Ultrasound Obstet Gynecol 2015
Published online in Wiley Online Library (wileyonlinelibrary.com). **DOI:** 10.1002/uog.14891

Forceps delivery is associated with increased risk of pelvic organ prolapse and muscle trauma: a cross-sectional study 16–24 years after first delivery

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KEYWORDS: Cesarean delivery; forceps delivery; levator avulsion; normal vaginal delivery; pelvic floor muscle trauma; pelvic organ prolapse; vacuum delivery

ABSTRACT

Objectives *To study possible associations between mode of delivery and pelvic organ prolapse (POP) and pelvic floor muscle trauma 16–24 years after first delivery and, in particular, to identify differences between forceps and vacuum delivery.*

Methods *This was a cross-sectional study including 608 women who delivered their first child in 1990–1997 and were examined with POP quantification (POP-Q) and pelvic floor ultrasound in 2013–2014. Outcome measures were POP ≥ Stage 2 or previous prolapse surgery, levator avulsion and levator hiatal area on Valsalva. Univariable and multivariable logistic regression analyses and ANCOVA were applied to identify outcome variables associated with mode of delivery.*

Results *Comparing forceps to vacuum delivery, the adjusted odds ratios (aOR) were 1.72 (95% CI, 1.06–2.79;* P = 0.03*) for POP ≥ Stage 2 or previous prolapse surgery and 4.16 (95% CI, 2.28–7.59;* P < 0.01*) for levator avulsion. Hiatal area on Valsalva was larger, with adjusted mean difference (aMD) of 4.75 cm^2 (95% CI, 2.46–7.03;* P < 0.01*). Comparing forceps with normal vaginal delivery, the adjusted odds ratio (aOR) was 1.74 (95% CI, 1.12–2.68;* P = 0.01*) for POP ≥ Stage 2 or surgery and 4.35 (95% CI, 2.56–7.40;* P < 0.01*) for levator avulsion; hiatal area on Valsalva was larger, with an aMD of 3.84 cm^2 (95% CI, 1.78–5.90;* P < 0.01*). Comparing Cesarean delivery with normal vaginal delivery, aOR was 0.06 (95% CI, 0.02–0.14;* P < 0.01*) for POP ≥ Stage 2 or surgery and crude OR was 0.00 (95% CI, 0.00–0.30;* P < 0.01*) for levator avulsion; hiatal area on Valsalva was smaller, with an aMD of −8.35 cm^2 (95% CI, −10.87 to −5.84;* P < 0.01*). No differences were found between vacuum and normal vaginal delivery.*

Conclusions *We found that mode of delivery was associated with POP and pelvic floor muscle trauma in women from a general population, 16–24 years after their first delivery. Forceps was associated with significantly more POP, levator avulsion and larger hiatal areas than were vacuum and normal vaginal deliveries. There were no statistically significant differences between vacuum and normal vaginal deliveries. Cesarean delivery was associated with significantly less POP and pelvic floor muscle trauma than were normal or operative vaginal delivery. Copyright © 2015 ISUOG. Published by John Wiley & Sons Ltd.*

INTRODUCTION

Pelvic organ prolapse (POP) influences daily activities, sexual function and the ability to perform exercise in many women. POP may have a large impact on quality of life, and the economic costs for healthcare services related to POP are high. By the age of 85 years, 13–21% of women in western countries have been subjected to surgery for POP[1–3].

Several risk factors for POP have been established, such as age, body mass index (BMI), ethnicity, hysterectomy, constipation, smoking habits and chronic coughing[3–9]. POP is also associated with parity and mode

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Accepted: 24 April 2015

of delivery[4–13], and studies have found a lower prevalence after Cesarean delivery than after normal vaginal delivery[9,11,13]. A few studies have compared the prevalence of POP after forceps and vacuum delivery and the results are conflicting. One study demonstrated that forceps, but not vacuum delivery, was associated with a higher prevalence of POP compared with normal vaginal delivery[10], whereas another study found a protective effect of forceps[11].

A higher prevalence of POP may be explained by the increased risk of pelvic floor muscle trauma during operative vaginal delivery. Levator avulsion injury and increased levator hiatal area are risk factors for POP as demonstrated by ultrasound[14–16] and magnetic resonance imaging (MRI)[17–19]. Studies among urogynecological patients and women a few months after delivery have demonstrated a higher prevalence of avulsion injuries and increased levator hiatal areas after forceps delivery, but not after vacuum delivery[18,20–28].

The aims of this study were to identify possible associations between mode of delivery and POP and pelvic floor muscle trauma in women of the general population, 16–24 years after their first delivery, and to study the possible differences between forceps and vacuum deliveries.

METHODS

We conducted a cross-sectional study in which 847 women delivering at Trondheim University Hospital between 1 January 1990 and 31 December 1997 were invited for a clinical examination, including a four-dimensional (4D) ultrasound examination, between June 2013 and January 2014. We recruited women from a previous study of pelvic floor disorders[29], in which women had been identified from the Hospital's Patient Administrative System. In the previous study, we had invited all women whose first child had been delivered using forceps, vacuum or Cesarean section during 1990–1997 and women whose first delivery was normal vaginal from 1 January to 1 July of each calendar year, to ensure a similar proportion of normal deliveries during the whole study period. Vacuum and forceps deliveries were performed at approximately the same rate (3–5% of all deliveries) in Trondheim University Hospital during 1990–1997.

We defined four study groups according to the delivery mode of the first child: normal vaginal delivery, Cesarean delivery, forceps delivery and vacuum delivery. In the normal vaginal delivery group, women were included who may have had subsequent normal vaginal deliveries and Cesarean deliveries after the first delivery, but no forceps or vacuum deliveries. The Cesarean delivery group included women who had only delivered by Cesarean section. The forceps group included women who may have had forceps, normal or Cesarean delivery after their first child, but no vacuum delivery. The vacuum group included women who may have had vacuum, normal or Cesarean delivery after their first child, but no forceps delivery.

Exclusion criteria were stillbirth, breech delivery and infant birth weight < 2000 g at the index delivery; however, women were not excluded if these conditions occurred in subsequent pregnancies. Women were excluded if their postal code indicated that they lived far from Trondheim in 2013. Informed consent was obtained from all participants. The study was approved by the Regional Committee for Medical and Health Research Ethics (REK midt 2012/666). A flowchart of study participants is presented in Figure 1.

All women in the current study had responded to a postal questionnaire in 2013 regarding symptoms of POP, urinary and fecal incontinence; these results have been published elsewhere[29]. The questionnaire included information on weight, height, smoking habit, chronic coughing, menopause and use of hormone replacement therapy, hysterectomy and surgery for POP and urinary and fecal incontinence. Information about delivery method, infant birth weight, epidural analgesia, perineal tears and indication for operative vaginal delivery at first delivery was obtained from the hospital records. Additional information about subsequent deliveries (delivery mode, infant birth weight, head circumference, parity, elective or emergency Cesarean delivery, year of delivery) was obtained from the Norwegian Medical

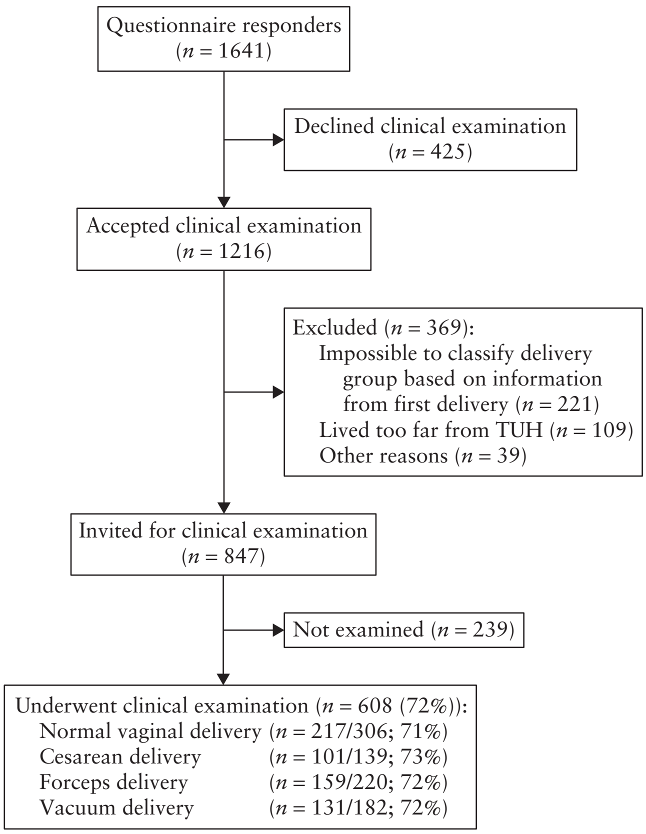

Figure 1 Flowchart of study participants, comprising women who had their first delivery during 1990–1997 at Trondheim University Hospital (TUH).

Birth Registry and cross-checked with the Hospital's Patient Administrative System.

A power calculation was based on a previous study of primiparous women indicating a higher risk of pelvic floor muscle trauma after forceps delivery (35%) than after normal vaginal delivery (13%) and vacuum delivery (9%)[22], and a study identifying ultrasound-verified muscle trauma as a factor that doubles the risk of POP[15]. To detect a similar difference in prevalence of levator avulsion between delivery groups (35% *vs* 13%), we would need 58 women in each group with a power of 80% and a 5% significance level. We assumed a smaller difference in POP prevalence (12.5% in the normal vaginal delivery group and 25.0% in the forceps group) and found that a sample size of 152 women in each delivery group would be sufficient to find a statistically significant and clinically relevant difference between delivery groups with power of 80% and significance level of 5%. We did not perform power calculations for the detection of differences in hiatal area.

All clinical and ultrasound examinations were performed by the first author (I.V.). At the time of the examination, I.V. was blinded to demographic and clinical background data. Women were asked to withhold any information regarding previous deliveries and gynecological operations until the examination had been completed. Women were examined in the supine position in a gynecological examination chair with an empty urinary bladder and bowel. The lower abdomen was covered with a cloth to hide any surgical scars.

The clinical examination included staging of POP according to the POP quantification (POP-Q) system[30]. This provided the following quantification of the prolapse in each compartment (anterior, mid, posterior): Stage 0 (no prolapse demonstrated); Stage 1 (most distal part of the prolapse > 1 cm above the hymen); Stage 2 (most distal part of the prolapse ≤ 1 cm above or below the plane of the hymen); Stage 3 (most distal part of the prolapse > 1 cm below the hymen); and Stage 4 (complete eversion of the vagina and uterus). Data from the POP-Q were analyzed for each compartment and the presence of POP in at least one of all three compartments (any POP) was registered. Five women had undergone prolapse surgery and were cured objectively (POP < Stage 2). We did not check their hospital records for POP stage before surgery, but in Norway the agreed indication for POP surgery is POP ≥ Stage 2 with concomitant prolapse symptoms. We defined a composite outcome variable, combining POP ≥ Stage 2 or previous POP surgery, hereafter referred to as 'POP ≥ Stage 2 or surgery'. POP Stage 3 included women with more severe prolapses.

After POP-Q staging had been performed, 4D ultrasound volumes were acquired with a GE Voluson S6 device (GE Medical Systems, Zipf, Austria), using the RAB 4–8RS abdominal three-dimensional probe and an acquisition angle of 85°. Volumes were acquired at rest, during pelvic floor muscle contraction and during Valsalva maneuver for a minimum of 6 seconds[31]. Three volumes were acquired for contraction (including a relaxed state at the beginning of each volume) and Valsalva, yielding a total of six volumes per woman.

Offline analysis of the ultrasound volumes was performed 6–14 months after the ultrasound scan on a computer using the 4D View Version 14 Ext. 0 software (GE Medical Systems). Analysis was performed by the first author (I.V.), who was blinded to clinical and demographic data at the time of the analysis. Pelvic floor muscle trauma was defined by either levator avulsion or larger levator hiatal area. Tomographic ultrasound imaging was used to identify levator avulsion on pelvic floor muscle contraction. Avulsion was diagnosed if all three central slices (the slice in the plane of minimal hiatal dimensions, i.e. where the distance between the posterior border of the symphysis and the anterior border of the puborectalis muscle is shortest, and the slices 2.5 and 5.0 mm cranial to this) showed abnormal muscle insertion[32]. Avulsion was diagnosed as unilateral or bilateral (Figure 2) and the number of women with levator avulsion (unilateral or bilateral) was registered. Hiatal area was measured in the plane of minimal hiatal dimensions in a rendered volume of 1- to 2-cm thickness, as described previously[33]. All six volumes for rest/contraction and Valsalva were analyzed. Ultrasound images defining the hiatal area at rest, on contraction and on Valsalva in women with or without unilateral or bilateral avulsions are presented in Figure 3. The largest hiatal areas at rest and during Valsalva maneuver were registered for each woman. The smallest hiatal area, representing the best contraction, was registered for pelvic floor muscle contraction. Some women were unable to perform a proper Valsalva maneuver without co-activation of the pelvic floor muscles. When the hiatal area produced on Valsalva maneuver was smaller than the area at rest, the hiatal area during Valsalva was defined as invalid and registered as missing.

Statistical analysis

The primary statistical analysis was to compare POP, levator avulsion and hiatal area in women with forceps delivery and those with vacuum delivery. Secondary analyses were comparisons of outcomes between Cesarean, forceps and vacuum deliveries and normal vaginal delivery.

Statistical analysis was performed with IBM SPSS statistics version 21 (IBM SPSS, Armonk, NY, USA). Continuous variables were tested for normal distribution. We used the two-sample *t*-test for continuous variables and the chi-square test or Fisher's exact test for categorical variables to identify any differences in demographics and clinical background data between study groups. $P < 0.05$ was considered statistically significant. Univariable logistic regression was used for calculation of crude odds ratios (cOR) for delivery modes. Multivariable logistic regression analysis was used to correct for possible confounding factors and calculation of adjusted odds ratios (aOR) with 95% CI. ANCOVA was used to test for significant differences between delivery

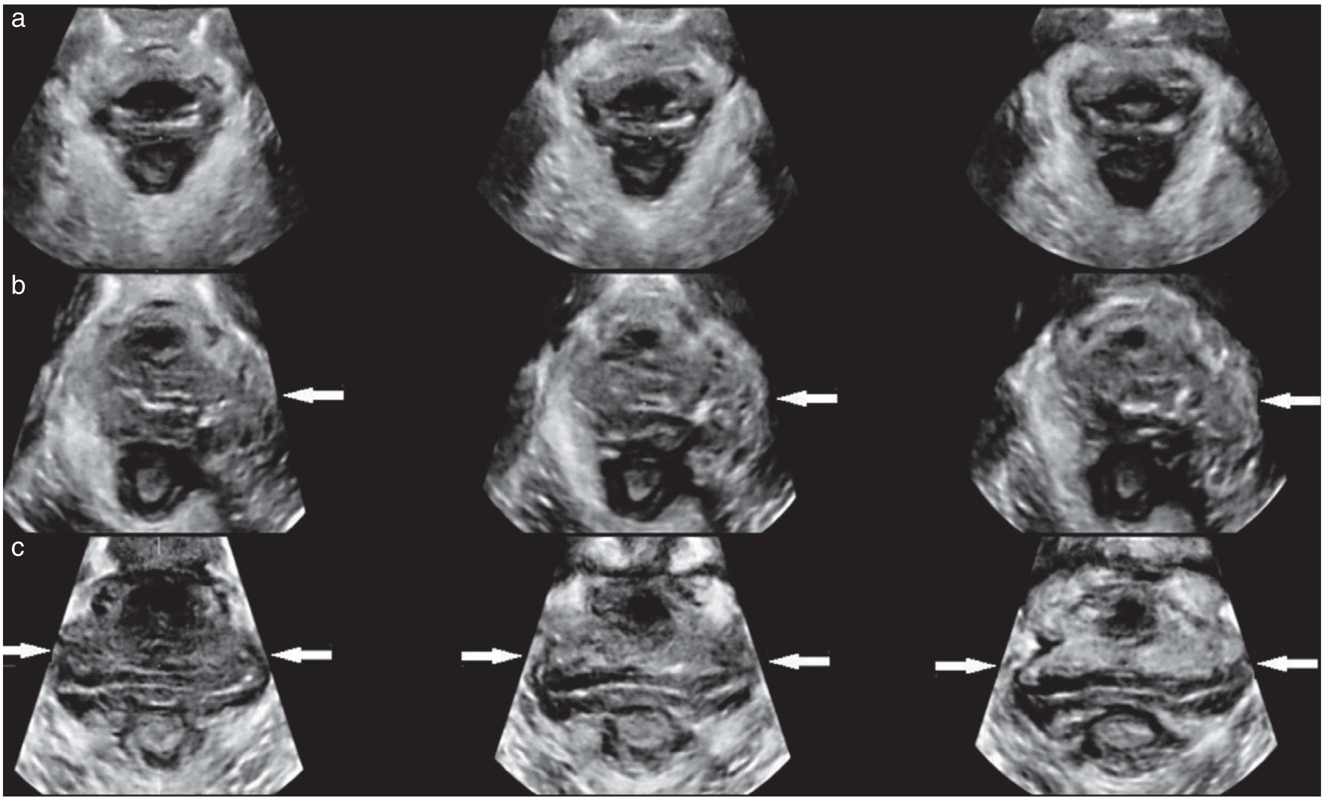

Figure 2 Three central slices on tomographic ultrasound imaging, showing intact levator (a), unilateral avulsion (b) and bilateral avulsion (c). Avulsion is indicated by arrows.

modes for hiatal areas at rest, on contraction and on Valsalva. Both univariable ANCOVA for unadjusted mean difference (MD) with 95% CI between delivery groups and multivariable ANCOVA corrected for possible confounding factors for adjusted MD with 95% CI are reported. When sample numbers were small (e.g. the number of women with POP Stage 3), Fisher's exact test was used for calculation of cOR with 95% CI (http://www.r-fiddle.org/#/).

Based on clinical knowledge and results from previous studies, we considered several potential confounding variables. Univariable logistic regression was used to test the association of each variable with POP $\geq$ Stage 2 or surgery and levator avulsion before entering the variable into the multivariable model. ANCOVA was used to test the association of each factor with hiatal area on Valsalva. For comparison of risks between delivery groups in the final logistic regression model and for the multivariable ANCOVA analysis, we selected age in 2013, parity (number of deliveries), BMI and largest infant's birth weight. Head circumference was omitted because of correlation with birth weight, and both menopause and age at delivery were omitted because of correlation with age in 2013. Other potential confounding variables (smoking, coughing, hysterectomy, epidural, indication for operative vaginal delivery and perineal tears) showed no statistically significant association with main outcome variables and were not entered into the multivariable regression model. Reliable information on the use of hormone replacement therapy, oxytocin augmentation during delivery and episiotomy was not available. When data were missing, analysis was performed on study participants with complete data.

RESULTS

During 2013–2014, 608 (72%) of the 847 women who delivered in 1990–1997 attended the clinical examination. There were no differences in participation rate between delivery groups (Figure 1); however, a significantly greater number of women included in the present study had symptoms of POP compared with the background population (15% *vs* 11%; $P = 0.01$)[29]. The study women were older at examination (47.9 *vs* 47.3 years; $P < 0.01$) and at their first delivery, but there were no statistically significant differences for parity, largest infant's birth weight or BMI. In total, 607 ultrasound datasets of six volumes were analyzed. One dataset had not been stored properly, and in one dataset there was an artifact making avulsion analysis impossible, though hiatal area could be measured. Continuous variables were approximately normally distributed.

Demographics and clinical background data are shown in Table 1. Women in the normal vaginal delivery group were significantly younger at examination and first delivery, had lower BMI and higher parity compared with all other delivery groups. Women in the Cesarean delivery group were older at examination and first delivery, and had higher BMI and lower parity than the vaginal delivery

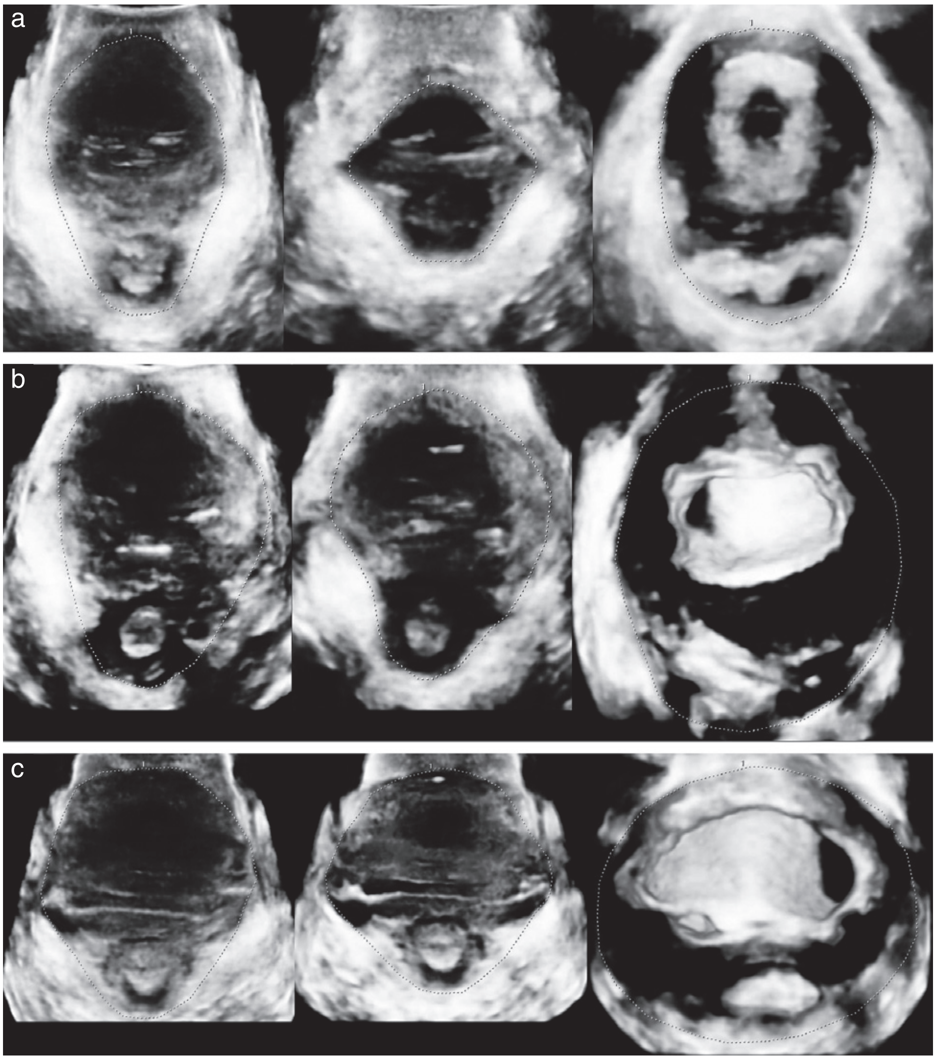

Figure 3 Tomographic ultrasound images of hiatal areas at rest, on pelvic floor muscle contraction and on Valsalva maneuver in women with: (a) intact levator (19.7, 9.6 and 23.8 cm^2, respectively), (b) unilateral avulsion (27.3, 19.8 and 46.1 cm^2, respectively) and (c) bilateral avulsion (27.3, 25.6 and 47.3 cm^2, respectively).

groups. Women in the forceps and vacuum delivery groups were comparable as to age, BMI and parity, but infants were significantly larger in the vacuum group.

Table 2 demonstrates the prevalence of POP in the anterior, mid and posterior compartments, previous prolapse surgery, levator avulsion and mean hiatal areas according to delivery group. No women were found to have POP Stage 4.

Table 3 presents comparisons between delivery groups for the main outcome variables. Forceps was significantly associated with an increased risk of POP ≥ Stage 2 or surgery when compared with vacuum (aOR, 1.72 (95% CI, 1.06–2.79); $P = 0.03$) and normal vaginal delivery (aOR, 1.74 (95% CI, 1.12–2.68); $P < 0.01$) and of POP ≥ Stage 3 when compared with vacuum delivery (cOR, ∞ (95% CI, 1.16–∞); $P = 0.02$). Forceps was also associated with an increased risk for avulsion injury when compared with both vacuum (65/159 after forceps *vs* 19/130 after vacuum; aOR, 4.16 (95% CI, 2.28–7.59); $P < 0.01$) and normal vaginal delivery (29/216 after normal delivery; aOR, 4.35 (95% CI, 2.56–7.40); $P < 0.01$). The mean hiatal areas were significantly larger after forceps than after vacuum or normal vaginal delivery (Table 3). There were no statistically significant differences in prevalence of POP ≥ Stage 2 or surgery, levator avulsion or hiatal areas between vacuum and normal vaginal delivery. Cesarean delivery was associated with a decreased risk of POP ≥ Stage 2 or surgery (aOR, 0.06 (95% CI, 0.02–0.14); $P < 0.01$), levator avulsion (cOR, 0.00 (95% CI, 0.00–0.30); $P < 0.01$) and hiatal areas were significantly smaller when compared with normal vaginal delivery. The study was not sufficiently powered to determine differences between elective ($n = 23$) and acute ($n = 78$) Cesarean deliveries, but no difference was found in POP prevalence (2/23 and 4/78, respectively) and hiatal areas were similar in the two Cesarean subgroups.

In Table S1, the contribution of other risk factors to POP ≥ Stage 2 or surgery, levator avulsion and hiatal area is presented. In a multivariable regression model, age in 2013 was associated with an increased risk of POP ≥ Stage 2 or surgery (aOR, 1.05 (95% CI, 1.01–1.09); $P = 0.02$)

Table 1 Background characteristics of 608 women who delivered their first child during 1990–1997 at Trondheim University Hospital and subsequently underwent a clinical pelvic examination in 2013–2014, according to mode of delivery

Characteristic	*Forceps delivery* (n = *159*)	*Vacuum delivery* (n = *131*)	*Normal vaginal delivery* (n = *217*)	*Cesarean delivery* (n = *101*)*	*Total* (n = *608*)	P: *Forceps* vs *vacuum delivery*	P: *Forceps* vs *normal vaginal delivery*	P: *Vacuum* vs *normal vaginal delivery*	P: *Cesarean* vs *normal vaginal delivery*
Age in 2013 (years)	48.18 ± 4.83	47.63 ± 5.03	46.82 ± 4.53	50.36 ± 4.64	47.94 ± 4.88	0.35	< 0.01	0.12	< 0.01
Age at 1st delivery (years)	28.52 ± 4.52	28.40 ± 4.67	27.02 ± 4.09	30.31 ± 4.80	28.25 ± 4.58	0.83	< 0.01	< 0.01	< 0.01
BMI (kg/m^2) (*n* = 598)	25.96 ± 4.42	26.41 ± 5.12	24.93 ± 4.17	26.56 ± 4.46	25.79 ± 4.54	0.43	0.02	< 0.01	< 0.01
Parity	2.15 ± 0.74	2.23 ± 0.76	2.45 ± 0.82	1.73 ± 0.73	2.20 ± 0.81	0.38	< 0.01	0.01	< 0.01
BW of largest infant (g)									
All deliveries	3832.8 ± 481.8	3962.5 ± 494.6	3842.4 ± 458.1	3814.4 ± 631.0	3861.1 ± 505.9	0.03	0.84	0.02	0.65
Vaginal deliveries (*n* = 507)†	3820.3 ± 484.9	3948.7 ± 490.6	3839.0 ± 454.3	—	3861.5 ± 475.5	0.03	0.70	0.04	—
HC of largest infant (cm)	36.47 ± 1.40	36.88 ± 1.68	36.23 ± 1.21	36.55 ± 1.49	36.48 ± 1.44	0.02	0.08	< 0.01	0.04
Menopause (*n* = 541)	37/138 (26.8)	26/115 (22.6)	30/200 (15.0)	33/88 (37.5)	126/541 (23.3)	0.44	< 0.01	0.09	< 0.01
Hysterectomy (*n* = 606)	12/158 (7.6)	3/131 (2.3)	7/216 (3.2)	8/101 (7.9)	30/606 (5.0)	0.04	0.06	0.61	0.07
Smoker (*n* = 606)	34/158 (21.5)	27/131 (20.6)	36/216 (16.7)	22/101 (21.8)	119/606 (19.6)	0.85	0.24	0.36	0.27
Chronic coughing (*n* = 606)	13/158 (8.2)	4/131 (3.1)	14/216 (6.5)	3/101 (3.0)	34/606 (5.6)	0.06	0.52	0.16	0.20
Epidural analgesia	33/159 (20.8)	35/131 (26.7)	16/217 (7.4)	—	84/507 (16.6)	0.23	< 0.01	< 0.01	—
Perineal tear grade 3–4‡	19/159 (12.0)	12/131 (9.2)	—	—	31/290 (10.7)	0.44	—	—	—
Prolonged 2nd stage of labor‡	75/159 (47.2)	76/131 (58.0)	—	—	151/290 (52.1)	0.07	—	—	—
Fetal distress in labor‡	70/159 (44.0)	50/131 (38.2)	—	—	120/290 (41.4)	0.31	—	—	—

Data are given as mean ± SD or *n*/*N* (%). Continuous variables were compared using *t*-test and categorical variables were compared using chi-square test. *23 elective and 78 acute Cesarean deliveries. †12 vaginally parous women delivered their heaviest child by Cesarean section: three in the normal vaginal delivery group, four in the forceps group and five in the vacuum group. ‡Prevalence of perineal tears, prolonged second stage labor and fetal distress in labor were analyzed for only forceps and vacuum groups. BMI, body mass index; BW, birth weight; HC, head circumference.

Table 2 Pelvic organ prolapse (POP), levator avulsion and hiatal area in women who delivered their first child during 1990–1997 at Trondheim University Hospital and subsequently underwent a clinical pelvic examination in 2013–2014, according to mode of delivery (normal vaginal, Cesarean, forceps or vacuum)

Outcome	*Forceps* (n = *159)*	*Vacuum* (n = *131)*	*Normal vaginal* (n = *217)*	*Cesarean* (n = *101)*	*Total* (n = *608)*
POP in anterior compartment					
≥ Stage 2	60 (37.7)	36 (27.5)	72 (33.2)	4 (4.0)	172 (28.3)
≥ Stage 3	4 (2.5)	0 (0)	3 (1.4)	0 (0)	7 (1.2)
POP in mid compartment					
≥ Stage 2	13 (8.2)	6 (4.6)	10 (4.6)	0 (0)	29 (4.8)
≥ Stage 3	3 (1.9)	0 (0)	2 (0.9)	0 (0)	5 (0.8)
POP in posterior compartment					
≥ Stage 2	54 (34.0)	42 (32.1)	56 (25.8)	2 (2.0)	154 (25.3)
≥ Stage 3	1 (0.6)	0 (0)	0 (0)	0 (0)	1 (0.2)
POP in any compartment					
≥ Stage 2	97 (61.0)	67 (51.1)	105 (48.4)	6 (5.9)	275 (45.2)
≥ Stage 3	7 (4.4)	0 (0)	4 (1.8)	0 (0)	11 (1.8)
Previous prolapse surgery (*n* = 593: 155, 129, 211, 98)*†	8 (5.2)	2 (1.6)	5 (2.4)	0 (0)	15 (2.5)
Cured	3 (1.9)	0 (0)	2 (0.9)	0 (0)	5 (0.8)
Still POP ≥ stage 2	5 (3.2)	2 (1.6)	3 (1.4)	0 (0)	10 (1.7)
POP ≥ stage 2 or previous prolapse surgery	100 (62.9)	67 (51.1)	107 (49.3)	6 (5.9)	280 (46.1)
Levator avulsion (*n* = 606: 159, 130, 216, 101)*					
Any	65 (40.9)	19 (14.6)	29 (13.4)	0 (0)	113 (18.6)
Unilateral	29 (18.2)	10 (7.7)	17 (7.9)	0 (0)	56 (9.2)
Bilateral	36 (22.6)	9 (6.9)	12 (5.6)	0 (0)	57 (9.4)
Hiatal area (cm^2)					
At rest (*n* = 607: 159, 130, 217, 101)*	25.17 ± 5.45	22.64 ± 4.50	23.30 ± 4.58	19.85 ± 3.79	23.07 ± 4.98
On contraction (*n* = 607: 159, 130, 217, 101)*	17.82 ± 5.42	16.02 ± 4.31	15.86 ± 4.26	12.83 ± 3.24	15.90 ± 4.73
On Valsalva (*n* = 554: 151, 120, 192, 91)*‡	38.81 ± 9.79	34.27 ± 10.45	34.52 ± 9.53	26.50 ± 7.60	34.32 ± 10.29

Data are given as *n* (%) or mean ± SD. *After total *n*, numbers are given in parentheses for forceps, vacuum, normal vaginal and Cesarean delivery groups. †15 women did not respond to the question on previous prolapse surgery. ‡53 women were not able to perform a proper Valsalva.

and levator avulsion (aOR, 1.08 (95% CI, 1.02–1.13); $P < 0.01$). The largest infant's birth weight was associated with POP ≥ Stage 2 or surgery (aOR, 1.05 (95% CI, 1.01–1.09); $P = 0.02$), levator avulsion (aOR, 1.06 (95% CI, 1.01–1.12); $P = 0.02$) and larger hiatal areas. The contributing effect of parity on POP ≥ Stage 2 or surgery disappeared after adjusting for other confounding variables in the multivariable regression model. BMI was found to be a significant confounder only for hiatal area.

DISCUSSION

We found statistically significant associations between delivery mode and POP ≥ Stage 2 or previous prolapse surgery, levator avulsion and hiatal areas. Forceps delivery had increased risks of POP or surgery and levator avulsion and was associated with larger hiatal area compared with vacuum and normal vaginal delivery. Cesarean delivery had decreased risks of prolapse or surgery and levator avulsion and was associated with smaller hiatal area when compared with normal vaginal delivery. There were no differences between vacuum and normal vaginal delivery.

We studied women from the general population 16–24 years after their first delivery; a long time interval is important when studying conditions that occur several years after delivery. A sufficient number of women were followed-up after forceps ($n = 159$) and vacuum ($n = 131$) deliveries, therefore a direct comparison was possible. The quality of data on delivery mode was good, as delivery mode was defined according to the Hospital's Patient Administrative System and the Norwegian Medical Birth Registry rather than from questionnaires or interviews 16–24 years after the delivery. All clinical and ultrasound examinations were performed by one skilled urogynecologist (I.V.) and women were examined in a standardized manner.

Women included in the present study had more prolapse symptoms than women in a previously published study comprising the same population[29]. However, we found the participation rate to be similar for all delivery groups. We argue that, although the external validity may be questioned, the internal validity (comparison between delivery groups) was good. Since Norwegian women are predominantly white Europeans, a cautious interpretation of the study results is necessary for other ethnic groups.

In the present study, vacuum delivery was permitted for all fetal head positions and at higher stages in the birth canal, whereas forceps delivery was only permitted when the fetal head was in the occiput anterior or posterior position at the pelvic floor. This gives a possible bias towards more complications in the vacuum group. In addition, forceps delivery was performed twice as often as vacuum delivery (5% *vs* 2.5%) in Trondheim University Hospital during 1985–1989 and at the same frequency (3–5%) between 1990–1997. Thus, doctors were possibly better trained in forceps than vacuum

Table 3 Univariable and multivariable logistic regression and ANCOVA analyses of pelvic organ prolapse (POP) in any compartment, muscle avulsion and hiatal areas in women who delivered their first child during 1990–1997 at Trondheim University Hospital and subsequently underwent a clinical pelvic examination in 2013–2014

Variable:	*Forceps* vs *vacuum delivery*		*Forceps* vs *NVD*		*Vacuum* vs *NVD*		*Cesarean* vs *NVD*	
Categorical	*cOR*	*aOR*	*cOR*	*aOR*	*cOR*	*aOR*	*cOR*	*aOR*
POP ≥ Stage 2 or previous surgery	1.62 (1.02–2.64) $P = 0.045$	1.72 (1.06–2.79) $P = 0.03$	1.74 (1.15–2.65) $P < 0.01$	1.74 (1.12–2.68) $P = 0.01$	1.08 (0.70–1.66) $P = 0.74$	1.04 (0.66–1.64) $P = 0.87$	0.07 (0.03–0.15) $P < 0.01$	0.06 (0.02–0.14) $P < 0.01$
POP Stage 3	∞ (1.16–∞)* $P = 0.02$	—	2.45 (0.71–8.53) $P = 0.16$	2.06 (0.57–7.52) $P = 0.27$	0.00 (0.00–2.55)* $P = 0.30$	—	0.00 (0.00–3.31)* $P = 0.31$	—
Levator avulsion (uni- or bilateral)	4.04 (2.26–7.22) $P < 0.01$	4.16 (2.28–7.59) $P < 0.01$	4.46 (2.70–7.37) $P < 0.01$	4.35 (2.56–7.40) $P < 0.01$	1.10 (0.59–2.06) $P = 0.76$	0.96 (0.50–1.83) $P = 0.89$	0.00 (0.00–0.30)* $P < 0.01$	—
Continuous	*uMD*	*aMD*	*uMD*	*aMD*	*uMD*	*aMD*	*uMD*	*aMD*
Hiatal area (cm^2)								
At rest	2.53 (1.36–3.71) $P < 0.01$	2.65 (1.56–3.75) $P < 0.01$	1.87 (0.52–2.89) $P < 0.01$	1.66 (0.64–2.60) $P < 0.01$	−0.66 (−1.65 to 0.33) $P = 0.19$	−1.03 (−2.07 to 0.003) $P = 0.05$	−3.44 (−4.47 to −2.41) $P < 0.01$	−3.71 (−4.90 to −2.53) $P < 0.01$
On contraction	1.79 (0.64–2.95) $P < 0.01$	1.87 (0.82–2.91) $P < 0.01$	1.96 (0.98–2.94) $P < 0.01$	1.77 (0.83–2.70) $P < 0.01$	0.17 (−0.77 to 1.10) $P = 0.73$	−0.10 (−1.09 to 0.89) $P = 0.84$	−3.03 (−3.9 to −2.09) $P < 0.01$	−3.25 (−4.39 to −2.12) $P < 0.01$
On Valsalva	4.54 (2.11–6.97) $P < 0.01$	4.75 (2.46–7.03) $P < 0.01$	4.30 (2.23–6.36) $P < 0.01$	3.84 (1.78–5.90) $P < 0.01$	−0.25 (−2.51 to 2.02) $P = 0.83$	−0.91 (−3.1 to 1.29) $P = 0.42$	−8.01 (−10.26 to −5.77) $P < 0.01$	−8.35 (−10.87 to −5.84) $P < 0.01$

Values in parentheses are 95% CIs. Crude odds ratio (cOR) calculated from univariable logistic regression analysis and adjusted odds ratio (aOR) from multivariable logistic regression. Unadjusted mean difference (uMD) of hiatal areas between delivery modes calculated from univariable ANCOVA and adjusted mean differences (aMD) from multivariable ANCOVA. aOR and aMD were adjusted for age in 2013, parity, body mass index and birth weight of largest infant. *cOR calculated by Fisher's exact test when numbers were low. NVD, normal vaginal delivery.

delivery at the beginning of the study period. However, since doctors were well trained in both methods, we argue that the comparison between forceps and vacuum deliveries was done in a setting in which any pelvic floor trauma was most likely a consequence of the delivery method rather than of the doctor's skill. The cross-sectional study design does not allow us to suggest a cause–effect relationship between mode of delivery and POP and muscle trauma.

We studied women with a longer time interval from delivery than other similar studies[9–11]. The POP prevalence in the present study was similar to that in two previous studies[6,11] but differed from others[5,7–10,12]. This may be explained by the use of different definitions for POP or differences in study populations regarding age, parity, ethnicity and mode of delivery. Our results support previous studies demonstrating a higher prevalence of levator avulsion and larger hiatal areas after forceps than vacuum and normal vaginal deliveries[18,20–28].

Our study also confirms the results from a smaller study that demonstrated an increased risk of POP after forceps compared with normal vaginal delivery, and no increase in risk after vacuum delivery[10]. One previous study found an association between prolapse surgery and forceps delivery[34]. We found a higher prevalence of prolapse surgery after forceps (5.2%) than vacuum (1.6%) delivery, but because of small numbers we were only able to demonstrate a statistically significant difference when prolapse surgery was combined with the outcome POP ≥ Stage 2. Mean age at first prolapse surgery at Trondheim University Hospital is currently 63 years (unpubl. hospital data), whereas women in the study had a mean age 48 years. A previous study demonstrated an average latency of 33.5 years between the time of first delivery and prolapse surgery in women with avulsion[35]. Thus, a longer follow-up (more than 16–24 years) would help clarify whether prolapse surgery occurs more often after a forceps than a vacuum delivery. A longer follow-up would also help explain the lack of differences in symptoms (POP and incontinence) between the forceps and the vacuum group observed in a previous report from this study population[29].

Hiatal area was larger and there were more cases of levator avulsion in the forceps group, despite the fact that infants in the vacuum group were significantly larger. A possible explanation is that pelvic floor muscle trauma is more likely to occur during forceps delivery due to a traumatic effect of the forceps blades and the traction force exerted. The findings in this study imply that the use of vacuum should be preferred to forceps in a delivery situation in which both methods may be an option. This is supported in a recent commentary on studies of prevalence of levator avulsion[36].

In conclusion, we found that mode of delivery was associated with POP and pelvic floor muscle trauma in women from a general population, 16–24 years after their first delivery. Forceps was associated with significantly more POP, levator avulsion and larger hiatal areas than were vacuum and normal vaginal deliveries. There were no statistically significant differences between vacuum and normal vaginal deliveries. Cesarean delivery was associated with significantly less POP and pelvic floor muscle trauma than were normal or operative vaginal deliveries.

ACKNOWLEDGMENTS

We thank Christine Østerlie and Tuva K. Halle for help with identifying potential study participants, Johan Morten Dreier and Berit Marianne Bjelkaasen for help with questionnaires, and Guri Kolberg for help with coordination of clinical examinations.

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SUPPORTING INFORMATION ON THE INTERNET

The following supporting information may be found in the online version of this article:

Table S1 Association of potential confounding factors with pelvic organ prolapse ≥ Stage 2 or previous prolapse surgery, levator avulsion and hiatal area on Valsalva