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Perinatal and maternal morbidity and mortality among term singletons following midcavity operative vaginal delivery versus caesarean delivery

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Objective To quantify severe perinatal and maternal morbidity/mortality associated with midcavity operative vaginal delivery compared with caesarean delivery.

Design Population-based, retrospective cohort study.

Setting British Columbia, Canada.

Population Term, singleton deliveries (2004–2014) by attempted midcavity operative vaginal delivery or caesarean delivery in the second stage of labour, stratified by indication for operative delivery (n = 10 901 deliveries; 5057 indicated for dystocia, 5844 for fetal distress).

Methods Multinomial propensity scores and mulitvariable log-binomial regression models were used to estimate adjusted rate ratios (ARR) and 95% confidence intervals (95% CI).

Main outcome measures Composite severe perinatal morbidity/mortality (e.g. convulsions, severe birth trauma and perinatal death) and severe maternal morbidity (e.g. severe postpartum haemorrhage, shock, sepsis and cardiac complications).

Results Among deliveries with dystocia, attempted midcavity operative vaginal delivery was associated with higher rates of severe perinatal morbidity/mortality compared with caesarean delivery (forceps ARR 2.11, 95% CI 1.46–3.07; vacuum ARR 2.71, 95% CI 1.49–3.15; sequential ARR 4.68, 95% CI 3.33–6.58). Rates of severe maternal morbidity/mortality were also higher following midcavity operative vaginal delivery (forceps ARR 1.57, 95% CI 1.05–2.36; vacuum ARR 2.29, 95% CI 1.57–3.36). Among deliveries with fetal distress, there were significant increases in severe perinatal morbidity/mortality following attempted midcavity vacuum (ARR 1.28, 95% CI 1.04–1.61) and in severe maternal morbidity following attempted midcavity forceps delivery (ARR 2.34, 95% CI 1.54–3.56).

Conclusion Attempted midcavity operative vaginal delivery is associated with higher rates of severe perinatal morbidity/mortality and severe maternal morbidity, though these effects differ by indication and instrument.

Keywords Birth injury, caesarean delivery, forceps extraction, instrumental vaginal delivery, obstetric trauma, operative vaginal delivery, vacuum extraction.

Tweetable abstract Perinatal and maternal morbidity is increased following midcavity operative vaginal delivery.

Linked article This article has journal club questions by Jen Jardine, p. 703 in this issue. To view these visit https://doi.org/10.1111/1471-0528.15220.

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Introduction

The increased use of operative vaginal delivery has recently been advocated by the American College of Obstetricians and Gynecologists and the Society for Maternal–Fetal Medicine as a strategy to reduce the caesarean delivery rate.[1] The evaluation of approaches to achieve this end are underway[2] and the current discourse surrounding operative vaginal delivery centres around methods to promote the skills required to effect such intervention.[3,4] However, there is substantial uncertainty in the literature[5–11] regarding the balance of perinatal and maternal risks and benefits

between operative vaginal delivery and caesarean delivery. This is at least partly because previous research has been compromised by a lack of information on pelvic station, a key determinant of perinatal and maternal outcomes.[12–14]

Pelvic station is a measure of the descent of the fetal head with respect to the maternal ischial spines and operative vaginal deliveries are categorised as outlet, low or midcavity procedures. At midcavity station the leading part of the fetal skull is between 0 and 2 cm below the spines, at low cavity it is >2 cm below the ischial spines but not on the pelvic floor, and at outlet station the leading part of the fetal skull is on the pelvic floor and visible.[12] Operative vaginal deliveries at midcavity require the greatest operator skill and experience; consequently, it is at midcavity station that the decision between operative vaginal delivery and caesarean delivery presents a serious challenge. Midcavity operative vaginal deliveries account for up to 20% of all operative vaginal deliveries in industrialised settings and 2–3% of term, singleton deliveries overall.[15] The literature on perinatal and maternal outcomes contrasting midcavity operative vaginal delivery and caesarean delivery is based on studies undertaken 25–30 years ago[9–11] that are no longer reflective of the current obstetric practice.

We, therefore, carried out a study aimed at quantifying the effect of operative vaginal delivery at midcavity station on perinatal and maternal morbidity and mortality compared with caesarean delivery in a cohort of women in the second stage of labour.

Methods

We conducted a population-based cohort study including all term (37–41 weeks of gestation) singletons delivered by midcavity operative vaginal delivery or caesarean delivery in the second stage of labour, in British Columbia, Canada. Data for the study were obtained from the province's Perinatal Data Registry. This database contains detailed demographic and clinical information on all mothers and babies in the province and is collated by trained medical record abstractors using standardised forms and coding rules. Data quality is continually assessed by means of quality and consistency checks, and information in the database has been validated[16–18] and used routinely for health planning and research.[19,20]

The study period was restricted to fiscal years from 1 April 2004 to 31 March 2014 (hereafter referred to as years 2004–2014), when diagnoses and procedures among mothers and babies were consistently coded with the Canadian version of the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10-CA) and the Canadian Classification of Health Interventions (CCI), respectively. This included information on stage of labour and pelvic station for all operative vaginal deliveries and the stage of labour when caesarean delivery was carried out.

Deliveries were excluded if the infant had any congenital anomaly or if the mother had a hypertensive disorder, diabetes mellitus or a placental abnormality. Further exclusions were made if the fetus was in a non-vertex presentation. Deliveries were stratified by indication for operative delivery (dystocia or fetal distress).[21]

Deliveries at midcavity station were defined based on the Classification According to Station and Rotation[12] and included operative vaginal delivery by forceps, vacuum and sequential instruments in cases where the head was engaged and the leading point of the fetal skull was above the +2-cm station but below the 0-cm station. We used an intention-to-treat framework, e.g. both successful and failed forceps deliveries (followed by caesarean delivery) were included in the attempted midcavity forceps category. Attempted midcavity vacuum deliveries and attempted sequential instrumentation deliveries were defined in a similar manner.

The study included two primary outcomes, composite severe perinatal morbidity/mortality and composite severe maternal morbidity. Severe perinatal morbidity/mortality included convulsions, assisted ventilation by endotracheal intubation, 5-minute Apgar score <4, severe birth trauma (intracranial haemorrhage, skull fracture, severe injury to the central or peripheral nervous systems, long bone injury, subaponeurotic haemorrhage, and injury to liver or spleen), stillbirth and neonatal death. Severe maternal morbidity included severe postpartum haemorrhage (requiring transfusion), shock, sepsis, obstetric embolism, cardiac complications and acute renal failure. Secondary outcomes included respiratory distress in the infant (including hyaline membrane disease, idiopathic respiratory distress syndrome, transient tachypnoea of the newborn and other neonatal respiratory distress), postpartum haemorrhage, as well as birth and obstetric trauma. Birth trauma included intracranial haemorrhage, injury to the central or peripheral nervous systems, injury to the scalp or the skeleton, and other birth injury. Obstetric trauma included severe perineal lacerations (third- and fourth-degree), cervical and high vaginal laceration, pelvic haematoma, obstetric injury to the pelvic organs, pelvic joints or ligaments, and other obstetric trauma. The inclusion and exclusion criteria, indications for operative delivery, confounders and outcomes of interest along with the associated ICD-10-CA and CCI codes used in the study are listed in the Supporting information (Table S1).

The effect of midcavity operative vaginal delivery was quantified using two approaches, namely, confounder adjustment using propensity score methods and multivariable regression. Although regression methods are commonly used to adjust for confounding factors in non-experimental

studies, propensity score analysis has recently gained traction especially in studies involving rare outcomes. Propensity score analysis involves a two-step procedure in which the propensity for a subject to have received an intervention (midcavity operative vaginal or caesarean delivery) is first quantified based on their confounder patterns. Adjustment for this propensity score is carried out through a second step that effectively eliminates bias due to associations between the determinant being studied (midcavity operative vaginal delivery) and the confounding factors.

We used multinomial propensity scores to estimate the probability that a woman would have delivered by midcavity forceps, midcavity vacuum, sequential midcavity instrumentation or caesarean delivery given her covariate pattern after stratifying by indication (dystocia or fetal distress). The confounders included in the propensity score were maternal age (<20, 20–24, 25–29, 30–34, 35–39, ≥40 years), parity (0, ≥1), prepregnancy weight (kg), previous caesarean delivery (Y/N), position of the fetal head at delivery (occiput anterior versus occiput posterior/transverse), birthweight (<3000, 3000–3499, 3500–3999, 4000–4499, ≥4500 g), income quintile (a household size-adjusted measure of household income; lower values represent lower income) and year of birth. All possible two-way interactions were included in the propensity score estimation. We used the Toolkit for Weighting and Analysis of Nonequivalent Groups (TWANG) package to estimate the propensity scores and weights by implementing generalised boosted regression models.[22] Box plots were used to assess overlap between the weighted mode of delivery groups. We then used log-binomial regression to regress our composite perinatal and maternal outcomes against indicator variables denoting mode of delivery in the weighted sample. Adjusted rate ratios (ARR) and 95% confidence intervals (CI) were obtained.

In addition, we modelled the same associations using (1) logistic regression adjusting for the same eight covariates listed above and (2) multivariable logistic regression with propensity score weighting and including the same eight covariates that were included in the propensity score to obtain doubly robust estimators. These estimates were interpreted as ARRs since the outcomes were rare. Modification of the effect of mode of delivery on perinatal and maternal morbidity/mortality by position of the fetal head at delivery (occiput anterior versus occiput posterior/transverse) and by a diagnosis of prolonged second stage of labour (ICD-10 CA O631, yes/no) was examined by introducing interaction terms into the regression models. Missing values for prepregnancy weight (15%), position of the fetal head at delivery (29%) and income quintile (1.5%) were addressed with multiple imputation using the fully conditional method to create ten imputed data sets. The discriminant function method was used to impute values for categorical variables and linear regression was used for continuous variables.[23] Lastly, the magnitude of absolute effects was quantified by calculating adjusted rate differences and the adjusted number-needed-to-treat (NNT). The adjusted NNTs represent the number of women delivered by operative vaginal delivery that would have had to be delivered by caesarean to avoid one case of the outcome of interest. All analyses were carried out using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). The study was approved by the University of British Columbia's Clinical Research Ethics Board (H12-0277).

Patient involvement

Patients were not involved in the development or design of this study.

Results

The study population included 10 901 deliveries; 5057 attempted midcavity operative vaginal or caesarean deliveries with dystocia and 5844 attempted midcavity operative vaginal or caesarean deliveries with fetal distress (see Supporting information, Figure S1). The rate of severe perinatal morbidity/mortality was 1.42% and 2.34% in the dystocia and fetal distress groups, respectively. The rate of severe maternal morbidity was 1.03% in both groups. Nulliparous women, older women (≥35 years), women with higher prepregnancy weight (≥70 kg) and those who delivered at later gestational ages were more likely to have had a caesarean delivery (Table 1). Attempted midcavity forceps was more commonly used in nulliparous women compared with attempted midcavity vacuum, whereas the reverse was true among multiparous women. Attempted operative vaginal delivery was more common in deliveries with babies of lower birthweight, whereas caesarean delivery was more frequent in macrosomic infants (≥4000 g). Women with dystocia had higher rates of caesarean delivery compared with women who had fetal distress. Operative vaginal delivery was more likely to be successful following forceps attempts (92.6% and 91.5% among women with dystocia and fetal distress, respectively) than following vacuum extraction attempts (80.0% and 88.1%, respectively; Table 1). Propensity score weighting converged and achieved good balance in the mode of delivery groups; the overlap of propensity scores in the weighted groups was satisfactory in both the dystocia and fetal distress cohorts (see Supporting information, Figures S2, S3, S4 and S5).

Severe perinatal morbidity/mortality

Among deliveries with dystocia, attempted midcavity operative vaginal delivery was associated with higher rates of severe perinatal morbidity/mortality compared with

Table 1. Mode of delivery by maternal, infant and obstetric factors among women in the second stage of labour delivering term singletons by attempted midcavity operative vaginal delivery (OVD) or caesarean delivery, British Columbia, 2004–2014 (*n* = 10 901)

Maternal/neonatal characteristic	Caesarean delivery (*n* = 4524) *n* (%)	Attempted midcavity forceps (*n* = 3978) *n* (%)	Attempted midcavity vacuum (*n* = 1913) *n* (%)	Attempted sequential midcavity OVD (*n* = 486) *n* (%)	*P*-value*
Maternal age (years)					
<20	96 (39.3)	79 (32.4)	51 (20.9)	18 (7.4)	<0.001
20–24	506 (39.4)	426 (33.1)	288 (22.4)	66 (5.1)	
25–29	1309 (41.4)	1109 (35.1)	583 (18.5)	158 (5.0)	
30–34	1638 (42.3)	1464 (37.8)	608 (15.7)	163 (4.2)	
35–39	798 (41.2)	753 (38.9)	318 (16.4)	69 (3.6)	
≥40	177 (44.1)	147 (36.7)	65 (16.2)	12 (3.0)	
Parity					
0	3860 (42.6)	3433 (37.9)	1382 (15.2)	388 (4.3)	<0.001
≥1	664 (36.1)	545 (29.7)	531 (28.9)	98 (5.3)	
Pre-pregnancy weight (kg)					
<55	956 (36.9)	1063 (41.0)	439 (16.9)	133 (5.1)	<0.001
55–59	678 (39.9)	652 (38.4)	295 (17.4)	75 (4.4)	
60–69	1131 (41.9)	986 (36.5)	466 (17.3)	117 (4.3)	
≥70	1082 (47.5)	730 (32.1)	373 (16.4)	91 (4.0)	
Missing	677 (41.4)	547 (33.5)	340 (20.8)	70 (4.3)	
Gestational age (weeks)					
37–38	868 (38.1)	865 (38.0)	448 (19.7)	98 (4.3)	<0.001
39–41	3656 (42.4)	3113 (36.1)	1465 (17.0)	388 (4.5)	
Position of fetal head at delivery					
Occiput anterior	1063 (19.9)	2777 (51.9)	1222 (22.8)	289 (5.4)	<0.001
Occiput posterior/transverse	1632 (67.0)	448 (18.4)	266 (10.9)	89 (3.7)	
Missing	1829 (58.7)	753 (24.2)	425 (13.6)	108 (3.5)	
Birthweight (g)					
<2500	11 (17.2)	30 (46.9)	21 (32.8)	<5 (<8.0)	<0.001
2500–2999	315 (30.5)	451 (43.6)	229 (22.1)	39 (3.8)	
3000–3499	1464 (37.2)	1573 (39.9)	723 (18.4)	180 (4.6)	
3500–3999	1761 (43.6)	1404 (34.8)	688 (17.0)	184 (4.6)	
≥4000	973 (53.3)	520 (28.5)	252 (13.8)	81 (4.4)	
Episiotomy					
None	4524 (59.6)	1534 (20.2)	1306 (17.2)	222 (2.9)	<0.001
Median	0 (0.0)	110 (50.5)	77 (35.3)	31 (14.2)	
Mediolateral	0 (0.0)	2334 (75.4)	530 (17.1)	233 (7.5)	
Indication					
Dystocia	2405 (47.6)	1763 (34.9)	690 (13.6)	199 (3.9)	<0.001
Fetal distress	2119 (36.3)	2215 (37.9)	1223 (20.9)	287 (4.9)	
Income quintile					
1	941 (41.8)	817 (36.3)	384 (17.1)	109 (4.8)	0.46
2	943 (41.0)	886 (38.5)	379 (16.5)	91 (4.0)	
3	959 (42.7)	801 (35.6)	383 (17.0)	105 (4.7)	
4	892 (40.9)	781 (35.8)	414 (19.0)	92 (4.2)	
5	725 (41.2)	628 (35.7)	328 (18.6)	80 (4.5)	
Missing	64 (39.3)	65 (39.9)	25 (15.3)	9 (5.5)	
Successful OVD trial**					
Dystocia	–	1633 (92.6)	552 (80.0)	164 (82.4)	<0.001
Fetal distress	–	2027 (91.5)	1078 (88.1)	244 (85.0)	

*Chi-square or Fisher's exact test.

**Successful OVDs express the number (%) of successful OVDs in a specific category divided by the number of attempted OVDs in that category stratified by indication (dystocia or fetal distress).

caesarean delivery (forceps 1.7%, vacuum 2.2%, sequential 3.5% and caesarean 0.8%; forceps ARR 2.11, 95% CI 1.46–3.07, vacuum ARR 2.17, 95% CI 1.49–3.15, sequential ARR 4.68, 95% CI 3.33–6.58; Table 2). Rates of severe birth trauma were similarly higher in attempted forceps deliveries (1.0%; ARR 4.33, 95% CI 2.31–8.11) and attempted vacuum deliveries (1.0%; ARR 3.16, 95% CI 1.65–6.05) compared with caesarean delivery (0.3%). Sequential midcavity instrument use was associated with the highest rates of severe birth trauma (ARR 8.04, 95% CI 4.41–14.7) and any birth trauma (11.6% versus 1.2% in caesarean deliveries; ARR 10.2, 95% CI 7.75–13.5; Table 2). Attempted midcavity forceps and vacuum deliveries were also associated with significantly higher rates of respiratory distress and all birth trauma (Table 2 and see Supporting information, Table S2).

Among deliveries with fetal distress, the rate of severe perinatal morbidity/mortality was similar in the attempted midcavity forceps, sequential instrument and caesarean delivery groups. However, it was significantly higher in the attempted midcavity vacuum group (2.6% versus 1.9% in caesarean group; ARR 1.28, 95% CI 1.04–1.61; Table 3 and see Supporting information, Table S2). Severe birth trauma rates were higher in all the attempted midcavity operative vaginal delivery group (forceps 1.1%; ARR 4.90, 95% CI 2.73–8.82; vacuum 0.7%; ARR 2.31, 95% CI 1.21–4.40; sequential <1.7%; ARR 3.18, 95% CI 1.68–6.00) compared with the caesarean delivery group (0.2%). The rate of assisted ventilation by endotracheal tube was significantly lower among attempted midcavity forceps deliveries compared with caesarean delivery (ARR 0.69, 95% CI 0.49–0.97). The rate of any birth trauma was higher in all operative vaginal delivery categories (forceps 4.4% versus 1.8% following caesarean delivery; ARR 3.18, 95% CI 2.50–4.05; vacuum 5.3%; ARR 3.64, 95% CI 2.86–4.62; sequential 9.4%; ARR 6.42, 95% CI 5.09–8.08). Adjusted rate differences, 95% CIs, and adjusted NNTs are listed in Table 4; NNT for severe perinatal morbidity/mortality was 109 for midcavity forceps, 103 for midcavity vacuum and 33 for sequential instrumentation in deliveries with dystocia.

Severe maternal morbidity

Rates of severe maternal morbidity were higher following midcavity operative vaginal delivery compared with caesarean delivery in the dystocia group (1.2% and 1.5% following forceps and vacuum, respectively compared with 0.8% following caesarean delivery; forceps ARR 1.57, 95% CI 1.05–2.36; vacuum ARR 2.29, 95% CI 1.57–3.36); Table 2 and see Supporting information, Table S2). In deliveries with fetal distress, rates of maternal morbidity were increased following attempted midcavity forceps (1.5% versus 0.7% in caesarean delivery; ARR 2.34, 95% CI

Table 2. Rate ratios expressing the association between operative vaginal delivery (OVD) versus caesarean delivery and severe perinatal and maternal morbidity/mortality among women with dystocia with adjustment using weighted multinomial propensity scores, British Columbia, 2004–2014

Outcome	Caesarean delivery (*n* = 2405)		Attempted midcavity forceps (*n* = 1763)		Attempted midcavity vacuum (*n* = 690)		Attempted sequential midcavity OVD (*n* = 199)	
	Rate (%)	ARR (95% CI)	Rate (%)	ARR (95% CI)	Rate (%)	ARR (95% CI)	Rate (%)	ARR (95% CI)
Severe perinatal morbidity/mortality	0.83	Reference	1.70	2.11 (1.46–3.07)	2.17	2.17 (1.49–3.15)	3.52	4.68 (3.33–6.58)
Severe birth trauma	0.29	Reference	0.96	4.33 (2.31–8.11)	1.01	3.16 (1.65–6.05)	<2.51	8.04 (4.41–14.7)
Assisted ventilation by endotracheal tube	0.25	Reference	0.51	1.21 (0.61–2.37)	<0.72	1.36 (0.70–2.64)	<2.51	4.05 (2.31–7.10)
Respiratory distress	1.49	Reference	3.63	1.68 (1.33–2.12)	4.78	1.84 (1.46–2.31)	4.52	1.99 (1.58–2.50)
Birth trauma	1.16	Reference	4.03	4.18 (3.12–5.61)	7.68	7.65 (5.78–10.1)	11.6	10.2 (7.75–13.5)
Severe maternal morbidity	0.79	Reference	1.19	1.57 (1.05–2.36)	1.45	2.29 (1.57–3.36)	<2.51	1.48 (0.98–2.25)
Severe postpartum haemorrhage	0.50	Reference	0.96	2.46 (1.43–4.25)	1.30	4.17 (2.50–6.97)	<2.51	1.78 (1.00–3.20)
Postpartum haemorrhage	4.62	Reference	21.2	4.39 (3.80–5.07)	13.9	3.38 (2.92–3.93)	17.6	3.91 (3.38–4.53)
Obstetric trauma	3.83	Reference	26.4	8.48 (7.22–9.96)	11.6	3.61 (3.03–4.29)	22.6	6.90 (5.86–8.13)
Severe perineal laceration (third/fourth degree)*	0.00	Reference	23.0 (21.1–25.0)		10.3 (8.24–12.8)		21.1 (16.0–27.3)	

Results adjusted for maternal age, parity, previous caesarean delivery, pre-pregnancy weight, position of fetal head at delivery, birthweight, income quintile, and year of delivery.
*Rate (%) and 95% CI provided for severe perineal lacerations as relative estimates could not be estimated due to small numbers (0.00%) in the reference group.

Table 3. Rate ratios expressing the association between operative vaginal delivery (OVD) versus caesarean delivery and severe perinatal and maternal morbidity/mortality among women with fetal distress with adjustment using weighted multinomial propensity scores, British Columbia, 2004–2014

Outcome	Caesarean delivery (*n* = 2119)		Attempted midcavity forceps (*n* = 2215)		Attempted midcavity vacuum (*n* = 1223)		Attempted sequential midcavity OVD (*n* = 287)	
	Rate (%)	ARR (95% CI)	Rate (%)	ARR (95% CI)	Rate (%)	ARR (95% CI)	Rate (%)	ARR (95% CI)
Severe perinatal morbidity/mortality	1.89	Reference	2.66	1.15 (0.90–1.45)	2.62	1.28 (1.04–1.61)	2.09	1.04 (0.80–1.35)
Severe birth trauma	0.24	Reference	1.13	4.90 (2.73–8.82)	0.65	2.31 (1.21–4.40)	<1.74	3.18 (1.68–6.00)
Neonatal convulsions	0.42	Reference	0.32	0.66 (0.36–1.21)	0.49	1.27 (0.76–2.15)	<1.74	1.23 (0.70–2.14)
Assisted ventilation by endotracheal tube	1.13	Reference	1.08	0.69 (0.49–0.97)	1.55	1.18 (0.87–1.59)	<1.74	0.41 (0.26–1.22)
5-minute Apgar <4	0.33	Reference	0.32	0.68 (0.35–1.32)	0.49	1.87 (1.10–3.17)	<1.74	1.11 (0.59–2.07)
Respiratory distress	7.13	Reference	7.31	1.07 (0.93–1.23)	6.62	1.09 (0.95–1.26)	9.06	1.60 (1.40–1.83)
Birth trauma	1.84	Reference	4.42	3.18 (2.50–4.05)	5.31	3.64 (2.86–4.62)	9.41	6.42 (5.09–8.08)
Severe maternal morbidity	0.66	Reference	1.53	2.34 (1.54–3.56)	0.57	0.79 (0.46–1.35)	1.74	2.96 (1.94–4.51)
Severe postpartum haemorrhage	0.33	Reference	1.31	4.19 (2.39–7.37)	<0.41	0.80 (0.37–1.72)	<1.74	3.97 (2.21–7.13)
Sepsis	<0.24	Reference	<0.23	0.71 (0.30–1.67)	< 0.41	1.03 (0.46–2.27)	<1.74	2.65 (1.34–5.25)
Postpartum haemorrhage	5.05	Reference	19.8	3.89 (3.41–4.44)	12.4	2.76 (2.40–3.17)	17.8	3.90 (3.41–4.47)
Obstetric trauma	4.77	Reference	24.2	5.63 (4.91–6.45)	9.89	2.78 (2.40–3.23)	25.8	6.42 (5.59–7.36)
Severe perineal laceration (third/fourth degree)*	0.00	Reference	19.8 (18.2–21.5)		8.50 (7.07–10.2)		22.0 (17.6–27.1)	

Results adjusted for maternal age, parity, previous caesarean delivery, pre-pregnancy weight, position of fetal head at delivery, birthweight, income quintile, and year of delivery.
*Rate (%) and 95% CI provided for severe perineal lacerations as relative estimates were not estimable due to small numbers (0.00%) in the reference group.

1.54–3.56) and sequential operative vaginal delivery (1.7%; ARR 2.96, 95% CI 1.94–4.51; Table 3). This higher maternal morbidity was mainly due to higher rates of severe postpartum haemorrhage in the midcavity forceps group (1.3% versus 0.3%; ARR 4.19, 95% CI 2.39–7.37). In women with dystocia, the ARR for severe postpartum haemorrhage among women delivered by midcavity forceps was 2.46 (95% CI 1.43–4.25), whereas the same ARR was 4.17 (95% CI 2.50–6.97) for women delivered by vacuum (Table 2).

Obstetric trauma

Obstetric trauma rates were high following attempted vacuum delivery (11.6% versus 3.8% following caesarean deliveries; ARR 3.61, 95% CI 3.03–4.29; Table 2 and see Supporting information, Table S2) and highest following attempted midcavity forceps delivery (26.4% versus 3.8%; ARR 8.48, 95% CI 7.22–9.96) among women with dystocia. Obstetric trauma rates among deliveries with fetal distress were similar (Table 3 and see Supporting information, Table S2). Severe perineal laceration rates were high among attempted midcavity operative vaginal deliveries, ranging from 8.5% following attempted vacuum deliveries for fetal distress to 23.0% among attempted forceps deliveries for dystocia (see Supporting information, Figures S6 and S7). NNT for obstetric trauma was three for midcavity forceps, ten for midcavity vacuum and four for sequential instrumentation among women with dystocia (Table 4).

Sensitivity analyses and effect modification

The associations between attempted midcavity operative vaginal delivery and severe perinatal and maternal morbidity/mortality were similar when a multivariable logistic regression model was used although the confidence intervals were wider in the logistic regression model (see Supporting information, Table S3). The model using propensity score weights and doubly robust estimators also produced similar estimates although the ARRs were attenuated in the log-binomial model with propensity score weighting alone (see Supporting information, Table S4). The estimates from the data with multiple imputation were very similar to the complete case estimates. The association between attempted midcavity vacuum delivery and severe perinatal morbidity/mortality was modified by the position of the fetal head at delivery among deliveries with fetal distress (ARR for deliveries with fetal head in occiput anterior

Table 4. Adjusted rate differences (RD; per 100 deliveries) and number needed to treat (NNT) for perinatal and maternal outcomes following attempted midcavity operative vaginal delivery (OVD) compared with caesarean delivery, British Columbia, 2004–2014

Outcome	Attempted midcavity forceps			Attempted midcavity vacuum			Attempted midcavity sequential OVD		
	RD	95% CI	NNT	RD	95% CI	NNT	RD	95% CI	NNT
Dystocia									
Severe perinatal morbidity/mortality	0.92	(0.38–1.72)	109	0.97	(0.41–1.78)	103	3.05	(1.93–4.63)	33
Severe birth trauma	0.97	(0.38–2.06)	104	0.63	(0.19–1.46)	160	2.04	(0.99–3.97)	49
Respiratory distress	1.01	(0.49–1.67)	99	1.25	(0.69–1.95)	80	1.48	(0.86–2.24)	68
Birth trauma	3.69	(2.46–5.35)	27	7.71	(5.54–10.6)	13	10.7	(7.83–14.5)	9
Severe maternal morbidity	0.45	(0.04–1.07)	222	1.02	(0.45–1.86)	98	0.38	(−0.02–0.99)	264
Severe postpartum haemorrhage	0.73	(0.22–1.63)	137	1.59	(0.75–2.99)	63	0.39	(0.00–1.10)	256
Postpartum haemorrhage	15.7	(12.9–18.8)	6	11.0	(8.87–13.5)	9	13.4	(11.0–16.3)	7
Obstetric trauma	28.7	(23.8–34.3)	3	11.8	(9.15–14.9)	10	22.6	(18.6–27.3)	4
Fetal distress									
Severe perinatal morbidity/mortality	0.28	(−0.19 to 0.85)	353	0.53	(0.08–1.15)	189	0.08	(−0.38 to 0.66)	1323
Severe birth trauma	0.94	(0.42–1.88)	107	0.31	(0.05–0.82)	318	0.52	(0.16–1.20)	191
Assisted ventilation (endotracheal tube)	−0.35	(−0.58 to −0.03)	−285	0.20	(−0.15 to 0.67)	492	−0.67	(−0.84 to 0.25)	−150
Respiratory distress	0.50	(−0.50 to 1.64)	200	0.64	(−0.36 to 1.85)	156	4.28	(2.85–5.92)	23
Birth trauma	4.01	(2.76–5.61)	25	4.86	(3.42–6.66)	21	9.97	(7.53–13.0)	10
Severe maternal morbidity	0.88	(0.36–1.69)	113	−0.14	(−0.36 to 0.23)	−722	1.29	(0.62–2.32)	77
Severe postpartum haemorrhage	1.05	(0.46–2.10)	95	−0.07	(−0.21 to 0.24)	−1515	0.98	(0.40–2.02)	102
Postpartum haemorrhage	14.6	(12.2–17.4)	7	8.89	(7.07–11.0)	11	14.7	(12.2–17.5)	7
Obstetric trauma	22.1	(18.7–26.0)	5	8.49	(6.68–10.6)	12	25.9	(21.9–30.3)	4

The adjusted NNT reflects the average number of women delivered by operative vaginal delivery that would have had to be delivered by caesarean to avoid one case of the outcome of interest. Adjusted rate differences estimated using caesarean delivery as the reference group. All models adjusted for maternal age, parity, prepregnancy weight, previous caesarean delivery, position of the fetal head at delivery, birthweight, income quintile and year of delivery.

position 0.97 (95% CI 0.48–1.96), ARR in deliveries with fetal head in occiput posterior position 3.00 (95% CI 1.28–7.01, *P*-value for interaction 0.03; see Supporting information, Table S5).

The association between attempted midcavity operative vaginal delivery and severe perinatal morbidity/mortality was similar among women with and without a prolonged second stage of labour (see Supporting information, Tables S6 and S7). However, the association between attempted midcavity forceps and severe maternal morbidity was modified by duration of second stage among deliveries with fetal distress (ARR without prolonged second stage 5.58, 95% CI 1.94–16.1, ARR with prolonged second stage 0.86, 95% CI 0.32–2.29, *P* value for interaction 0.003; see Supporting information, Table S7). Prolonged second stage similarly attenuated the association between attempted midcavity forceps delivery and respiratory distress and obstetric trauma among women with dystocia and between attempted midcavity vacuum delivery and postpartum haemorrhage among deliveries with fetal distress.

Discussion

Main findings

Our study showed that among term singleton deliveries in the second stage of labour, attempted midcavity operative vaginal delivery was associated with an increased risk of severe perinatal morbidity/mortality compared with caesarean delivery. The magnitude of the increased risk varied by indication for delivery, being significantly larger in the dystocia group relative to the fetal distress group. This difference in the effect of attempted operative vaginal delivery by indication appears to reflect the greater fetal jeopardy associated with fetal distress and the consequent higher baseline rate of adverse outcomes even in the caesarean delivery group. We also found substantially greater risk of birth and obstetric trauma following operative vaginal delivery compared with caesarean delivery, with 2.8- to 8.5-fold higher rates depending on indication and instrument. Composite severe maternal morbidity rates were higher

among operative vaginal delivery groups compared with the caesarean delivery group except for midcavity vacuum deliveries among women with fetal distress.

Strengths and limitations

The strengths of our data source and analysis include an ability to identify operative vaginal deliveries at midcavity station and to restrict our caesarean delivery cohort to women in the second stage of labour. Women who had a failed operative vaginal delivery (and eventually delivered by caesarean) were included in the operative vaginal delivery group. This ensured a clinically appropriate comparison of the different modes of delivery using an intention-to-treat framework. We used propensity score analysis, which has advantages over regression analysis estimates in specific situations,[24–27] although in this instance the findings were similar to results from multivariable regression.

The limitations of our study include its non-experimental design. Although we used state-of the-art propensity score analysis and multivariable regression methods to control for confounding, such methods cannot address imbalances between groups due to unmeasured confounders. On the other hand, the feasibility of conducting randomised trials for assessing the safety of midcavity operative vaginal delivery is questionable. More importantly, non-experimental evaluation of the unintended effects of midcavity vacuum and forceps delivery on maternal and perinatal severe morbidity (such as obstetric and birth trauma) is not likely to be compromised by confounding by indication (which biases estimates of the intended effect).[28] The inability to account for the skill of the operator is another potential limitation; the findings of our study may not be applicable to practitioners with proficiency and expertise in midcavity operative vaginal delivery. Nevertheless, our study quantifies the effect of the average contemporary practitioner in Canada and this is relevant for women in labour who have a limited ability to assess their provider's expertise in midcavity operative vaginal delivery. Another limitation relates to the determination of pelvic station, which can be challenging *per se* and can be affected by moulding and fetal head position.[29,30] Our study findings reflect the average safety of midcavity operative vaginal delivery as carried out under current norms of diagnosis and available expertise. Although we restricted caesarean deliveries to those carried out in the second stage of labour, we were constrained by our inability to ascertain information on pelvic station for caesarean deliveries. However, only a small fraction of caesarean deliveries would have been carried out with the fetal head above midcavity station.[31] On the other hand, our estimates of the adverse effects of midcavity operative vaginal delivery may have been underestimated as some caesarean deliveries in the second stage of labour would have been carried out with the fetal head below midcavity station.[32,33] Further limitations of our data source included the absence of information on the use of rotational forceps and missing information on a significant fraction of subjects for variables such as prepregnancy weight and position of the fetal head, which was addressed using multiple imputation. We were also unable to assess long-term effects of caesarean delivery and midcavity operative vaginal delivery.

Interpretation

The increase in severe maternal morbidity following midcavity forceps delivery was primarily due to the increased rate of severe postpartum haemorrhage. Higher rates of severe postpartum haemorrhage were also found in midcavity vacuum deliveries among women with dystocia. Increased rates of postpartum haemorrhage following vacuum delivery at low and outlet station has been reported previously,[34] although such reports were restricted to babies with birthweight ≥4000 g. Studies that have compared postpartum haemorrhage in midcavity operative vaginal deliveries and caesarean deliveries have yielded conflicting results[8,9,35,36] at least partly due to differences in definitions of postpartum haemorrhage. We defined severe postpartum haemorrhage as postpartum haemorrhage requiring transfusion to ensure a clinically meaningful and standardised outcome. Although cases of postpartum haemorrhage observed in our study were due to atonic postpartum haemorrhage, the high rates of obstetric trauma following midcavity operative vaginal delivery in our study suggest that some proportion of such haemorrhage was due to cervical, vaginal and perineal trauma.[37]

Third- and fourth-degree perineal laceration rates in our study were high following midcavity operative vaginal delivery. Similar high rates have been reported in other recent studies of operative vaginal delivery.[13,31] Validation studies[18] show that the diagnosis of third- and fourth-degree perineal lacerations in Canadian hospitalisation data is accurate (sensitivity and specificity of 97.1% and 99.9%, respectively, for third-degree, and 94.7% and 99.9%, respectively, for fourth-degree tears). With rates of obstetric anal sphincter injury as high as 23.0% following attempted midcavity forceps deliveries, it is imperative that the risks and relevant long-term quality-of-life implications for pelvic floor health of attempted midcavity operative vaginal delivery be discussed with women both in the antenatal period, as well as during labour (as currently done with regard to the surgical risks associated with caesarean delivery).

Conclusion

Attempted midcavity operative vaginal delivery is associated with substantially higher rates of severe birth trauma and obstetric trauma. Rates of severe perinatal and maternal morbidity/mortality following midcavity operative vaginal

delivery are also increased, though these associations vary by indication and instrument used. The retrospective nature of our analysis limits our ability to make causal inferences based on these results and carefully designed prospective studies examining this issue are warranted. Nevertheless, our results suggest that encouraging higher rates of operative vaginal delivery as a strategy to reduce the caesarean delivery rate could result in increases in severe perinatal and maternal morbidity, especially birth trauma, severe postpartum haemorrhage and obstetric trauma.

Disclosure of interest

None declared. Completed disclosure of interests form available to view online as Supporting Information.

Contribution to authorship

GMM and KSJ proposed the study concept and design and were assisted by AS, SL, YS, RB and GWC. GMM acquired the data and carried out the analyses. AS, SL, YS, RB, GWC and KSJ reviewed the preliminary and final analyses. GMM drafted the manuscript and AS, SL, YS, RB, GWC and KSJ provided critical input in connection with the intellectual content. All authors approved the final version of the manuscript.

Details of ethics approval

The study was approved on 3 December 2012 by the University of British Columbia's Clinical Research Ethics Board (H12-0277).

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Supporting Information

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

Figure S1. Derivation of study cohort.

Figure S2. Propensity score unweighted and weighted effect size plots for the dystocia cohort.

Figure S3. Propensity score unweighted and weighted effect size plots for the fetal distress cohort.

Figure S4. Propensity score overlap assessment by mode of delivery in the dystocia cohort.

Figure S5. Propensity score overlap assessment by mode of delivery in the fetal distress cohort.

Figure S6. Rates (per 100 deliveries) and 95% confidence intervals of third and fourth-degree perineal lacerations following midcavity operative vaginal delivery by instrument, indication, and type of episiotomy, British Columbia, 2004–2014.

Figure S7. Rates (per 100 deliveries) and 95% confidence intervals of third and fourth-degree perineal lacerations following midcavity operative vaginal delivery by instrument and indication, British Columbia, 2004–2014.

Table S1. International Classification of Diseases and Related Health Problems Tenth Revision, Canadian version (ICD-10-CA), and Canadian Classification of Health Interventions (CCI) codes used for population selection and to classify determinants, outcomes, and confounders.

Table S2. Numbers and rates of all components of perinatal and maternal outcomes by attempted mode of delivery, British Columbia, 2004–2014.

Table S3. Rate ratios expressing the association between operative vaginal delivery (OVD) versus caesarean delivery and severe perinatal and maternal morbidity/mortality among women with dystocia and fetal distress with adjustment using multivariable logistic regression, British Columbia, 2004–2014.

Table S4. Rate ratios expressing the association between operative vaginal delivery (OVD) versus caesarean delivery and severe perinatal and maternal morbidity/mortality among women with dystocia and fetal distress with adjustment using regression with propensity score weights and doubly robust estimators, British Columbia, 2004–2014.

Table S5. Adjusted rate ratios (ARR) and 95% confidence intervals (CI) for severe perinatal and maternal composite morbidity and mortality following deliveries by attempted midcavity operative vaginal delivery compared with caesarean delivery, stratified by position of fetal head at delivery, British Columbia, 2004–2014.

Table S6. Adjusted rate ratios (ARR) and 95% confidence intervals (CI) for perinatal and maternal outcomes following deliveries with dystocia by attempted midcavity operative vaginal delivery compared with caesarean delivery, stratified by prolonged second stage of labour, British Columbia, 2004–2014.

Table S7. Adjusted rate ratios (ARR) and 95% confidence intervals (CI) for perinatal and maternal outcomes following deliveries with fetal distress by attempted midcavity operative vaginal delivery compared with caesarean delivery, stratified by prolonged second stage of labour, British Columbia, 2004–2014. ■

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