyses and SW SAS and STATISTICA packages were used for type and timing of imaging analyses.

Results We included 37 primary non-randomised studies from 17 countries and involving 5594 women. Incidence rates of LA were 1, 15, 21, 38.5 and 52% following caesarean, spontaneous, vacuum, spatula and forceps births, respectively, with no differences by imaging modality. Odds ratio of LA following spontaneous birth versus caesarean section was 10.69. The odds ratios for LA following vacuum and forceps compared with spontaneous birth were 1.66 and 6.32, respectively. LA was more likely to occur unilaterally than bilaterally following spontaneous ($P < 0.0001$) and vacuum-assisted ($P = 0.0103$) births but not forceps. Incidence was higher if assessment was performed in the first 4 weeks postpartum.

Conclusions LA incidence rates following caesarean, spontaneous, vacuum and forceps deliveries were 1, 15, 21 and 52%, respectively. Ultrasound and magnetic resonance imaging were comparable tools for LA diagnosis.

Keywords Assisted birth, birth, caesarean, forceps, hiatus, labour, magnetic resonance imaging, operative, parturition, pelvic floor, perineum, prolapse, transperineal, ultrasound, vacuum, ventouse.

Tweetable abstract Levator avulsion incidence rates after caesarean, spontaneous, vacuum and forceps deliveries were 1, 15, 21 and 52%, respectively.

Please cite this paper as: Rusavy Z, Paymova L, Kozerovsky M, Veverkova A, Kalis V, Kamel RA, Ismail KM. Levator ani avulsion: a Systematic evidence review (LASER). BJOG 2021; https://doi.org/10.1111/1471-0528.16837.

Introduction

Gainey was probably the first to document a possible association between vaginal birth and levator ani muscle abnormalities in living women in 1943.[1] However, DeLancey and associates were the first to demonstrate this on magnetic resonance imaging (MRI).[2] Levator ani trauma plays a key role in the pathophysiology of pelvic organ prolapse. Indeed, the associated urogenital hiatus ballooning leads to a four-fold higher risk of pelvic organ prolapse development in women after obstetric levator avulsion (LA).[3] Furthermore, it is an important risk factor for cystocele recurrence after urogynaecological reconstructive surgery.[4–6]

Palpation of the site of insertion of the levator ani muscle[1] or assessment of ballooning of the levator hiatus using pelvic

Prospero registration: CRD42019120206
Presentation: Not presented at the time of submission

organ prolapse quantification system parameters[7] have been suggested as methods of assessing the levator ani muscle; however, the diagnostic accuracy of these methods is dependent on the skill of the examiner and natural variation in anatomy can pose some limitations. Hence, diagnosis relies on imaging modalities mainly in the form of three-dimensional/four-dimensional (3D/4D) ultrasonography or MRI.[8–11]

There has been a variation in the description of levator ani muscle injuries depending on the diagnostic imaging modality. Using MRI, a muscle injury grading system ranging from 0, no injury, to 3, complete loss of the pubococcygeal portion, was proposed; based on the overall score for both sides, the trauma is classified into minor or major defects.[12] However, the term 'levator avulsion', was coined by Dietz and Lanzarone to describe the loss of continuity between the levator ani muscle and the pelvic sidewall.[13] This was further defined on tomographic ultrasound,[14] a method that is now internationally standardised.[15]

There is wide variation in the reported incidence rates of LA following the first childbirth, which could be due to several factors. Furthermore, there are no set standards for the optimal postnatal time to assess the levator ani muscle. The aim of this systematic review was to assess the current published literature with regards to the reported incidence rate of LA by mode of birth, imaging modality and the timing of diagnosis. Finally, because of our interest in the biomechanical factors involved in avulsion, we wanted to explore if there were any differences in LA laterality and mode of birth.

Methods

Eligibility criteria, information sources and search strategy

A protocol using widely recommended methods for systematic reviews of observational studies was developed and pre-registered with PROSPERO (CRD42019120206) and the PRISMA statement and checklist were followed throughout the review preparation, conduct and reporting. Patients were not involved in the development of this review and we did not use any particular core outcome set.

MEDLINE, EMBASE, CINAHL, AMED and Maternity and Infant Care (MIDIRS) databases were searched electronically from inception to April 2019. A combination of medical subject headings (MeSHs), encompassing different modes of birth and LA, keywords, and word variants using Boolean operators 'OR' and 'AND' to capture relevant text citations were used (for search strategy, see Table S1). We included all study designs in our search, with the exception of case series and case reports, No language restrictions were applied, but the search was limited to human studies. A database of all citations' abstracts was compiled.

Study selection

Studies were selected in a three-stage process. First, two independent reviewers (LP and AV) screened titles and abstracts of potential articles identified by our search using the RAYYAN software package[16] and the full selected articles were obtained. Second, two independent reviewers (LP and MK) assessed each of the selected articles against predesigned inclusion/exclusion criteria. A study was included only if LA was assessed by an imaging modality and it reported data on LA in primiparous women following a first vaginal birth (spontaneous or operative) or those delivered by caesarean section (CS). Case–control studies, where recruitment was based on presence or absence of LA, and studies not presenting LA by mode of birth were excluded from our review. Finally, reference lists of included articles were manually searched to identify relevant papers not captured by electronic searches.

Data extraction and synthesis

Data were extracted on study design, participants' characteristics, mode of birth, type(s) of imaging used, timing of imaging in relation to birth, laterality of avulsion and the diagnostic criteria used for diagnosis. LP and MK extracted data independently in duplicates. Extracted information was logged in an excel spreadsheet.

Any discrepancies in the study selection or extracted information were reviewed by VK, ZR and KI for a final decision.

RevMan v5.3 was used for the meta-analyses, which were performed if data from two or more eligible studies were available.[17] The number of positive events and the total number of potential events were analysed and summarised with the resulting incidence rate and its 95% CI. Meta-analytical estimates of the overall incidence rate (point estimate and 95% CI) were obtained by fitting random-effects models because of the high likelihood of clinical and statistical heterogeneity; the inverse variance method with Log-transformation of the incidence rate was used. For these analyses the event mean and 95% CI were used to calculate the standard error of the mean using the calculator facility in RevMan. If the 95% CI was not provided in the study, then it was calculated based on a Gaussian approximation. Binomial approximation (exact confidence limits calculation) was used for smaller n and smaller or greater P. For odds ratios (OR) comparisons, only the studies that reported on both of the compared modes of birth contributed to the analysis and these were calculated using the Cochran–Mantel–Haenszel approach. The I^2 statistic was used as a measure of statistical heterogeneity, where the cut-offs for low and high heterogeneity were considered to be <25 and >75%, respectively.[18,19] The Gaussian approximation calculation of the standard error of the mean and the comparisons for the type of imaging modality, timing of imaging and laterality of LA were performed using SW SAS (SAS Institute Inc., Cary, NC, USA) and STATISTICA (StatSoft Inc., Tulsa, OK, USA). A P value <0.05 was used as a cut-off for statistical significance.

Assessment of risk of bias

Data were extracted regarding study design, target population, participant selection process, participant characteristics and statistical methodology. Two independent reviewers (RK and KI) used the Joanna Briggs Institute Prevalence Critical Appraisal Tool (Table S2) to assess the risk of bias and quality of included studies.[20] Quality assessment was then used to assess the methodological adequacies of the included studies and assist with interpretation of the systematic review findings and potential bias resultant from study heterogeneity.

Results

Study selection and study characteristics

The literature search for this review was conducted on 25 April 2019 following an a priori set strategy (Table S1). It identified 363 citations, from which 57 full articles were selected for detailed review. Reference lists review of the selected articles did not identify any further articles for consideration. Of the 57 selected articles, 20 did not meet our inclusion criteria and were excluded from further analysis (Table S3). A total of 37 primary non-randomised studies from 17 countries and involving 5594 women were included in our systematic review (Figure 1, Tables S4, S5).[9,13,21–55] All studies were reported in English with the exception of one study, which was in Czech, and hence the authors undertook the translation.

Risk of bias of included studies

None of the included studies fulfilled all ten quality assessment criteria. Eight studies (20.5%) fulfilled nine of the ten criteria. Twenty-one (53.8%) and seven (17.9%) studies satisfied eight and seven of the ten criteria, respectively. The remaining three studies (7.7%) fulfilled at least five out of the ten assessment parameters (Table S6). No studies were excluded from the systematic review for failure to fulfil the quality criteria. The risk of publication bias for pooled data was assessed by funnel plots (Figures S1–S5).

Synthesis of results

Incidence rate of LA by mode of birth irrespective of imaging modality

For studies that have assessed LA at multiple postpartum time-points, we used the last reported time-point for this analysis.

Levator avulsion and CS

A total of 23 studies involving 1207 women who were only delivered by CS contributed data for this outcome.[9,13,21–25,27,28,31–33,35,39–44,49,51,53,54] All the studies reported no LAs with the exception of Araujo et al.,[43] Guedea et al.[32] and Aydin et al.,[35] who reported LA incidence rates of 14, 5 and 40%, respectively. A meta-analysis of all 23 studies showed an overall incidence rate of 0.03 (3%) (0.00–0.05, I^2 = 66%). The incidence rate reported by Aydin et al.[35] was deemed an outlier compared with the rest of the results and removal of this study from the analysis reduced I^2 from 66% to zero; hence a decision was made to exclude this study from further analyses because of its effect on the degree of statistical heterogeneity. Meta-analysis of the remaining 22 studies, involving 1120 women, showed a pooled incidence rate of 0.01 (1%) (0.00–0.02, I^2 = 0%) for LA in women delivered by CS (Figure 2, Figure S1).

Levator avulsion and first spontaneous vaginal delivery

We identified 23 studies involving a total of 2152 women that assessed LA following the first spontaneous vaginal birth.[9,21,24,28,29,31–34,37,39,41,43–48,50–53,55] The pooled incidence rate of LA in these studies was 0.16 (16%) (0.13–0.19, I^2 = 73%). The highest incidence rate of LA of 0.58 (58%) was reported by Araujo et al.,[43] which was much higher than the rates reported by other studies. Excluding this study reduced the degree of heterogeneity, as measured by I^2 from 73 to 66%. Excluding this study from the analysis resulted in an overall LA incidence rate following a spontaneous birth of 0.15 (15%) (0.12–0.18; Figure 2, Figure S1).

Levator avulsion and vacuum extraction in the first vaginal delivery

Thirteen studies including 796 women contributed to this analysis.[9,21,24,29–32,34,39,41,46,47,52] The pooled incidence rate for LA following vacuum extraction was 0.21 (21%) (0.16–0.27, I^2 = 68%; Figure 2, Figure S1).

Levator avulsion and forceps in the first vaginal delivery

A total of 469 women from 13 studies contributed to this analysis.[9,21,24,28–31,33,36,39,41,43,52] The overall incidence rate of LA following the first vaginal birth by forceps was 0.52 (52%) (0.44–0.61, I^2 = 66%; Figure 2, Figure S1).

There was only one study that reported on LA and the use of a spatula in the first vaginal delivery. In their study, Guedea et al reported that five of the 13 women delivered by spatula (38.5%) were diagnosed with LA postnatally.[32]

Odds ratios of LA by mode of birth irrespective of imaging modality

It was decided a priori that odds ratios would be calculated for the following clinically meaningful comparisons; spontaneous delivery versus CS, vacuum versus spontaneous

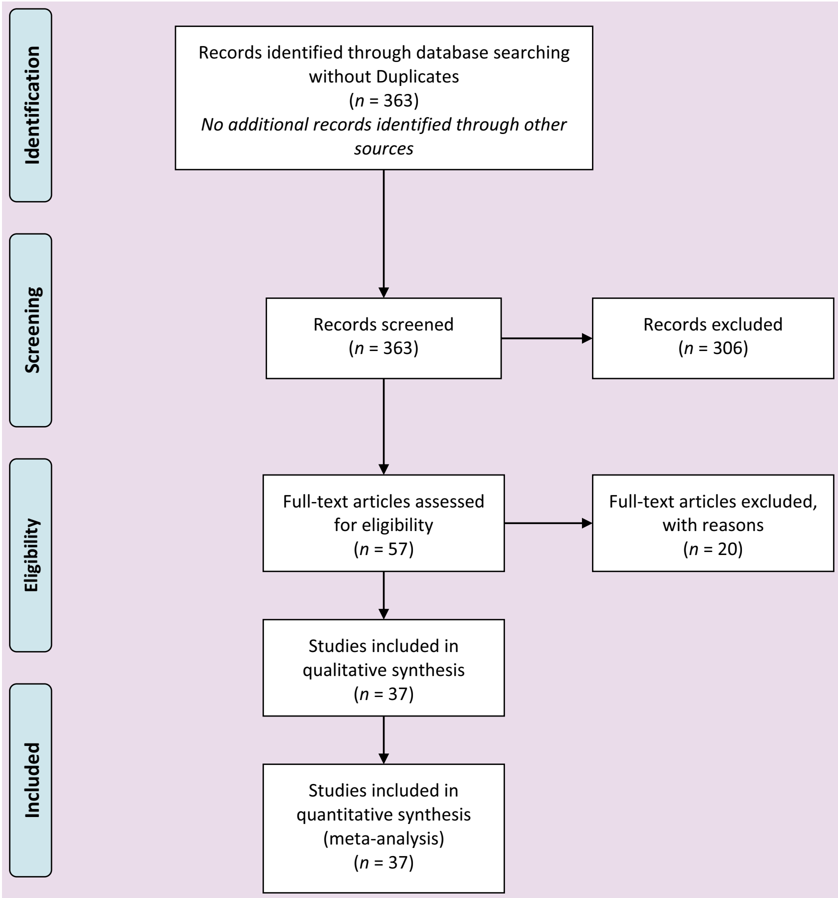


Figure 1. PRISMA flow diagram.

delivery, forceps versus spontaneous delivery and forceps versus vacuum. For this analysis, only studies that reported on the two compared modalities were included. A total of 12 studies involving 1570 women reported on LA following spontaneous delivery and CS at first birth.[9,21,24,28,31–33,39,41,44,51,53] The calculated odds ratio for having an LA following a spontaneous delivery compared with CS was 10.69 (5.44–21.0, I^2 = 0%) (Figure 3, Figure S2). The odds ratio of an LA following vacuum compared with spontaneous delivery was 1.66 (0.99–2.79, I^2 = 62%). This was based on 12 studies reporting on a total of 1783 births (Figure 3, Figure S3).[9,21,24,29,31,32,34,39,41,46,47,52] Whereas that following forceps versus spontaneous delivery was 6.32 (4.56–8.76, I^2 = 0%) (Figure 3, Figure S4) as assessed by ten studies involving 1372 women.[9,21,24,28,29,31,33,41,51,52] For this analysis we did not include the study by Thibault-Gagnon et al.[39] because removing this study from the analysis reduced the I^2 from 47 to 0% without much change in the OR (5.68 [3.49–9.22]). LA following forceps compared with vacuum extraction at the first vaginal birth was reported by nine studies and the pooled odds ratio was 4.09 (2.87–5.84, I = 0%) (Figure 3, Figure S5).[9,21,24,29–31,39,41,52]

Incidence rate of LA by imaging modality

Of the 37 included studies, five (13.5%), involving 249 births, used MRI,[23,25,27,52,55] whereas the rest used ultrasound for diagnosis. For this analysis we did not include the studies by Aydin et al.[35] and Araujo et al.[43] because of their impact on statistical heterogeneity. The comparisons for the rates of LA following different modes of birth by imaging modality are presented in Table 1. None of these comparisons reached statistical significance. The difference remained non-significant when all the studies were included in the analysis.

Laterality of LA by mode of birth

The assessment as to whether a unilateral LA was on the right or the left side was assessed by three,[28,37,46] two[30,46] and three[28,30,36] studies following spontaneous, vacuum and forceps deliveries, respectively. Assessment regarding the LA being unilateral or bilateral was reported by

Study or Subgroup	Incidence	SE	Total	Total	Weight	Incidence IV, Random, 95% CI
1.1.1 Caesarean section						
51 Araujo Jn et al. (2013)	0	0.1574	10	0	0.1%	0.00 [−0.31, 0.31]
13 Dietz & Lanzarone (2005)	0	0.1454	11	0	0.1%	0.00 [−0.28, 0.28]
42 Valsky et al. (2009)	0	0.1112	15	0	0.2%	0.00 [−0.22, 0.22]
21 Abdool et al. (2018)	0	0.102	24	0	0.3%	0.00 [−0.20, 0.20]
44 Kamisan Atan et al. (2018)	0	0.0945	18	0	0.3%	0.00 [−0.19, 0.19]
28 Cassado Garriga et al. (2011)	0	0.0859	20	0	0.4%	0.00 [−0.17, 0.17]
43 Araujo et al. (2018)	0.14285714	0.07636036	21	3	0.5%	0.14 [−0.01, 0.29]
54 Marsoosi et al. (2015)	0	0.07	25	0	0.6%	0.00 [−0.14, 0.14]
25 Heilbrun et al. (2010)	0	0.0609	29	0	0.7%	0.00 [−0.12, 0.12]
27 Novellas et al. (2010)	0	0.059	30	0	0.8%	0.00 [−0.12, 0.12]
32 Guedea et al. (2015)	0.05882353	0.05706721	17	1	0.9%	0.06 [−0.05, 0.17]
23 Brandon et al. (2012)	0.05	0.04873397	20	1	1.2%	0.05 [−0.05, 0.15]
40 Volloyhaug et al. (2017)	0	0.0402	45	0	1.7%	0.00 [−0.08, 0.08]
53 Liu et al. (2014)	0	0.0378	48	0	1.9%	0.00 [−0.07, 0.07]
09 van Delft et al. (2014)	0	0.0378	48	0	1.9%	0.00 [−0.07, 0.07]
33 Cassado Garriga et al. (2011)	0	0.0304	60	0	3.0%	0.00 [−0.06, 0.06]
31 Albrich et al. (2012)	0.05263158	0.02561391	76	4	4.2%	0.05 [0.00, 0.10]
49 Chan et al. (2014)	0	0.0242	76	0	4.7%	0.00 [−0.05, 0.05]
24 Volloyhaug et al. (2015)	0	0.0183	101	0	8.3%	0.00 [−0.04, 0.04]
39 Thibault-Gagnon et al. (2014)	0.01538462	0.01526581	65	1	11.9%	0.02 [−0.01, 0.05]
41 Shek & Dietz (2010)	0	0.0147	126	0	12.8%	0.00 [−0.03, 0.03]
22 Caudwell-Hall et al. (2017)	0	0.008	235	0	43.4%	0.00 [−0.02, 0.02]
Subtotal (95% CI)			**1120**	**10**	**100.0%**	**0.01 [−0.00, 0.02]**
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 9.63$, df = 21 ($P = 0.98$); $I^2 = 0\%$						
Test for overall effect: $Z = 1.11$ ($P = 0.27$)						
1.1.2 Spontaneous delivery						
55 Shi et al. (2016)	0.4	0.1549	10	4	0.7%	0.40 [0.10, 0.70]
32 Guedea et al. (2015)	0	0.1454	11	0	0.8%	0.00 [−0.28, 0.28]
44 Kamisan Atan et al. (2018)	0.2593	0.0843	27	7	2.1%	0.26 [0.09, 0.42]
33 Cassado Garriga et al. (2011)	0.15	0.0798	20	3	2.2%	0.15 [−0.01, 0.31]
51 Araujo Jn et al. (2013)	0.0625	0.0605	16	1	3.2%	0.06 [−0.06, 0.18]
31 Albrich et al. (2012)	0.3857	0.0582	70	21	3.4%	0.39 [0.27, 0.50]
53 Liu et al. (2014)	0.1702	0.0548	47	8	3.6%	0.17 [0.06, 0.28]
45 Aydin et al. (2015)	0.369	0.0527	84	31	3.8%	0.37 [0.27, 0.47]
21 Abdool et al. (2018)	0.1176	0.0451	51	6	4.4%	0.12 [0.03, 0.21]
28 Cassado Garriga et al. (2011)	0.1333	0.0439	60	8	4.5%	0.13 [0.05, 0.22]
34 Garcia-Mejido et al. (2017)	0.098	0.0416	51	5	4.7%	0.10 [0.02, 0.18]
48 Garcia-Mejido et al. (2016)	0.1216	0.038	74	9	5.1%	0.12 [0.05, 0.20]
46 Garcia-Mejido et al. (2017)	0.0959	0.0345	73	7	5.4%	0.10 [0.03, 0.16]
47 Michalec et al. (2016)	0.0978	0.031	92	9	5.8%	0.10 [0.04, 0.16]
09 van Delft et al. (2014)	0.0978	0.031	92	9	5.8%	0.10 [0.04, 0.16]
52 Kearney et al. (2006)	0.1154	0.028	130	15	6.1%	0.12 [0.06, 0.17]
39 Thibault-Gagnon et al. (2014)	0.1438	0.0277	160	23	6.1%	0.14 [0.09, 0.20]
29 Chan et al. (2012)	0.1542	0.0255	201	31	6.3%	0.15 [0.10, 0.20]
50 Youssef et al. (2019)	0.2137	0.0253	262	56	6.4%	0.21 [0.16, 0.26]
37 Cassado Garriga et al. (2014)	0.1289	0.0241	194	25	6.5%	0.13 [0.08, 0.18]
41 Shek & Dietz (2010)	0.1183	0.0237	186	22	6.5%	0.12 [0.07, 0.16]
24 Volloyhaug et al. (2015)	0.1336	0.0231	217	29	6.6%	0.13 [0.09, 0.18]
Subtotal (95% CI)			**2128**	**329**	**100.0%**	**0.15 [0.12, 0.18]**
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 61.94$, df = 21 ($P < 0.00001$); $I^2 = 66\%$						
Test for overall effect: $Z = 10.63$ ($P < 0.00001$)						
1.1.3 Vacuum extraction						
21 Abdool et al. (2018)	0.25	0.2165	4	1	1.5%	0.25 [−0.17, 0.67]
31 Albrich et al. (2012)	0.4	0.1549	10	4	2.6%	0.40 [0.10, 0.70]
32 Guedea et al. (2015)	0.5	0.1336	14	7	3.3%	0.50 [0.24, 0.76]
52 Kearney et al. (2006)	0.1667	0.1076	12	2	4.5%	0.17 [−0.04, 0.38]
29 Chan et al. (2012)	0.333	0.068	48	16	7.6%	0.33 [0.20, 0.47]
34 Garcia-Mejido et al. (2017)	0.3519	0.065	54	19	8.0%	0.35 [0.22, 0.48]
09 van Delft et al. (2014)	0.1333	0.0621	30	4	8.3%	0.13 [0.01, 0.26]
39 Thibault-Gagnon et al. (2014)	0.1915	0.0574	47	9	8.8%	0.19 [0.08, 0.30]
46 Garcia-Mejido et al. (2017)	0.3425	0.0555	73	25	9.0%	0.34 [0.23, 0.45]
41 Shek & Dietz (2010)	0.0882	0.0486	34	3	9.9%	0.09 [−0.01, 0.18]
47 Michalec et al. (2016)	0.1196	0.0338	92	11	11.7%	0.12 [0.05, 0.19]
24 Volloyhaug et al. (2015)	0.145	0.0308	131	19	12.0%	0.14 [0.08, 0.21]
30 Chung et al. (2015)	0.166	0.0237	247	41	12.8%	0.17 [0.12, 0.21]
Subtotal (95% CI)			**796**	**161**	**100.0%**	**0.21 [0.16, 0.27]**
Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 37.50$, df = 12 ($P = 0.0002$); $I^2 = 68\%$						
Test for overall effect: $Z = 7.64$ ($P < 0.00001$)						
1.1.4 Forceps delivery						
31 Albrich et al. (2012)	1	0.4975	1	1	0.8%	1.00 [0.02, 1.98]
21 Abdool et al. (2018)	0.4	0.21908902	5	2	3.2%	0.40 [−0.03, 0.83]
51 Araujo Jn et al. (2013)	0.222	0.1385799	9	2	5.9%	0.22 [−0.05, 0.49]
29 Chan et al. (2012)	0.71428571	0.12073632	14	10	6.9%	0.71 [0.48, 0.95]
52 Kearney et al. (2006)	0.66666667	0.11111111	18	12	7.5%	0.67 [0.45, 0.88]
09 van Delft et al. (2014)	0.47619048	0.10898517	21	10	7.6%	0.48 [0.26, 0.69]
41 Shek & Dietz (2010)	0.35	0.10665365	20	7	7.7%	0.35 [0.14, 0.56]
33 Cassado Garriga et al. (2011)	0.45454545	0.10615895	22	10	7.8%	0.45 [0.25, 0.66]
39 Thibault-Gagnon et al. (2014)	0.40909091	0.10482356	22	9	7.9%	0.41 [0.20, 0.61]
30 Chung et al. (2015)	0.71428571	0.07573917	42	17	9.9%	0.71 [0.57, 0.86]
28 Cassado Garriga et al. (2011)	0.61666667	0.06276794	60	37	10.9%	0.62 [0.49, 0.74]
36 Krofta et al. (2009)	0.63157895	0.05533237	76	48	11.5%	0.63 [0.52, 0.74]
24 Volloyhaug et al. (2015)	0.40880503	0.03898746	159	65	12.6%	0.41 [0.33, 0.49]
Subtotal (95% CI)			**469**	**230**	**100.0%**	**0.52 [0.44, 0.61]**
Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 35.53$, df = 12 ($P = 0.0004$); $I^2 = 66\%$						
Test for overall effect: $Z = 11.78$ ($P < 0.00001$)						

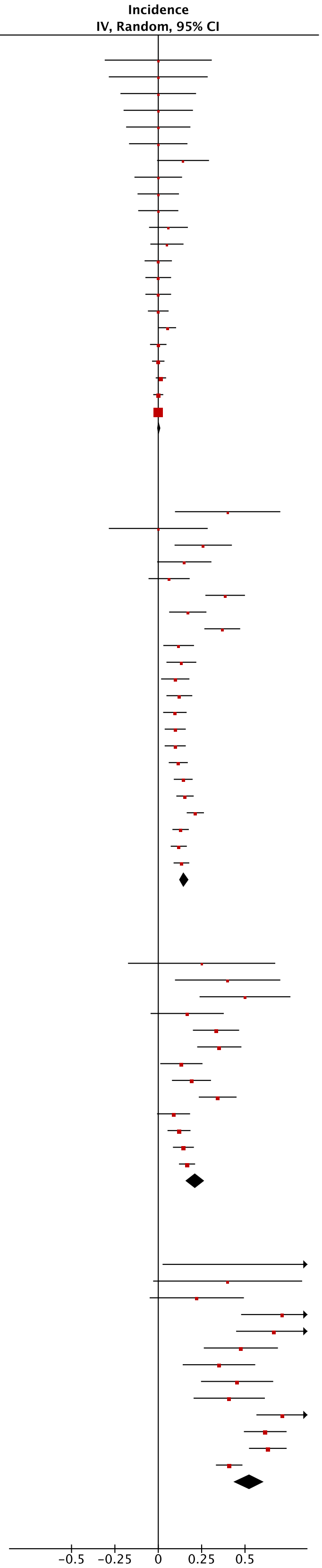
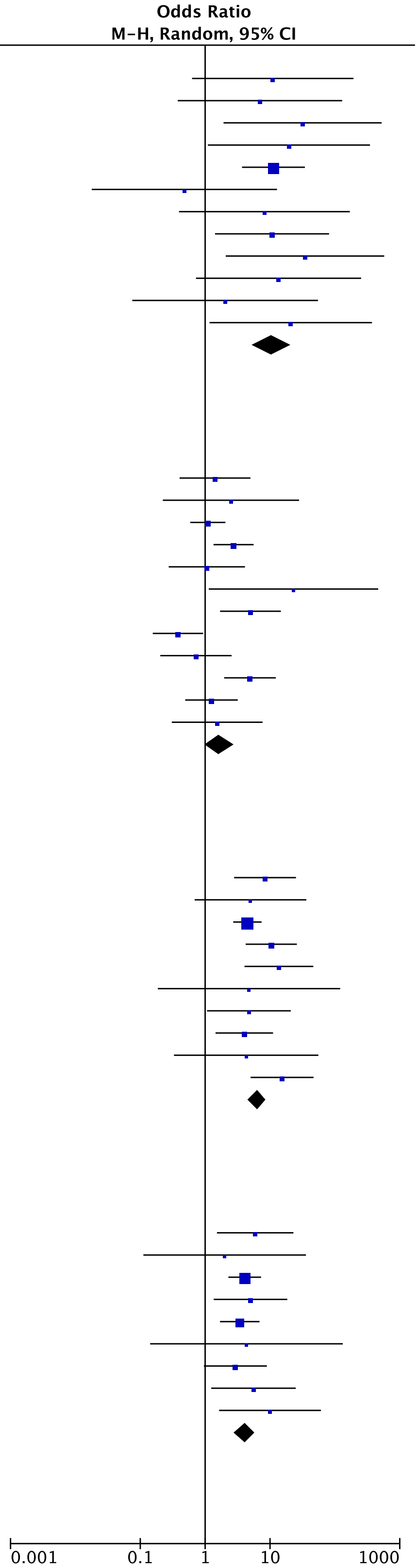


Figure 2. Incidence rate of levator avulsion by mode of birth.

Study or Subgroup	Events	Total	Events	Total	Weight	Odds Ratio M-H, Random, 95% CI
4.1.1 Spontaneous vs. Caesarean delivery						
09 van Delft et al. (2014)	9	92	0	48	5.6%	11.04 [0.63, 193.81]
21 Abdool et al. (2018)	6	51	0	24	5.4%	7.00 [0.38, 129.54]
24 Volloyhaug et al. (2015)	29	217	0	101	5.8%	31.77 [1.92, 525.36]
28 Cassado Garriga et al. (2011)	8	60	0	60	5.5%	19.59 [1.10, 347.61]
31 Albrich et al. (2012)	27	70	4	76	36.7%	11.30 [3.70, 34.50]
32 Guedea et al. (2015)	0	11	1	17	4.2%	0.48 [0.02, 12.81]
33 Cassado Garriga et al. (2011)	3	20	0	20	5.0%	8.20 [0.40, 169.90]
39 Thibault-Gagnon et al. (2014)	23	160	1	65	11.1%	10.74 [1.42, 81.32]
41 Shek & Dietz (2010)	22	186	0	126	5.8%	34.60 [2.08, 575.94]
44 Kamisan Atan et al. (2018)	7	27	0	18	5.3%	13.54 [0.72, 253.74]
51 Araujo Jn et al. (2013)	1	16	0	10	4.2%	2.03 [0.08, 54.83]
53 Liu et al. (2014)	8	47	0	48	5.5%	20.87 [1.17, 372.94]
Subtotal (95% CI)		**957**		**613**	**100.0%**	**10.69 [5.44, 21.00]**
Total events	143		6			
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 6.37$, df = 11 ($P = 0.85$); $I^2 = 0\%$						
Test for overall effect: $Z = 6.87$ ($P < 0.00001$)						
4.1.2 Vacuum vs. Spontaneous delivery						
09 van Delft et al. (2014)	4	30	9	92	8.0%	1.42 [0.40, 4.99]
21 Abdool et al. (2018)	1	4	6	51	3.5%	2.50 [0.22, 28.06]
24 Volloyhaug et al. (2015)	19	131	29	217	12.4%	1.10 [0.59, 2.05]
29 Chan et al. (2012)	16	48	31	201	11.8%	2.74 [1.35, 5.59]
31 Albrich et al. (2012)	4	10	27	70	7.5%	1.06 [0.27, 4.11]
32 Guedea et al. (2015)	7	14	0	11	2.5%	23.00 [1.14, 465.16]
34 Garcia-Mejido et al. (2017)	19	54	5	51	9.2%	4.99 [1.70, 14.69]
39 Thibault-Gagnon et al. (2014)	9	47	23	60	10.5%	0.38 [0.16, 0.93]
41 Shek & Dietz (2010)	3	34	22	186	8.0%	0.72 [0.20, 2.56]
46 Garcia-Mejido et al. (2017)	25	73	7	73	10.3%	4.91 [1.96, 12.28]
47 Michalec et al. (2016)	11	92	9	92	10.2%	1.25 [0.49, 3.18]
52 Kearney et al. (2006)	2	12	15	130	6.2%	1.53 [0.31, 7.68]
Subtotal (95% CI)		**549**		**1234**	**100.0%**	**1.66 [0.99, 2.79]**
Total events	120		183			
Heterogeneity: $Tau^2 = 0.47$; $Chi^2 = 28.86$, df = 11 ($P = 0.002$); $I^2 = 62\%$						
Test for overall effect: $Z = 1.91$ ($P = 0.06$)						
4.1.3 Forceps vs. Spontaneous delivery						
09 van Delft et al. (2014)	10	21	9	92	8.8%	8.38 [2.80, 25.15]
21 Abdool et al. (2018)	2	5	6	51	2.7%	5.00 [0.69, 36.27]
24 Volloyhaug et al. (2015)	65	159	29	217	42.2%	4.48 [2.71, 7.41]
28 Cassado Garriga et al. (2011)	37	60	8	60	12.9%	10.46 [4.22, 25.93]
29 Chan et al. (2012)	10	14	31	201	7.1%	13.71 [4.04, 46.49]
31 Albrich et al. (2012)	1	1	27	70	1.0%	4.75 [0.19, 120.69]
33 Cassado Garriga et al. (2011)	10	22	3	20	4.8%	4.72 [1.07, 20.89]
41 Shek & Dietz (2010)	7	20	22	186	10.2%	4.01 [1.45, 11.14]
51 Araujo Jn et al. (2013)	2	9	1	16	1.6%	4.29 [0.33, 55.59]
52 Kearney et al. (2006)	12	18	15	130	8.5%	15.33 [5.01, 46.90]
Subtotal (95% CI)		**329**		**1043**	**100.0%**	**6.32 [4.56, 8.76]**
Total events	156		151			
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 8.27$, df = 9 ($P = 0.51$); $I^2 = 0\%$						
Test for overall effect: $Z = 11.07$ ($P < 0.00001$)						
4.1.4 Forceps vs. Vacuum delivery						
09 van Delft et al. (2014)	10	21	4	30	6.9%	5.91 [1.52, 22.95]
21 Abdool et al. (2018)	2	5	1	4	1.5%	2.00 [0.11, 35.81]
24 Volloyhaug et al. (2015)	65	159	19	131	37.7%	4.08 [2.28, 7.28]
29 Chan et al. (2012)	10	14	16	48	7.4%	5.00 [1.36, 18.45]
30 Chung et al. (2015)	17	42	41	247	25.8%	3.42 [1.69, 6.89]
31 Albrich et al. (2012)	1	1	4	10	1.1%	4.33 [0.14, 132.32]
39 Thibault-Gagnon et al. (2014)	9	22	9	47	10.1%	2.92 [0.96, 8.94]
41 Shek & Dietz (2010)	7	20	3	34	5.6%	5.56 [1.24, 24.93]
52 Kearney et al. (2006)	12	18	2	12	3.9%	10.00 [1.64, 60.92]
Subtotal (95% CI)		**302**		**563**	**100.0%**	**4.09 [2.87, 5.84]**
Total events	133		99			
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 2.32$, df = 8 ($P = 0.97$); $I^2 = 0\%$						
Test for overall effect: $Z = 7.76$ ($P < 0.00001$)						



Test for subgroup differences: $Chi^2 = 24.77$, df = 3 ($P < 0.0001$), $I^2 = 87.9\%$

Figure 3. Comparison of risk of levator avulsion between different modes of birth.

Table 1. Levator avulsion rates by imaging modality, laterality and timing of diagnosis

Comparison	Only CS		Spontaneous delivery		Vacuum extraction		Forceps delivery	
	Rate	***P***	**Rate**	***P***	**Rate**	***P***	**Rate**	***P***
Imaging modality								
Ultrasound	9/1041 (0.9%)	0.5203**	316/1988 (15.9%)	0.4655*	159/784 (20.3%)	0.7571**	213/436 (48.9%)	0.1385*
MRI	1/79 (1.3%)		19/140 (13.6%)		2/12 (16.7%)		12/18 (66.7%)	
Laterality								
Left LA			10/327 (3.06%)	0.0202*	30/320 (9.38%)	0.3661*	28/178 15.73%)	0.4819*
Right LA			23/327 (7.03%)		37/320 (11.56%)		33/178 (18.54%)	
Unilateral LA			69/767 (3.91%)	<.0001*	60/543 (11.05%)	0.0103*	90/337 (26.71%)	0.3283*
Bilateral LA			30/767 (9.0%)		36/543 (6.63%)		79/337 (23.44%)	
Timing of imaging after birth								
0–1 month	5/224 (2.2%)	0.4802**	98/237 (41.4%)	<.0001*	4/10 (40%)	0.2268**	17/30 (56.7%)	0.1096*
>1–3 months	1/204 (0.5%)	0.6347**	52/363 (14.3%)	0.7293*	61/325 (18.8)	0.6268*	74/137 (54%)	0.0240*
>3–6 months	1/461 (0.2%)	0.1371**	138/743 (18.6%)	0.0190*	13/85 (15.3%)	0.3064*	18/47 (38.3%)	0.7511*
>6–12 months	1/66 (1.5%)	1.0000**	43/400 (10.8%)	0.2141*	45/191 (23.6%)	0.4803*	70/116 (60.3%)	0.0014*
>12 months	3/261 (1.2%)	Ref.	66/489 (13.5%)	Ref.	38/185 (20.5%)	Ref.	65/159 (40.9%)	Ref.

*Chi-square test.
**Fisher's exact test.

eight studies following spontaneous,[24,28,37,46–48,53,55] four studies following vacuum[24,30,46,47] and four studies after forceps[24,28,30,36] deliveries. The rate of right LA following spontaneous delivery was higher compared with left LA and this difference reached statistical significance ($P = 0.0202$). Furthermore, the rate of unilateral LA was significantly higher than bilateral LA following spontaneous ($P < 0.0001$) and vacuum ($P = 0.0103$) deliveries. All the other comparisons relating to laterality of avulsion and mode of birth did not reach statistical significance (Table 1).

Incidence rate of LA depending on timing of imaging after birth

Similar to the incidence rate of LA by imaging modality we did not include the Aydin et al.[35] and Araujo et al.[43] studies because of their effect on statistical heterogeneity. A total of eight,[27,31,33,42,45,51,53,54] six,[9,23,28–30,55] eight,[13,21,22,38,39,41,45,50] nine[25,26,32,33,36,46–48,52] and six[24,34,37,40,44,56] studies reported performing their imaging modality to assess LA at 0–1, >1–3, >3–6, >6–12 and >12 months after birth. respectively. Two of the included studies reported LA avulsion rates at two time-points each.[28,45] Using LA rate at >12 months as the reference standard there was a trend to higher reported LA rates at 0–1 month for all birth modalities. However, this reached statistical significance for spontaneous vaginal delivery only ($P < 0.0001$). There was also a statistically significant difference in the reported LA rate after spontaneous and forceps deliveries at >3–6 months ($P = 0.0190$) and >6–12 months ($P = 0.0014$) when compared with reported LA for the same mode of birth at >12 months, respectively (Table 1 and Figure S6).

When all the studies were included, the LA avulsion rate was significantly higher at 0–1 months in the CS group ($P < 0.0001$) and at >6–12 months ($P = 0.0334$) in the spontaneous birth group compared with the rate >12 months after the birth. The reported LA avulsion rate at >3–6 months following spontaneous birth was not significantly different from that reported at >12 months.

Discussion

Main findings

We calculated the pooled incidence rate of LA following CS, spontaneous, vacuum extraction and forceps-assisted births to be 1, 15, 21 and 52%, respectively. The odds ratio of having an LA following a spontaneous delivery compared with CS was 11. The risk of having an LA if a vacuum was used to assist the first vaginal birth was not significantly different from that for a spontaneous birth while the odds ratio of LA if forceps was used to assist the first birth was 6 compared with spontaneous delivery. LA was more likely to occur on the right-hand side following a spontaneous birth ($P = 0.0202$). Furthermore, unilateral compared with bilateral LA was significantly more likely to occur following spontaneous and vacuum-assisted births ($P < 0.0001$ and $P = 0.0103$, respectively). We did not identify statistically significant differences in the pooled incidence rates of LA following different modes of birth by imaging modality. Finally, there was a trend to higher reported LA rates when assessment was performed in the first 4 weeks postnatally compared with later dates. However, this reached statistical significance for spontaneous delivery only ($P < 0.0001$).

Strengths and limitations

The main strength of our systematic review lies in the methodology we followed. Our search strategy and study selection criteria were set a priori. Furthermore, decisions about study inclusion and data extraction were all performed in duplicates by two independent reviewers. However, we appreciate that there are some limitations to our review that might have introduced bias into our findings. There was evidence of moderate to high degrees of heterogeneity between studies in some of our analyses. This might be a reflection of variation in obstetric practices between the studies, but also could be due to differences in the degree of expertise between practitioners diagnosing the LA. Second, some of the studies included in our review were small observational studies and some fulfilled only half of the quality assessment criteria and, hence, were at high risk of bias. Nevertheless, we did not exclude any studies based on their quality assessment because we wanted our review to be comprehensive and to present a realistic view of the current state of evidence.

Interpretation

Our results concur with previous studies showing good agreement between MRI and 3D/4D transperineal ultrasound, as reported by several groups.[57–59] Although MRI has a superior spatial resolution and fluid-sensitive sequences allowing for exploration of oedema, ultrasound assessment is more feasible, acceptable and cost effective. Indeed, only 14% of studies, providing 249 (4%) of a total of 5594 patients included in our review, were performed using MRI.

Friedman et al. published a meta-analysis exploring mode of birth and the associated risk of LA.[60] Their review included 20 studies that met their inclusion criteria with 12 of these contributing to their calculation of the odds ratios of LA following forceps and vacuum compared with normal vaginal delivery. These were 6.94 (4.93–9.78) and 1.31 (1.00–1.72), respectively, both similar to our findings. In our review we only included studies that have reported on the first vaginal birth and ensured that this is clearly presented in our data to avoid extrapolation of our findings to any assisted vaginal birth. The use of an obstetric forceps has been identified as an independent intrapartum risk factor for levator ani injury.[41] Our review corroborates existing evidence of the significantly higher association of LA with forceps compared with other birth modes. Moreover, we also demonstrated a higher risk of bilateral lesions with forceps compared with spontaneous and vacuum-assisted births. Hence, forceps use was not only associated with a higher risk of injury, but also with the risk of bilateral LA.

When comparing rates of reported right and left LA in cases of unilateral avulsion, the incidence rate of avulsion on the right-hand side was higher than the left for all modes of vaginal birth. However, this difference reached statistical significance following spontaneous deliveries only ($P < 0.0001$). It is plausible that this could be secondary to the direction of fetal head rotation if in a right occipito-posterior position. Alternatively, it could be the sigmoid colon protecting the left levator ani, or otherwise, displacing the head and increasing tension on the right levator ani muscle. It is unlikely though that this difference could be attributed to the laterality of an episiotomy, as mediolateral episiotomy was suggested not to be associated with the occurrence of LA.[61] Indeed, the reason(s) for this difference is beyond the scope of our systematic review, although it is an observation that warrants further exploration, probably via finite element models.[62,63]

There is a paucity of research with regard to the optimal timing for the assessment of the pelvic floor postnatally. In our study, the incidence rate of LA was higher when imaging was performed in the first month compared with later time-points. However, this difference was only significant for spontaneous births. It is possible that the lack of significance might be secondary to the small number of events for some of the time points. It has been suggested that early imaging can result in over diagnosis because of soft-tissue changes and haematomas that would undergo a natural process of remodelling or resolution 6–12 weeks postnatally.[45,64] Our systematic review has demonstrated that the calculated LA incidence rate was still significantly higher at >3–6 and at >6–12 months, compared with >12 months post birth following spontaneous and forceps deliveries, respectively. Although only speculative, it is possible that recovery and remodelling of the pelvic floor takes longer following a forceps-assisted delivery compared with a spontaneous birth.

Conclusion

Transperineal ultrasound should be considered the mainstay modality for the diagnosis of LA for its comparable efficacy, better availability and lower cost compared with other imaging modalities. However, early postpartum imaging is better avoided because of the risk of over-diagnosis. Although the numbers included in the analysis of imaging timing were relatively small, it seems reasonable to defer a final diagnosis till after 6 months postnatally. This duration might need to be extended to more than 12 months following a forceps-assisted birth.

There is no doubt that forceps delivery is associated with a higher incidence rate and severity of LA compared with spontaneous birth. However, given that instruments are used to assist a vaginal birth only when indicated, we believe that comparing forceps to spontaneous birth is not clinically meaningful. What is more relevant is the comparison between forceps-assisted and vacuum-assisted births. The debate among obstetricians and gynaecologists regarding the use of forceps in current obstetrics given its negative impact on the pelvic floor in the short-term and long-term is ongoing. However, irrespective of professionals' opinions and views, it is important that women are made aware of the potential implications of our findings so that they can make an informed choice about their care if their vaginal birth is to be assisted. Arguably, the same principle could be applied to vaginal birth and CS; nevertheless, the latter is a major surgical intervention that has associated short-term and long-term implications and complications and these should be included in any counselling about mode of birth.

Finally, although the clinical relevance of the side of avulsion is doubtful, it might shed some light on the pathogenesis of LA, which has the potential to aid in considering interventions and manoeuvres to mitigate the risk of such trauma.

Disclosure of interests

None declared. Completed disclosure of interests form available to view online as supporting information.

Contribution to authorship

ZR contributed to protocol development, advice on literature search, study selection, data extraction, data management and manuscript writing. LP, MK and AV contributed to study selection, data extraction, data management and manuscript editing. VK contributed to protocol development, study selection, data extraction and manuscript editing. RK contributed to study quality assessment, data analysis and presentation and manuscript writing. KMI conceived the idea and contributed to protocol development, advice on literature search, study selection and quality assessment, data analysis and manuscript writing.

Details of ethics approval

In view of the nature of the study, ethics approval was not required.

Funding

The study was supported by the Charles University Research Fund (Progres Q39). The statistical analysis for the study was funded by the GA UK (Charles University Grant Agency, project No. 918119). KI is partly funded by project No. CZ.02.1.01/0.0/0.0/16_019/0000787 'Fighting INfectious Diseases – FIND', awarded by the Ministry of Education, Youth and Sports of the Czech Republic, financed from The European Regional Development Fund. Funders were not involved in the design, analysis or reporting of this work.

Acknowledgements

The authors would like to thank Jan Rendla and Stanislav Kormunda for their help with literature search and statistical analysis.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Figure S1. Funnel plot for studies included in incidence meta-analysis.

Figure S2. Funnel plot for spontaneous delivery versus CS odds ratio meta-analysis.

Figure S3. Funnel plot for vacuum extraction versus spontaneous delivery odds ratio meta-analysis.

Figure S4. Funnel plot forceps versus spontaneous delivery odds ratio including Thibault-Gagnon et al.[4]

Figure S5. Funnel plot forceps versus vacuum odds ratio.

Figure S6. Incidence of levator avulsion depending on timing of imaging after birth.

Table S1. Search strategy.

Table S2. Criteria used for assessing included study quality based on The Joanna Briggs Institute Prevalence Critical Appraisal Tool.

Table S3. Excluded studies.

Table S4. Included studies.

Table S5. Diagnostic criteria for levator avulsion used in included studies.

Table S6. Quality assessment of included studies.

Video S1. Video abstract. ■

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