Published in final edited form as:

Obstet Gynecol. 2015 May ; 125(5): 1080–1087. doi:10.1097/AOG.0000000000000825.

Comparison of Levator Ani Muscle Avulsion Injury After Forceps and Vacuum-Assisted Vaginal Childbirth

Hafsa U. Memon, M.B.B.S¹, Joan L. Blomquist, MD², Hans P. Dietz, MD PhD³, Christopher B. Pierce, MHS⁴, Milena M. Weinstein, MD⁵, and Victoria L. Handa, MD, MHS¹

¹Department of Gynecology and Obstetrics, Johns Hopkins University, Baltimore, Maryland

²Department of Gynecology, Greater Baltimore Medical Center, Baltimore, Maryland

³Department of Obstetrics, Gynecology and Neonatology Sydney Medical School, Nepean, Australia

⁴Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland ⁵Department of Obstetrics and Gynecology, Massachusetts General Hospital, Harvard Medical School, Boston, Massachusetts

Abstract

Objective—Using three-dimensional transperineal ultrasound, we compared the prevalence of levator ani muscle injury after forceps with vacuum-assisted vaginal delivery.

Methods—This was a retrospective cohort study. Women who experienced at least one forceps delivery (across all deliveries) were compared to women who had at least one vacuum birth. On average, participants were 10 years from the index delivery. Three-dimensional transperineal ultrasound volumes were captured as cine loops at rest, with Valsalva and with pelvic floor muscle contraction. The primary outcome was levator ani muscle avulsion. Secondary outcomes included hiatal diameter and area. Prevalence of pelvic floor disorders was also compared between the two delivery groups.

Results—Among 45 participants in the forceps group and 28 participants in the vacuum group, there were no differences between groups in maternal age at first delivery, parity, body mass index, birth weight, episiotomy, and duration of second stage. History of anal sphincter laceration was more common in the forceps group. The prevalence of levator ani muscle avulsion was significantly higher after forceps compared with vacuum delivery {22/45 (49%) versus 5/28 (18%), $p=0.012$, prevalence ratio = 2.74 (95% CI: 1.17, 6.40), odds ratio = 4.40 (95% confidence interval: 1.42, 13.62)}. Controlling for delivery type, levator ani muscle avulsion was associated with symptoms of prolapse ($p=0.036$), although objective evidence of prolapse was not significantly different between groups ($p=0.20$).

Conclusion—Ten years after delivery, the prevalence of levator avulsion is almost tripled after forceps compared with vacuum-assisted vaginal delivery.

Corresponding Author: Hafsa U. Memon, M.B.B.S, 4940 Eastern Avenue, 301 Building, Baltimore, MD 21224; hafsa.memon@gmail.com.

Financial Disclosure: The authors did not report any potential conflicts of interest.

Presented as a poster at the 62nd Annual Clinical and Scientific Meeting of the American College of Obstetricians and Gynecologists Chicago from April 26–30, 2014.

Introduction

Forceps-assisted vaginal delivery is associated with increased prevalence of pelvic floor disorders and a significant reduction in pelvic floor muscle strength (1, 2, 3). In contrast, vacuum assisted vaginal delivery is not associated with prolapse or reduction in the strength of pelvic floor muscles when compared to spontaneous vaginal birth (3, 4). The mechanism for these differential associations between the type of operative vaginal delivery, pelvic floor disorders and decreased pelvic floor muscle strength is not clear.

Levator ani muscle is an important component of pelvic floor support system and injury to this muscle complex has been associated with pelvic floor disorders (5, 6, and 7). Levator ani muscle avulsion has been observed after 50–65% of forceps deliveries (8, 9, and 10). Similar association has not been noted for vacuum delivery (8). Since these two types of deliveries are practiced in the setting of second stage labor dystocia and to expedite delivery in certain obstetric scenarios, a critical question is whether the increased prevalence of levator injury after forceps delivery is related to the mode of delivery itself or it is a result of a difficult labor.

In this study, we investigated this important question by comparing the prevalence of levator ani muscle avulsion injury after forceps versus vacuum-assisted vaginal deliveries, several years after the index delivery. Such comparison is lacking from current literature. Our second goal was to assess whether levator ani muscle injury, independent of delivery type, is associated with pelvic floor disorders.

Materials and Methods

Participants were recruited from the Mothers Outcomes after Delivery study, an established longitudinal cohort study investigating pelvic floor outcomes among parous women. Institutional Review Board approval was obtained from Johns Hopkins Medical Institutions for the parent study as well as this ultrasound study.

The recruitment methods for this longitudinal cohort have been previously published in detail (2). At the time of this analysis, 1371 women were enrolled in the Mothers Outcomes After Delivery study. All study participants delivered their first child at Greater Baltimore Medical Center 5–15 years before enrollment. For the study presented here, the population of interest was the subset with a history of forceps or vacuum-assisted vaginal delivery. Using the established electronic data base of the Mothers Outcomes After Delivery study, we identified participants with a history of either a forceps or a vacuum-assisted vaginal birth across all childbirths. Only those women whose operative vaginal deliveries were confirmed from the review of hospital records were included in this study. Women with history of both forceps and vacuum-assisted deliveries were excluded. We also excluded women who were currently pregnant and those less than 6 months postpartum. Written informed consent was obtained for participation in this study.

Demographic data and additional obstetric histories of women who agreed to participate were abstracted from the established electronic data base of the longitudinal cohort. This included maternal age at first delivery and at the index delivery; maternal age, parity and

body mass index (calculated as weight [kg] / height [m²]) at the time of ultrasound; race (Caucasian or non-Caucasian), any vaginal birth with second stage of labor greater than 120 minutes; heaviest vaginal birth weight in grams; history of episiotomy, spontaneous perineal laceration and obstetric anal sphincter laceration. Obstetric histories were abstracted from hospital charts by trained personnel and were recorded in an electronic data base. For data missing from the medical record, or for some participants who delivered a subsequent child at a different hospital, we relied on the woman's reported description of all obstetric events.

Data regarding the presence or absence of pelvic floor disorders among women who agreed to participate in the ultrasound study was also extracted from the established electronic database of the Mothers Outcomes After Delivery cohort. Symptoms of pelvic floor disorders were assessed using the validated, self-administered Epidemiology of Prolapse and Incontinence Questionnaire, completed annually by the study participants (2). This questionnaire generates scores for four pelvic floor disorders: stress urinary incontinence, overactive bladder, anal incontinence and pelvic organ prolapse. In each case, a previously published validated threshold was used to define women who met criteria for each disorder, respectively (2). Study participants also underwent annual Pelvic Organ Prolapse Quantification examination as part of the Mothers Outcomes After Delivery study protocol (2). Prolapse was defined as descent of the cervix or any vaginal segment to or beyond the hymen (2).

Levator ani muscle avulsion was identified using three-dimensional transperineal ultrasound; ultrasound acquisition and interpretation was based on published protocols (9, 11). Specifically, the ultrasound was performed with the participant in the dorsal lithotomy position with an empty bladder. Before imaging, each patient was instructed in the technique of pelvic floor muscle contraction and Valsalva. We used the GE Voluson 730 system with RAB 4–8L 4D convex transducer (General Electric Corporate USA). The ultrasound transducer was covered with a sheath and applied to the perineum in the midsagittal plane. Landmarks of the symphysis pubis and the anal canal were identified. Three-dimensional ultrasound volumes were captured as cine loops at rest, Valsalva and pelvic floor muscle contraction and were stored on a compact disc for later analysis. All ultrasounds were performed by the principal investigator (HM), who was blinded to both the obstetric exposures of each participant, and the presence or absence of any pelvic floor disorders.

The ultrasound volumes were analyzed off-line using GE 4Dview, version 14 Ext 0 software (GE Healthcare Austria GmbH & Co OG). Using this software, the ultrasound volumes were rotated and displayed in the standard orthogonal planes - coronal, sagittal and transverse. At the time of this evaluation, examiners were masked to obstetrical history and to the presence or absence of pelvic floor disorders. We performed tomographic ultrasound imaging of the contraction volume at 2.5mm slice intervals, from 5 mm below to 12.5 mm above the plane of minimal hiatal dimension, producing eight slices per patient (9), as shown in Figure 1A. The diagnosis of levator avulsion was made if there was evidence of discontinuity between the levator muscle and the inferior pubis ramus during maximal pelvic floor contraction at the plane of minimal hiatal dimension and for at least 5 mm above that level, i.e. if discontinuation of levator muscles was noted in three continuous slices (Figure 1B). If diagnosis of levator avulsion was questionable, we used the levator-urethra gap to confirm

the presence of avulsion. The levator-urethra gap is the distance between the center of the urethra and medial aspect of the levator muscle insertion on the inferior pubic ramus, as shown in Figure 2A. This gap increases with detachment of the levator muscle from pelvic side walls (12), as shown in Figure 2B. A levator-urethra gap of 25 mm or more at the plane of minimal hiatal dimension and in the two slices cephalad to this plane on either side of the body have been shown to have a sensitivity of 63% and specificity of 94% for diagnosis of levator avulsion in Caucasian females (12). Measurement of the levator-urethra gap is reproducible and correlates with levator-symphysis gap, a measure of levator ani muscle avulsions on MRI imaging (13).

Additional outcomes of interest included the antero-posterior diameter of the hiatus, area of the hiatus and change in hiatal area from rest to pelvic floor muscle contraction and from rest to Valsalva. Antero-posterior hiatal diameter was measured as the shortest distance from the posteroinferior margin of the symphysis pubis to the rectal sling in the midsagittal plane at rest, Valsalva and pelvic floor muscle contraction (14). We measured hiatal area at the plane of minimal hiatal dimension on rest, Valsalva and pelvic floor muscle contraction volumes. The plane of minimal hiatal dimension is defined as the minimal distance between the hyperechoic posterior aspect of the pubic symphysis and the hyperechoic anterior margin of the levator ani muscle just behind the anorectal angle in midsagittal plane (15, 16). The change in hiatal area from rest to pelvic floor muscle contraction was calculated by subtracting area at pelvic floor muscle contraction from area at rest. The change in hiatal area from rest to Valsalva was calculated by subtracting area at rest from area at Valsalva.

To improve quality control with the three-dimensional transperineal ultrasound, we randomly-selected 15 women from 192 participants of the Mothers Outcomes after Delivery study who delivered exclusively via cesarean section without prior labor. These women served as negative controls in the ultrasound protocol as they were not expected to have any levator trauma. Additionally, their inclusion blinded the investigators performing and interpreting the ultrasound volumes to women's obstetrical history.

The primary analysis was a comparison of levator ani muscle avulsion between women with forceps assisted delivery and women with vacuum assisted delivery. Sample size was calculated for this aim. Prior publications suggest that incident levator ani muscle injury occurs in 50–65% of women after forceps assisted vaginal delivery (10). The incidence of levator injury after a vacuum delivery is not as well established but we anticipated that 10–20% of women with a history of vacuum delivery would have a levator injury (9, 10). For our power calculations, we assumed a type I error probability of 0.05. We also anticipated that participation would be similar in the two groups and therefore the ratio of forceps to vacuum participants would be 7:5. Based on these assumptions, we calculated a sample size of 96 (56 women in forceps delivery group and 40 women in vacuum delivery group) for the purpose of having 80% power to reject the null hypothesis that there is no difference in the prevalence of levator ani muscle avulsion injuries between the two groups. We evaluated differences between the two delivery groups in secondary outcomes of hiatal dimensions as well as demographic and obstetrical characteristics using Wilcoxon rank sum test for continuous variables and Fisher Exact test for categorical variables. Pelvic floor disorder outcomes were also compared between the two delivery groups using Chi-square conditional

exact test. *P* -value threshold of 0.05 was used for inference testing. All analysis was performed using SAS statistical software version 9.3 (copyright 2002–2010, SAS Institute INC., Cary, NC, USA).

Results

We identified a subset of 127 women from the participants of Mothers Outcomes After Delivery study who had history of either forceps or vacuum assisted vaginal delivery but not both types of operative vaginal deliveries. Five of these women were excluded because the history of operative vaginal delivery was reported by the participant but couldn't be verified from the medical records. Two additional women were excluded as they were pregnant at the time of ultrasound study. A total of 120 women met our eligibility criteria and were offered participation. Among these eligible participants, a total of 75 women agreed to participate and underwent three dimensional transperineal ultrasounds. Two of these 75 participants were excluded from the final analysis due to missing or interpretable volumes. Thus, 73 women were included in the final analysis. This included 45 women with a forceps delivery history and 28 women with a vacuum delivery history. There were no differences in the demographic characteristics or obstetric factors of women who were included in the final analysis ($N=73$) and those who were not included ($N=47$), as shown in the Appendix. Among 15 randomly selected women in the unlabored cesarean section group, 10 women agreed to participate.

Women in the forceps and vacuum delivery groups were comparable in most demographic factors, as summarized in Table I. Women with a history of forceps delivery were slightly older at their index delivery as compared to women with a history of vacuum delivery, although this difference was not statistically significant. Both delivery groups had similar time interval from index delivery to the ultrasound study (median interval: 10.3 versus 9.8 years, $p=0.73$). Three participants experienced two operative vaginal deliveries.

In terms of the obstetrical characteristics, majority of women in both groups were multiparous. More women in the forceps delivery group had history of prolonged second stage of labor compared to women in the vacuum delivery group but this difference was not statistically significant. There was no significant difference in the rates of episiotomy between the two groups. Most episiotomies performed at the time of operative delivery (36 of 48) were midline, with no difference in episiotomy type between groups ($p=0.29$). The only statistically significant difference between the two vaginal delivery groups was in history of anal sphincter laceration which was more common among women in the forceps assisted delivery group compared to women in the vacuum delivery group (57% vs. 19%, $p=0.002$).

Substantial differences were observed in the proportion of women with levator trauma in the forceps versus vacuum groups. We identified levator avulsions among 22/45 women (49%) who had undergone forceps delivery versus 5/28 who had undergone vacuum delivery (18%), $p=0.012$. Thus, the prevalence ratio was 2.74 (95% confidence interval: 1.17, 6.40) and the odds ratio was 4.40 (95% confidence interval: 1.42, 13.62). Among the 10 unlabored

cesarean delivery women serving as negative controls, nine had interpretable ultrasound volumes, of which none were found to have levator injury.

Women in the forceps group also had wider hiatal areas and larger antero-posterior hiatal diameters at rest, squeeze and Valsalva (Table II). These women also had larger change in the hiatal area from rest to Valsalva, indicating greater ballooning of the hiatus with Valsalva after a forceps delivery. Additionally, we observed less change in hiatal area from rest to squeeze among women with a history of forceps delivery, indicating less closure of the levator hiatus with voluntary levator contraction.

Although the prevalence of anal sphincter laceration (53%) and the levator ani muscle avulsion (49%) was similar among women in the forceps delivery group, these were not the same women. Only 11 out of 24 (46%) women in the forceps group with a history of anal sphincter laceration had evidence of levator avulsion. In comparison, among 21 women in the forceps group with no history of anal sphincter laceration, 11 (52%) had levator avulsion. We did not find a statistically significant association between anal sphincter laceration and levator ani muscle avulsion (fisher exact test, $p=0.77$). In addition, on multivariate analysis, the association between levator ani muscle avulsion and forceps delivery did not change after adjusting for history of anal sphincter laceration. Of note, our analysis was not adequately powered to study the association between levator avulsion and anal sphincter laceration.

Table III summarizes the prevalence of pelvic floor disorders between women with levator ani muscle avulsion injury and those without levator ani after adjusting for the type of operative vaginal delivery. As shown in Table III, irrespective of the delivery group, women with levator ani muscle avulsion injuries tended to have a higher prevalence of pelvic floor disorders (especially stress incontinence and prolapse) compared to women without levator ani muscle avulsion injuries. However, the only statistically significant difference found was for prolapse symptoms, which were significantly more common among women with levator avulsion ($p=0.036$).

Discussion

We observed a significant difference in the prevalence of levator avulsion between the forceps and vacuum delivery groups 10 years after operative vaginal birth. Other investigators have reported similar findings among women evaluated in the first year after delivery. Kearney et al reported levator muscle injury in 6 of 18 women 9–12 months after forceps birth versus 2 of 12 after vacuum birth (10). Similarly, levator avulsions were more common at 4 months postpartum among Australian women who had forceps delivery compared to women who had vacuum delivery (7/20 vs. 3/34, p value = 0.017) (9). Finally, 8 weeks after delivery, levator avulsions were significantly more common among Chinese women delivered by forceps (16/48) versus vacuum (10/14) (8). Our study not only supports the findings of these studies, it also provides evidence for persistent effect of forceps delivery a decade after the operative vaginal birth. Although the natural history of levator avulsion after childbirth is not well-known, it has been suggested that some avulsions

resolve over time (17, 18). Our study provides evidence for persistent effect of forceps delivery on levator ani muscles.

We also identified differences in levator function between the groups. Women in the forceps group had a wider levator hiatus, a smaller decrease in hiatal area with pelvic floor contraction, and greater widening of the hiatus area with Valsalva. These findings suggest a decreased ability to close the hiatus during a levator contraction and an inability of the avulsed levator muscle to maintain hiatal dimensions with increased abdominal pressure.

We found that women with levator ani muscle avulsion were significantly more likely to report prolapse symptoms, independent of delivery type. Other pelvic floor conditions were marginally more common among women with levator ani avulsion, but differences were not statistically significant. Our findings raise the question of whether levator injury could explain the known association between forceps and pelvic floor disorders (2–4). However, this study was not adequately powered to test this hypothesis. Our results argue in favor of a study with a sufficient sample size to simultaneously investigate the impact of operative delivery and levator avulsion on the development of pelvic floor disorders.

There are several strengths of this study. The investigators were blinded to patient's obstetrical exposures. We used well-defined and validated techniques for assessment of levator avulsion. Another strength is that only those participants whose operative vaginal delivery was confirmed from medical records were included in the study.

Although there was no difference between the forceps and vacuum delivery groups in terms of several potential confounding obstetric and demographic factors, the effects of unmeasured confounders cannot be eliminated due to observational nature of this study. For example, the obstetricians' choice for forceps versus vacuum may reflect unmeasured factors that could contribute to the higher proportion of levator injury after forceps delivery. This issue could hypothetically be addressed by conducting a randomized control study, but such study is unlikely to be feasible. Also, our study population was relatively small; thus, while the prevalence ratio of levator avulsion associated with forceps delivery is considerably greater than 1.0, the confidence interval is wide.

The overall rate of operative vaginal delivery has diminished in United States over the past two decades (with a parallel increase in the rate of primary Cesarean delivery) (19). However, in a recent statement, American College of Obstetrics and Gynecology recognized operative vaginal delivery as a safe practice that could potentially reduce primary cesarean deliveries (20). We believe that our research thus provides timely and clinically relevant information as obstetricians endeavor to employ operative vaginal delivery as a strategy to reduce cesarean during the second stage of labor. The relative increase in levator avulsion after forceps versus vacuum delivery and the suggestion of an association between levator ani injury and pelvic floor disorders in this setting provides evidence that vacuum may be a safer alternative to forceps. However, pelvic floor injury is only one important outcome; other maternal and neonatal factors should be considered in this important decision-making.

Acknowledgments

Supported by a ACOG/Kenneth Gottesfeld-Charles Hohler Memorial Foundation grant and the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development (R01HD056275).

References

1. Nygaard I, Barber MD, Burgio KL, Kenton K, Meikle S, Schaffer J, et al. Pelvic Floor Disorders Network Prevalence of symptomatic pelvic floor disorders in US women. *JAMA*. 2008; 300:1311–1316. [PubMed: 18799443]
2. Handa VL, Blomquist JL, Knoepp LR, Hoskey KA, McDermott KC, Muñoz A. Pelvic Floor Disorders 5–10 years after vaginal or cesarean childbirth. *Obstet Gynecol*. 2011; 118:777–784. [PubMed: 21897313]
3. Friedman S, Blomquist JL, Nugent JM, McDermott KC, Muñoz A, Handa VL. Pelvic Muscle Strength after Childbirth. *Obstet Gynecol*. 2012; 120(5):1021–1028. [PubMed: 23090518]
4. Handa VL, Blomquist JL, McDermott KC, Friedman S, Munoz A. Pelvic Floor Disorders after Vaginal Birth Effect of Episiotomy, Perineal Laceration, and Operative Birth. *Obstet Gynecol*. 2012; 119:233–239. [PubMed: 22227639]
5. DeLancey JO. Structural support of the urethra as it relates to stress urinary incontinence: The hammock hypothesis. *Am J Obstet Gynecol*. 1994; 170(6):1713–1720. [PubMed: 8203431]
6. Delancey JO, Morgan DM, Fenner DE, Kearney R, Guire K, Miller JM, et al. Comparison of levator ani muscle defects and function in women with and without pelvic organ prolapse. *Obstet Gynecol*. 2007; 109:295–302. [PubMed: 17267827]
7. Dietz HP, Simpson JM. Levator trauma is associated with pelvic organ prolapse. *BJOG*. 2008; 115:979–984. [PubMed: 18503571]
8. Chan SS, Cheung RY, Yiu AK, Lee LL, Pang AW, Choy KW, et al. Prevalence of levator ani muscle injury in Chinese women after first delivery. *Ultrasound Obstet Gynecol*. 2012; 39(6):704–709. [PubMed: 22045587]
9. Shek KL, Dietz HP. Intrapartum risk factors for levator trauma. *BJOG*. 2010; 117(12):1485–1492. [PubMed: 20735379]
10. Kearney R, Miller JM, Ashton-Miller JA, DeLancey JO. Obstetric factors associated with levator ani muscle injury after vaginal birth. *Obstet Gynecol*. 2006; 107(1):144–149. [PubMed: 16394052]
11. Dietz HP. Ultrasound imaging of the pelvic floor: Part II Three-dimensional or volume imaging. *Ultrasound Obstet Gynecol*. 2004; 23:615–625. [PubMed: 15170808]
12. Dietz HP, Abbu A, Shek KL. The levator-urethra gap measurement: a more objective means of determining levator avulsion? *Ultrasound Obstet Gynecol*. 2008; 32(7):941–945. [PubMed: 19035543]
13. Zhuang RR, Song YF, Chen ZQ, Ma M, Huang HJ, Chen JH, et al. Levator avulsion using a tomographic ultrasound and magnetic resonance-based model. *Am J Obstet Gynecol*. 2011; 205(3):232. [PubMed: 21620359]
14. Dietz HP, Shek C, Clarke B. Biometry of the pubovisceral muscle and levator hiatus by 3-dimensional pelvic floor ultrasound. *Ultrasound Obstet Gynecol*. 2005; 25:580–585. [PubMed: 15883982]
15. Dietz HP, Shek C, De Leon J, Steensma AB. Ballooning of the levator hiatus. *Ultrasound Obstet Gynecol*. 2008; 31(6):676–680. [PubMed: 18470963]
16. Abdool Z, Shek KL, Dietz HP. The effect of levator avulsion on hiatal dimension and function. *Am J Obstet Gynecol*. 2009; 201(1):89. [PubMed: 19426956]
17. Shek KL, Chantarasorn V, Langer S, Dietz HP. Does levator trauma 'heal'? *Ultrasound Obstet Gynecol*. 2012; 40:570–575. [PubMed: 22648932]
18. Chan SS, Cheung RY, Yiu KW, Lee LL, Chung TK. Effect of levator ani muscle injury on primiparous women during the first year after childbirth. *Int Urogynecol*. 2014
19. Martin JA, Hamilton BE, Ventura SJ, Osterman MJ, Mathews TJ. Births: Final Data for 2011. *National Vital Statistics Report*. 2013; 62(1)

20. Safe prevention of the primary cesarean delivery. Obstetric Care Consensus No. 1. American College of Obstetricians and Gynecologists. Obstet Gynecol. 2014; 123:693–711. [PubMed: 24553167]

Appendix. Demographic and Obstetric Characteristics of 120 Eligible Participants, by Inclusion Status

	Frequency (%) or Median [Interquartile Range] ^a		
Characteristics	Included In Final Analysis (N=73)	Did Not Include In Final Analysis (N=47)	P-value ^b
Current parity			
1	20 (27%)	14 (30%)	0.71
2	34 (47%)	24 (51%)	
3+	19 (26%)	9 (19%)	
African – American Race	5 (7%)	5 (11%)	0.51
Age at first delivery (years)	32 [29, 35]	33 [29, 37]	0.39
Age at index delivery (years)	33 [30, 36]	34 [30, 36]	0.43
Heaviest vaginal birth weight (grams)	3510 [3210, 3820]	3450 [3290, 3800]	0.63
Birth weight at index operative vaginal birth(grams)	3400 [3125, 3645]	3300 [3090, 3705]	0.61
Any vaginal birth with second stage >120 minutes	32 (44%)	27 (57%)	0.19
Second stage >120 minutes at index operative vaginal birth	29 (40%)	25 (53%)	0.19
At least one episiotomy	55 (75%)	35 (74%)	0.99
Episiotomy at index operative vaginal birth	48 (69%)	33 (72%)	0.84
Type of episiotomy at index operative vaginal birth			0.31
Midline	36 (75%)	20 (61%)	
Mediolateral	7 (15%)	6 (18%)	
At least one perineal laceration	37 (51%)	25 (53%)	0.85
Perineal laceration at index operative delivery	23 (32%)	13 (28%)	0.68
At least one anal sphincter laceration	29 (40%)	21 (45%)	0.70
Anal sphincter laceration at index operative vaginal birth	29 (42%)	21 (51%)	0.43

^aStatistical summaries are frequency (%) for categorical variables and median [Interquartile range] for continuous variables.

^bBased on Fisher Exact tests for categorical variables and Wilcoxon rank sum tests for continuous variables

Figure 1.

A. Ultrasound image (axial plane) of a normal levator ani muscle. **B.** Ultrasound image (axial plane) of a right-sided levator ani muscle avulsion. *Indicates a right-sided levator ani muscle avulsion.

Figure 2.

A. Ultrasound image (axial plane) showing normal levator-urethra gap of less than 25mm bilaterally. **B.** Ultrasound image (axial plane) showing right-sided levator avulsion with right levator-urethra gap of greater than 25mm (*white arrow*).

Table I

Demographic and Obstetric Characteristics of 73 Participants, by Delivery Group

	Frequency (%) or median [IQR] ^a		
Characteristics	Forceps (N=45)	Vacuum (N=28)	<i>P</i> –value ^b
Current parity			
1	14 (31%)	6 (20%)	0.53
2	21 (47%)	13 (46%)	
3+	10 (22%)	9 (30%)	
Median BMI (kg/m²) at ultrasound	24 [22, 25]	24 [21, 26]	0.69
African – American Race	2 (4%)	3 (11%)	0.37
Age at first delivery (years)	33 [30, 35]	31 [28, 33]	0.091
Age at index delivery (years)^c	34 [31, 36]	32 [29, 34]	0.12
Age at ultrasound (years)	43 [40, 46]	42 [39, 45]	0.28
Years from index operative delivery to ultrasound	10.3 [8.5, 11.7]	9.8 [7.3, 12.4]	0.73
Heaviest vaginal birth weight (grams)^d	3510 [3210, 3810]	3510 [3215, 3850]	0.97
Birth weight at index operative vaginal birth (grams)	3400 [3125, 3745]	3405 [3070, 3510]	0.33
Any vaginal birth with second stage >120 minutes^d	23 (51%)	9 (32%)	0.15
Second stage >120 minutes at index operative vaginal birth^c	21 (47%)	8 (29%)	0.15
At least one episiotomy^d	31 (69%)	23 (82%)	0.28
Episiotomy at index operative vaginal birth^c	28 (67%)	20 (71%)	0.79
Type of episiotomy at index operative vaginal birth			0.29
Midline	18/28 (64%)	18/20 (90%)	
Mediolateral	6/28 (21%)	1/20 (5%)	
At least one perineal laceration^d	22 (49%)	15 (54%)	0.81
Perineal laceration at index operative delivery	15 (35%)	8 (29%)	0.61
At least one anal sphincter laceration^d	24 (53%)	5 (18%)	0.006
Anal sphincter laceration at index operative vaginal birth^c	24 (57%)	5 (19%)	0.002

^aStatistical summaries are frequency (%) for categorical variables and median [interquartile range] for continuous variables.^bBased on Fisher Exact tests for categorical variables and Wilcoxon rank sum tests for continuous variables

^c Missing data: episiotomy at index operative delivery, N=3; anal sphincter laceration at index operative delivery, N=4; perineal laceration at index operative delivery, N=2; maternal age at index operative delivery, N=3.

^d For these variables, maternal self-report was substituted if obstetrical record data were missing

Table II

Secondary Outcome Measures by Delivery Group for N=73 women

	Median [Interquartile range]		
Characteristics	Forceps (N=45)	Vacuum (N=28)	<i>P</i> –value ^a
Median hiatal area (cm²)			
Rest	17 [14, 19]	15 [13, 17]	0.059
Pelvic floor muscle contraction	15 [12, 17]	11 [10, 14]	0.004
Valsalva	22 [18, 30]	17 [14, 24]	0.019
Change in area from rest (cm²)			
Pelvic floor muscle contraction	–2 [–3, 0]	–3 [–3, –1]	0.054
Valsalva	7 [2, 10]	4 [1, 6]	0.072
Median antero-posterior hiatal diameter (cm)			
Rest	6 [5, 6]	5 [5, 5]	0.024
Pelvic floor muscle contraction	5 [4, 6]	4 [4, 5]	<0.001
Valsalva	6 [6, 7]	5 [5, 6]	0.004

^a Derived from Wilcoxon rank sum test

Table III
Frequencies Of Pelvic Floor Disorders by Delivery Group and Levator Ani Muscle Avulsion Among 73 Participants

	Forceps (N=45)		Vacuum (N=28)		<i>P</i> ^{**}
	Avulsion Present N=22	Avulsion Absent N=23	Avulsion Present N=5	Avulsion Absent N=23	
Pelvic Floor Disorders*					
Stress Urinary Incontinence	9 (41%)	6 (26%)	1 (20%)	2 (9%)	0.25
Overactive Bladder	4 (18%)	2 (9%)	1 (20%)	4 (17%)	0.48
Anal Incontinence	5 (23%)	6 (26%)	1 (20%)	5 (22%)	0.99
Pelvic Organ Prolapse Symptoms	4 (18%)	1 (4%)	2 (40%)	1 (4%)	0.036
Pelvic Organ Prolapse On Examination	13 (59%)	9 (39%)	2 (40%)	7 (30%)	0.20

* Outcomes describe the event in question “ever” occurring across all visits of the longitudinal study prior to and including the visit at which the ultrasound was performed.

** Based on Chi-square conditional exact test evaluating differences between women with and without avulsion. Derived from multivariate logistic model adjusting for operative delivery type.