

Mode of delivery after a previous cesarean birth, and associated maternal and neonatal morbidity

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ABSTRACT

BACKGROUND: The mode of delivery for women with a previous cesarean delivery remains contentious. We conducted a study comparing maternal and infant outcomes after attempted vaginal birth after cesarean delivery versus elective repeat cesarean delivery.

METHODS: We used data from the Discharge Abstract Database that includes all hospital deliveries in Canada (excluding Quebec). In our analysis, we included singleton deliveries to women between 37 and 43 weeks gestation who had a single prior cesarean delivery between April 2003 and March 2015. The primary outcomes were severe maternal morbidity and mortality, and serious neonatal

morbidity and mortality. We used logistic regression to estimate adjusted rate ratios (RRs) and 95% confidence intervals (CIs).

RESULTS: Absolute rates of severe maternal morbidity and mortality were low but significantly higher after attempted vaginal birth after cesarean delivery compared with elective repeat cesarean delivery (10.7 v. 5.65 per 1000 deliveries, respectively; adjusted RR 1.96, 95% CI 1.76 to 2.19). Adjusted rate differences in severe maternal morbidity and mortality, and serious neonatal morbidity and mortality were small (5.42 and 7.09 per 1000 deliveries, respectively; number needed to treat 184 and 141, respectively). The association between

vaginal birth after cesarean delivery, and serious neonatal morbidity and mortality showed a temporal worsening (adjusted RR 0.94, 95% CI 0.77 to 1.15 in 2003–2005; adjusted RR 2.07, 95% CI 1.83 to 2.35 in 2012–2014).

INTERPRETATION: Although absolute rates of adverse outcomes are low, attempted vaginal birth after cesarean delivery continues to be associated with higher relative rates of severe morbidity and mortality in mothers and infants. Temporal worsening of infant outcomes after attempted vaginal birth after cesarean delivery highlights the need for greater care in selecting candidates, and more careful monitoring of labour and delivery.

Vaginal birth after cesarean delivery is increasingly contentious as rates of cesarean delivery rise and prior cesarean delivery serves as the most common single indication for a cesarean delivery. Planning mode of delivery for women with a previous cesarean delivery is challenging both for the patient and the care provider. An elective repeat cesarean delivery is associated with an increased risk of surgical complications, as well as an increased risk of abnormal placentation in subsequent pregnancies.^{1–11} On the other hand, attempted vaginal birth after cesarean delivery is associated with a higher risk of uterine rupture and other maternal and infant complications.^{1–11} In addition, a substantial proportion of women attempting a vaginal birth after cesarean delivery will require an emergency cesarean delivery,^{7,10} which increases the risk of maternal and infant complications.¹¹

Historically, rates of vaginal birth after cesarean delivery in Canada and the United States increased in the 1980s and early 1990s after endorsements by various groups including the Society of Obstetricians and Gynaecologists of Canada, and the

American College of Obstetricians and Gynecologists.^{12–17} However, studies in the mid-1990s, which showed high rates of severe maternal and infant morbidity associated with vaginal birth after cesarean delivery, resulted in cautionary guidelines from the American College of Obstetricians and Gynecologists in 1998 and 1999, and subsequent declines in rates of vaginal birth after cesarean delivery.^{1,2,18,19} The National Institutes of Health Consensus Development Conference Panel summarized the risks and benefits associated with vaginal birth after cesarean delivery in 2010, and in 2013, the American College of Obstetrics and Gynecology stated that most women with 1 previous cesarean delivery could be considered candidates for vaginal birth.^{9,20} Rates of vaginal birth after cesarean delivery have begun to increase again in the US from a low of about 8.4% of all births in 2008 and 2009 to 11.3% in 2014.²¹ In British Columbia, Canada, the proportion of women with a previous cesarean delivery who were deemed eligible for vaginal birth after cesarean delivery increased from 75% in 2010 to 80% in 2014.²²

It is important to monitor population rates of maternal and infant adverse outcomes after attempted vaginal birth after cesarean delivery because a uterine scar is a strong risk factor for uterine rupture. We conducted a study to assess whether contemporary obstetrical care has improved maternal and infant outcomes after attempted vaginal birth after cesarean delivery.

Methods

Setting and design

We conducted a retrospective cohort study, with all hospital deliveries to women in Canada between April 2003 and March 2015 serving as the source population.

Study population

For the primary analysis, we restricted the study population to women with a parity of 1, a previous cesarean delivery (ensuring that all women had only 1 previous cesarean delivery) and, in the current pregnancy, a singleton delivery at 37 to 43 weeks gestation. The comparison of interest was between elective repeat cesarean delivery and attempted vaginal birth after cesarean delivery. We also conducted analyses that compared outcomes in women who had an elective repeat cesarean delivery with those in women who had a successful or failed vaginal birth after cesarean delivery to obtain insight into the mechanisms underlying potential differences in outcomes. Definitions of different modes of delivery, and the diagnostic and procedure codes used are provided in Appendix 1, supplementary Table 1, available at www.cmaj.ca/lookup/suppl/doi:10.1503/cmaj.170371/-/DC1.

Data sources

We obtained data for the study from the Discharge Abstract Database of the Canadian Institute for Health Information. This database, which contains records for about 98% of all deliveries in Canada (excluding Quebec), is based on information that is routinely abstracted from medical charts by trained personnel using standardized definitions and processes.²³ The abstracted information includes details regarding maternal and infant characteristics, labour and delivery, and diagnoses and procedures. All diagnoses during the study period were coded using the International Statistical Classification of Diseases and Related Health Problems, 10th revision, Canadian version, whereas procedures were coded using the Canadian Classification of Health Interventions. The validity of the perinatal information in the Discharge Abstract Database has been assessed previously and found to be accurate.^{24,25}

Outcomes

The primary maternal outcome was composite severe maternal morbidity and mortality, which included severe postpartum hemorrhage (i.e., postpartum hemorrhage requiring blood transfusion, cesarean hysterectomy, hysterectomy or procedures to control bleeding such as ligation or embolization of pelvic vessels, and B-lynch suture of the uterus), disseminated intravascular coagulation, cardiac arrest, cardiopulmonary resuscitation, acute myocardial infarction, heart failure, pulmonary edema,

cardiac complications from anesthesia, assisted ventilation, adult respiratory distress syndrome, acute or unspecified renal failure, repair of injury to the bladder or urethra and maternal death.^{26,27} We also evaluated a second composite maternal outcome, restricted severe maternal morbidity and mortality, which included the same components except for postpartum hemorrhage requiring blood transfusion (the most common severe morbidity). We also assessed the following maternal outcomes: uterine rupture (including and excluding dehiscence of the uterine scar) and postpartum hemorrhage that required blood transfusion, procedures to control bleeding or hysterectomy.

The primary infant outcome was composite severe neonatal morbidity and mortality, which included neonatal seizures, any assisted ventilation (including assisted ventilation requiring endotracheal intubation or continuous positive airway pressure) and neonatal death.^{28,29} We also evaluated a second composite neonatal outcome that included neonatal death, neonatal seizures and assisted ventilation requiring endotracheal intubation (excluding assisted ventilation requiring continuous positive airway pressure). We also evaluated the following outcomes: neonatal death, assisted ventilation, neonatal seizures and respiratory distress syndrome.

Infant outcomes were evaluated after we restricted the population to infants without congenital anomalies.

Statistical analysis

The comparisons in maternal and infant outcomes between the groups of interest were quantified using rates, rate ratios (RRs) and 95% confidence intervals (CI), with women who had elective repeat cesarean deliveries as the reference group. Logistic models included maternal age, diabetes mellitus, hypertension and labour induction. We calculated adjusted rate differences from the absolute outcome rates for the elective repeat cesarean delivery group and adjusted RRs for attempted vaginal birth after cesarean delivery group, which we used to compute the number needed to treat (NNT). We evaluated temporal changes in maternal and infant effects from attempted vaginal birth after cesarean delivery by comparing adjusted RRs in early and later study periods (2003–2005 v. 2012–2014). We tested modification of the effect of attempted vaginal birth after cesarean delivery (on composite maternal and neonatal morbidity and mortality) by year using interaction terms.

We repeated these analyses for all women who had a previous cesarean delivery (i.e., without restriction by parity). We also conducted post hoc sensitivity analyses in women at 40 weeks gestation or more to address potential misclassification of elective repeat cesarean and attempted vaginal birth after cesarean delivery (because women planning an elective repeat cesarean delivery would have had this procedure before 40 wk). We used a 2-sided *p* value less than 0.05 to guide inference. All analyses were conducted using SAS version 9.2 (SAS Institute).

Ethics approval

The study was based on anonymized data and conducted under the surveillance mandate of the Public Health Agency of Canada, and ethics approval was not required.

Results

The source population included 3 047 401 women who delivered between 2003 and 2014. There were 1 975 401 women with a parity of 1 and a previous cesarean delivery who had a singleton delivery at 37 to 43 weeks gestation in the current pregnancy. Of these women, 77 426 (39.2%) were 30 to 34 years of age, 7026 (3.6%) had hypertension, 1510 (0.8%) had diabetes mellitus and 7307 (3.7%) had labour induction (Table 1). Women who had an elective repeat cesarean delivery were older and had slightly higher rates of hypertension and diabetes mellitus than women who delivered after an attempted vaginal birth after cesarean delivery. The attempted vaginal birth after cesarean delivery rate was 32.8% (7733/23 565) in 2003–2004, decreased to 28.2% (9633/34 205) in 2007–2008 and then increased to 31.4% (11 636/37 070) in 2013–2014. Among women who attempted vaginal birth after cesarean delivery, success rates declined from 50.2% (1689/3368) in 2003 to 47.8% (2347/4909) in 2008, before increasing to 50.8% (2987/5878) in 2014 (Appendix 2, supplementary Figure 1A, available at www.cmaj.ca/lookup/suppl/doi:10.1503/cmaj.170371/-/DC1).

Table 2 shows rates of severe maternal morbidity and mortality after elective repeat cesarean delivery and attempted vaginal birth after cesarean delivery in the study population. Women who had an attempted vaginal birth after cesarean delivery had significantly higher rates of uterine rupture, severe postpartum hemorrhage and composite severe maternal morbidity and mor-

tality compared to women who had an elective repeat cesarean delivery. The adjusted RR for composite severe maternal morbidity and mortality among women who had an attempted vaginal birth after cesarean delivery was 1.96 (95% CI 1.76 to 2.19) and 6.41 (95% CI 4.84 to 8.50) for uterine rupture (not including dehiscence). Analyses stratified by success/failure of the vaginal birth after cesarean delivery attempt showed that women who had a successful vaginal birth after cesarean delivery had significantly lower rates of restricted severe maternal morbidity and mortality (adjusted RR 0.57, 95% CI 0.45 to 0.73), whereas women with a failed vaginal birth after cesarean delivery had substantially higher rates (adjusted RR 2.58, 95% CI 2.25 to 2.95).

Rates of severe neonatal morbidity and mortality followed a mostly similar pattern, with rates of composite severe neonatal morbidity and mortality being significantly higher among women who delivered after an attempted vaginal birth after cesarean delivery compared with those delivering by elective repeat cesarean (adjusted RR 1.49, 95% CI 1.38 to 1.61; Table 3). Rates of neonatal seizures and assisted ventilation were significantly higher, whereas rates of neonatal death were nonsignificantly higher among women who delivered after an attempted vaginal birth after cesarean delivery. However, rates of neonatal respiratory distress syndrome were significantly lower among women delivering after an attempted vaginal birth after cesarean delivery (adjusted RR 0.90, 95% CI 0.86 to 0.94). Women with a successful vaginal birth after cesarean delivery had significantly lower rates

Table 1: Maternal characteristics and mode of delivery*

Characteristic	No. (%) of participants with a previous cesarean delivery <i>n</i> = 197 540	No. (%) of participants with an elective repeat cesarean <i>n</i> = 138 836	No. (%) of participants with an attempted VBAC <i>n</i> = 58 704	Rate of attempted VBAC delivery, %
Maternal age,† yr				
< 20	1716 (0.9)	1084 (0.8)	632 (1.1)	36.8
20–24	17 075 (8.6)	11 063 (8.0)	6012 (10.2)	35.2
25–29	46 936 (23.8)	31 600 (22.8)	15 336 (26.1)	32.7
30–34	77 426 (39.2)	54 267 (39.1)	23 159 (39.5)	29.9
≥ 35	54 385 (27.5)	40 821 (29.4)	13 564 (23.1)	24.9
Had hypertension	7026 (3.6)	5001 (3.6)	2025 (3.4)	28.8
Had diabetes mellitus	1510 (0.8)	1191 (0.9)	319 (0.5)	21.1
Had labour induction	7307 (3.7)	0 (0.00)	7307 (12.5)	100.0
Delivery occurred during				
2003–2004	23 565 (11.9)	15 832 (11.4)	7733 (13.2)	32.8
2005–2006	30 764 (15.6)	22 037 (15.9)	8727 (14.9)	28.4
2007–2008	34 205 (17.3)	24 572 (17.7)	9633 (16.4)	28.2
2009–2010	35 713 (18.1)	25 406 (18.3)	10 307 (17.6)	28.9
2011–2012	36 223 (18.3)	25 555 (18.4)	10 668 (18.2)	29.5
2013–2014	37 070 (18.8)	25 434 (18.3)	11 636 (19.8)	31.4

Note: VBAC = vaginal birth after cesarean.

*Our study was restricted to women with a parity of 1 who had a previous cesarean delivery and who delivered a singleton at 37 to 43 weeks gestation in the current pregnancy in Canada (excluding Quebec) from 2003 to 2014. Participants with missing values were excluded.

†For maternal age, the denominators used were 197 538 (no. of participants with a previous cesarean delivery), 138 835 (no. of participants with an elective repeat cesarean) and 58 703 (no. of participants with an attempted VBAC).

of neonatal respiratory distress syndrome, whereas those with a failed vaginal birth after cesarean delivery had significantly higher rates. Failed vaginal birth after cesarean delivery was associated with a threefold higher rate of neonatal death (Table 3).

Table 4 provides adjusted rate differences for maternal and infant outcomes and the NNT for attempted vaginal birth after cesarean delivery; 135 women attempting a vaginal birth after cesarean delivery would have to be delivered by elective repeat

Table 2: Severe maternal morbidity and mortality, by type of delivery*

Outcome	No. of deliveries	Rate per 1000 deliveries	Crude RR (95% CI)	Adjusted RR† (95% CI)
Uterine rupture				
Elective repeat cesarean	243	1.75	1.00 (Ref.)	1.00 (Ref.)
Attempted VBAC	583	9.93	5.72 (4.92 to 6.65)	5.24 (4.48 to 6.12)
Successful VBAC	38	1.30	0.74 (0.53 to 1.04)	0.64 (0.45 to 0.90)
Failed VBAC	545	18.5	10.8 (9.24 to 12.5)	9.62 (8.23 to 11.3)
Rupture not including dehiscence				
Elective repeat cesarean	69	0.50	1.00 (Ref.)	1.00 (Ref.)
Attempted VBAC	194	3.30	6.67 (5.07 to 8.78)	6.41 (4.84 to 8.50)
Successful VBAC	15	0.51	1.03 (0.59 to 1.80)	0.94 (0.54 to 1.66)
Failed VBAC	179	6.08	12.3 (9.32 to 16.2)	11.6 (8.77 to 15.5)
PPH and blood transfusion				
Elective repeat cesarean	226	1.63	1.00 (Ref.)	1.00 (Ref.)
Attempted VBAC	264	4.50	2.77 (2.32 to 3.31)	2.80 (2.33 to 3.37)
Successful VBAC	153	5.23	3.22 (2.63 to 3.96)	3.34 (2.69 to 4.14)
Failed VBAC	111	3.77	2.32 (1.85 to 2.91)	2.32 (1.84 to 2.92)
PPH and procedures for bleeding				
Elective repeat cesarean	213	1.53	1.00 (Ref.)	1.00 (Ref.)
Attempted VBAC	125	2.13	1.39 (1.11 to 1.73)	1.44 (1.15 to 1.82)
Successful VBAC	19	0.65	0.42 (0.26 to 0.68)	0.44 (0.28 to 0.72)
Failed VBAC	106	3.60	2.35 (1.86 to 2.97)	2.33 (1.83 to 2.97)
PPH and hysterectomy				
Elective repeat cesarean	76	0.55	1.00 (Ref.)	1.00 (Ref.)
Attempted VBAC	32	0.55	1.00 (0.66 to 1.51)	1.05 (0.68 to 1.62)
Successful VBAC	5	0.17	0.31 (0.13 to 0.77)	0.33 (0.13 to 0.84)
Failed VBAC	27	0.92	1.68 (1.08 to 2.60)	1.67 (1.06 to 2.64)
Maternal morbidity and mortality‡				
Elective repeat cesarean	784	5.65	1.00 (Ref.)	1.00 (Ref.)
Attempted VBAC	629	10.7	1.91 (1.72 to 2.12)	1.96 (1.76 to 2.19)
Successful VBAC	209	7.14	1.27 (1.09 to 1.48)	1.32 (1.13 to 1.55)
Failed VBAC	420	14.3	2.55 (2.26 to 2.87)	2.54 (2.25 to 2.87)
Restricted severe morbidity¶				
Elective repeat cesarean	645	4.65	1.00 (Ref.)	1.00 (Ref.)
Attempted VBAC	422	7.19	1.55 (1.37 to 1.76)	1.63 (1.43 to 1.85)
Successful VBAC	73	2.49	0.54 (0.42 to 0.68)	0.57 (0.45 to 0.73)
Failed VBAC	349	11.9	2.57 (2.26 to 2.93)	2.58 (2.25 to 2.95)

Note: CI = confidence interval, PPH = postpartum hemorrhage, RR = rate ratio, VBAC = vaginal birth after cesarean.

*There were 138 836 elective repeat cesarean deliveries, 58 704 attempted VBAC deliveries, 29 261 successful VBAC deliveries and 29 443 failed VBAC deliveries. Our study was restricted to women with a parity of 1 who had a previous cesarean delivery and who delivered a singleton at 37 to 43 weeks gestation in the current pregnancy in Canada (excluding Quebec) from 2003 to 2014.

†Logistic models included maternal age, diabetes mellitus, hypertension and labour induction.

‡Severe maternal morbidity and mortality included death, acute myocardial infarction, heart failure, pulmonary edema, disseminated intravascular coagulation, cardiac arrest, assisted ventilation, cardiac complications from anesthesia, cardiopulmonary resuscitation, adult respiratory distress syndrome, acute/unspecified renal failure, blood transfusion given PPH, shock procedures to control bleeding given PPH, cesarean hysterectomy given PPH, total hysterectomy open approach given PPH, subtotal hysterectomy open approach given PPH and repair of injury to bladder and urethra.

¶Restricted severe morbidity included the same conditions as for severe maternal morbidity and mortality, except blood transfusion given PPH.

cesarean to prevent 1 case of uterine rupture. The NNT was 184 for severe maternal morbidity and mortality, and 141 for severe neonatal morbidity and mortality.

Analyses comparing the association of vaginal birth after cesarean delivery with maternal and infant morbidity and mortality in

2003–2005 versus 2012–2014 showed no significant differences in adjusted RRs for adverse maternal outcomes but did show significantly higher adjusted RRs for severe neonatal morbidity and mortality in the later period (Table 5). Attempted vaginal birth after cesarean delivery was not associated with severe neonatal morbidity and

Table 3: Neonatal death and serious neonatal morbidity, by type of delivery*

Outcome	No. of births	Rate per 1000 deliveries	Crude RR (95% CI)	Adjusted RR† (95% CI)
Neonatal death				
Elective repeat cesarean	11	0.08	1.00 (Ref.)	1.00 (Ref.)
Attempted VBAC	12	0.22	2.58 (1.14 to 5.84)	2.32 (0.99 to 5.48)
Successful VBAC	< 5	< 0.18	1.71 (0.55 to 8.57)	1.46 (0.45 to 4.78)
Failed VBAC	8	0.29	3.45 (1.39 to 8.57)	3.22 (1.26 to 8.24)
Assisted ventilation				
Elective repeat cesarean	1835	14.0	1.00 (Ref.)	1.00 (Ref.)
Attempted VBAC	1111	20.0	1.44 (1.33 to 1.55)	1.49 (1.38 to 1.62)
Successful VBAC	400	14.3	1.03 (0.92 to 1.14)	1.08 (0.96 to 1.20)
Failed VBAC	711	25.6	1.86 (1.70 to 2.03)	1.88 (1.72 to 2.06)
Assisted ventilation excluding CPAP				
Elective repeat cesarean	396	3.01	1.00 (Ref.)	1.00 (Ref.)
Attempted VBAC	362	6.50	2.17 (1.88 to 2.50)	2.15 (1.85 to 2.49)
Successful VBAC	118	4.22	1.40 (1.14 to 1.73)	1.38 (1.12 to 1.71)
Failed VBAC	244	8.79	2.94 (2.50 to 3.45)	2.87 (2.44 to 3.39)
Neonatal seizures				
Elective repeat cesarean	79	0.60	1.00 (Ref.)	1.00 (Ref.)
Attempted VBAC	77	1.38	2.30 (1.68 to 3.15)	2.30 (1.65 to 3.19)
Successful VBAC	30	1.07	1.79 (1.17 to 2.72)	1.78 (1.15 to 2.76)
Failed VBAC	47	1.69	2.82 (1.97 to 4.05)	2.77 (1.91 to 4.01)
Respiratory distress syndrome				
Elective repeat cesarean	7231	55.0	1.00 (Ref.)	1.00 (Ref.)
Attempted VBAC	2699	48.5	0.88 (0.84 to 0.92)	0.90 (0.86 to 0.94)
Successful VBAC	1032	36.9	0.66 (0.62 to 0.70)	0.68 (0.63 to 0.72)
Failed VBAC	1667	60.1	1.10 (1.04 to 1.16)	1.12 (1.06 to 1.18)
Neonatal mortality and morbidity‡				
Elective repeat cesarean	1903	14.5	1.00 (Ref.)	1.00 (Ref.)
Attempted VBAC	1157	20.8	1.45 (1.34 to 1.56)	1.49 (1.38 to 1.61)
Successful VBAC	420	15.0	1.04 (0.93 to 1.16)	1.08 (0.97 to 1.21)
Failed VBAC	737	26.6	1.86 (1.71 to 2.03)	1.88 (1.72 to 2.05)
Restricted mortality and morbidity¶				
Elective repeat cesarean	469	3.57	1.00 (Ref.)	1.00 (Ref.)
Attempted VBAC	415	7.45	2.10 (1.84 to 2.40)	2.07 (1.81 to 2.38)
Successful VBAC	140	5.01	1.41 (1.16 to 1.70)	1.38 (1.13 to 1.68)
Failed VBAC	275	9.91	2.80 (2.41 to 3.25)	2.73 (2.34 to 3.19)

Note: CI = confidence interval, CPAP = continuous positive airway pressure, RR = rate ratio, VBAC = vaginal birth after cesarean.

*There were 131 493 elective repeat cesarean births, 55 691 attempted VBAC births, 27 947 successful VBAC births and 27 744 failed VBAC births without congenital anomalies. Our study was restricted to women with a parity of 1 who had a previous cesarean delivery and who delivered a singleton at 37 to 43 weeks gestation in the current pregnancy in Canada (excluding Quebec) from 2003 to 2014. Births with congenital anomalies were excluded.

†Logistic models included maternal age, diabetes mellitus, hypertension and labour induction.

‡Neonatal mortality and morbidity included neonatal death, neonatal seizures and assisted ventilation including CPAP.

¶Restricted mortality and morbidity included neonatal death, neonatal seizures and assisted ventilation not including CPAP.

Table 4: Adjusted rate differences for maternal and fetal outcomes (per 1000 deliveries) and number needed to treat for vaginal birth after cesarean delivery, by delivery type*

Outcome	Adjusted rate difference	
	Point estimate (95% CI)	NNT
Attempted VBAC delivery†		
Maternal		
Uterine rupture	7.42 (6.09 to 8.96)	135
Uterine rupture not including dehiscence	2.69 (1.91 to 3.73)	372
PPH and blood transfusion	2.93 (2.17 to 3.86)	341
Severe morbidity	5.42 (4.29 to 6.72)	184
Restricted morbidity	2.93 (2.00 to 3.95)	342
Neonatal		
Death	0.11 (0.00 to 0.37)	9056
Assisted ventilation	6.84 (5.30 to 8.65)	146
Assisted ventilation excluding CPAP	3.46 (2.56 to 4.49)	289
Seizures	0.78 (0.39 to 1.32)	1280
Respiratory distress syndrome	-5.50 (-7.70 to -3.30)	-182
Mortality and morbidity	7.09 (5.50 to 8.83)	141
Restricted mortality and morbidity	3.82 (2.89 to 4.92)	262
Successful VBAC†		
Maternal		
Uterine rupture	-0.63 (-0.96 to -0.18)	-1587
Uterine rupture not including dehiscence	-0.03 (-0.23 to 0.33)	-33 535
PPH and blood transfusion	3.81 (2.75 to 5.11)	263
Severe morbidity	1.81 (0.73 to 3.11)	553
Restricted morbidity	-2.00 (-2.56 to -1.25)	-501
Neonatal		
Assisted ventilation	1.12 (-0.56 to 2.79)	896
Respiratory distress syndrome	-17.6 (-20.4 to -15.4)	-57
Mortality and morbidity	1.16 (-0.43 to 3.04)	864
After failed VBAC delivery†		
Maternal		
Uterine rupture	15.1 (12.7 to 18.0)	66
Uterine rupture not including dehiscence	5.27 (3.86 to 7.21)	190
PPH and blood transfusion	2.15 (1.37 to 3.13)	465
Severe morbidity	8.70 (7.06 to 10.6)	115
Restricted morbidity	7.34 (5.81 to 9.06)	136
Neonatal		
Death	0.19 (0.02 to 0.61)	5385
Assisted ventilation	12.3 (10.1 to 14.8)	81
Assisted ventilation excluding CPAP	5.63 (4.34 to 7.20)	178
Seizures	1.06 (0.55 to 1.81)	940
Respiratory distress syndrome	6.60 (3.30 to 9.90)	152
Mortality and morbidity	12.7 (10.4 to 15.2)	79
Restricted mortality and morbidity	6.17 (4.78 to 7.81)	162

Note: CI = confidence interval, CPAP = continuous positive airway pressure, NNT = number needed to treat, PPH = postpartum hemorrhage, VBAC = vaginal birth after cesarean.

*Selected maternal and neonatal outcomes after attempted vaginal birth among women with a single previous pregnancy that resulted in a cesarean, who subsequently delivered a singleton at 37 to 43 weeks gestation in the current pregnancy in Canada (excluding Quebec) from 2003 to 2014. See footnotes to Table 2 and Table 3 for components of maternal and neonatal morbidity.

†Women who delivered by elective repeat cesarean served as the reference group.

mortality in 2003–2005 (adjusted RR 0.94, 95% CI 0.77 to 1.15), whereas this association was significant in 2012–2014 (adjusted RR 2.07, 95% CI 1.83 to 2.35; p value for difference in rate ratios < 0.05). The interaction term between attempted vaginal birth after cesarean delivery and year was significant for the neonatal morbidity outcomes ($p = 0.36$ for composite severe maternal morbidity, $p < 0.001$ for composite serious neonatal morbidity and $p < 0.001$ for respiratory distress syndrome; Appendix 2).

We found that analyses conducted for all women with a previous cesarean delivery showed essentially the same results (Appendix 1, supplementary Tables 1–6) with slight attenuation in adjusted RRs. Sensitivity analyses that were restricted to women at 40 weeks or more gestation also showed similar results for maternal outcomes (Appendix 1, supplementary Table 7) and significantly larger effects for neonatal outcomes (Appendix 1, supplementary Table 8). The adjusted RR expressing the association between attempted vaginal birth after cesarean delivery and severe neonatal morbidity and mortality, which was 1.49 (95% CI 1.38 to 1.61) in the primary analysis, was 2.37 (95% CI 1.91 to 2.96) in this sensitivity analysis (difference in RRs $p < 0.05$).

Interpretation

Our study showed that absolute rates of severe maternal and neonatal morbidity and mortality were low among women who attempted a vaginal birth after cesarean delivery and those who had an elective repeat cesarean delivery. However, relative rates of severe maternal and serious neonatal morbidity and mortality were substantially higher following attempted vaginal birth after cesarean delivery. Perhaps the most concerning finding was the temporal change in the effect of attempted vaginal birth after cesarean delivery on infant outcomes: severe neonatal morbidity and mortality rates were not significantly different following an attempted vaginal birth after cesarean delivery in 2003–2005, whereas such morbidity and mortality was 2-fold higher following an attempted vaginal birth after cesarean delivery in 2012–2014.

Although the number of women with a previous cesarean delivery increased from 2003 to 2014, rates of attempted vaginal birth after cesarean delivery and rates of success after a trial of labour were essentially unchanged. These stable rates likely conceal substantial changes in attitudes toward attempted vaginal birth after

cesarean delivery over the study period among women who are pregnant and health care providers. In 1998, the American College of Obstetricians and Gynecologists recommended that vaginal birth after cesarean delivery be attempted only in well-equipped

hospitals with “ready availability” emergency care.¹⁵ This ready availability terminology gave way to “immediate availability of emergency care” in 1999.¹⁶ The subsequent sharp decline in rates of vaginal birth after cesarean delivery led to a moderation of the

Table 5: Maternal and neonatal outcomes for vaginal birth after cesarean delivery for 2003–2005 versus 2012–2014, by delivery type*

Outcome	Adjusted RR (95% CI)†‡	
	2003–2005	2012–2014
Attempted VBAC		
Maternal		
Uterine rupture	6.74 (4.74 to 9.58)	5.47 (4.14 to 7.23)
Uterine rupture not including dehiscence	7.01 (3.71 to 13.2)	9.08 (5.20 to 15.9)
Severe morbidity	1.80 (1.32 to 2.46)	1.93 (1.62 to 2.30)
Neonatal		
Assisted ventilation	0.91 (0.74 to 1.12)	2.08 (1.84 to 2.36)
Assisted ventilation excluding CPAP	1.42 (0.96 to 2.10)	3.11 (2.40 to 4.03)
Seizures	1.62 (0.81 to 3.25)	2.92 (1.54 to 5.55)
Respiratory distress syndrome	0.81 (0.74 to 0.89)	1.07 (0.98 to 1.18)
Mortality and morbidity	0.94 (0.77 to 1.15)	2.07 (1.83 to 2.35)
Restricted mortality and morbidity	1.43 (1.01 to 2.02)	2.97 (2.32 to 3.79)
Successful VBAC		
Maternal		
Uterine rupture	0.71 (0.33 to 1.53)	0.69 (0.38 to 1.25)
Uterine rupture not including dehiscence	0.66 (0.15 to 2.95)	1.30 (0.47 to 3.59)
Severe morbidity	0.81 (0.47 to 1.39)	1.15 (0.89 to 1.49)
Neonatal		
Assisted ventilation	0.58 (0.42 to 0.80)	1.63 (1.38 to 1.92)
Assisted ventilation excluding CPAP	0.97 (0.56 to 1.69)	2.30 (1.64 to 3.22)
Seizures	1.58 (0.65 to 3.84)	2.61 (1.19 to 5.72)
Respiratory distress syndrome	0.60 (0.53 to 0.70)	0.82 (0.72 to 0.93)
Mortality and morbidity	0.64 (0.47 to 0.86)	1.64 (1.39 to 1.93)
Restricted mortality and morbidity	1.10 (0.69 to 1.76)	2.26 (1.65 to 3.10)
Failed VBAC		
Maternal		
Uterine rupture	12.4 (8.72 to 17.7)	10.3 (7.78 to 13.6)
Uterine rupture not including dehiscence	12.9 (6.81 to 24.4)	17.0 (9.69 to 29.7)
Severe morbidity	2.67 (1.92 to 3.73)	2.69 (2.22 to 3.25)
Neonatal		
Assisted ventilation	1.22 (0.96 to 1.55)	2.53 (2.19 to 2.93)
Assisted ventilation excluding CPAP	1.84 (1.19 to 2.86)	3.93 (2.94 to 5.24)
Seizures	1.66 (0.72 to 3.82)	3.22 (1.55 to 6.70)
Respiratory distress syndrome	1.01 (0.90 to 1.13)	1.34 (1.20 to 1.49)
Mortality and morbidity	1.22 (0.97 to 1.54)	2.50 (2.17 to 2.89)
Restricted mortality and morbidity	1.73 (1.17 to 2.57)	3.67 (2.79 to 4.83)

Note: CI = confidence interval, CPAP = continuous positive airway pressure, RR = rate ratio, VBAC = vaginal birth after cesarean.

*Our study contrasted women with an attempted vaginal birth after cesarean delivery compared with elective cesarean delivery among women with a single prior pregnancy that resulted in a cesarean (reference group), who subsequently delivered a singleton at 37 to 43 weeks gestation in the current pregnancy in Canada (excluding Quebec) from 2003 to 2005 ($n = 38\,752$ for maternal outcomes; $n = 36\,684$ for neonatal outcomes) and from 2012 to 2014 ($n = 55\,246$ for maternal outcomes; $n = 51\,991$ for neonatal outcomes).

†Text in boldface type indicates a statistically significant temporal change in the adjusted RR ($p < 0.05$).

‡Logistic models for maternal and neonatal outcomes included maternal age, diabetes mellitus, hypertension and labour induction.

position about the need for specialized services: in 2005, the Society of Obstetricians and Gynaecologists of Canada recommended that vaginal birth after cesarean deliveries be done in hospitals where a timely cesarean delivery was possible.³⁰

Evidence related to attempted vaginal birth after cesarean delivery and the changes to the guidelines mentioned previously likely explains the finding of no association between attempted vaginal birth after cesarean delivery and severe neonatal morbidity and mortality in 2003–2005. A seminal study showing a near 2-fold increase in major maternal complications after a trial of labour was published in 1996,¹ another study showing an 11-fold increase in perinatal death was published in 2002,²³ and a third study showing higher rates of maternal and infant complications was published in 2004.²⁴ The climate of concern created by these studies likely affected the selection of candidates and labour management for attempted vaginal birth after cesarean delivery and ensured better perinatal outcomes during 2003–2005. The increase in the adverse effects for attempted vaginal birth after cesarean delivery more recently may indicate a less rigorous approach to selection of candidates and management of attempted vaginal birth after cesarean delivery. A reduction in the availability of obstetricians with expertise in vaginal birth after cesarean delivery and temporal changes in maternal characteristics are other possibilities.

The evaluation and interpretation of risks associated with attempted vaginal birth after cesarean delivery presents a challenge because risk perspectives vary widely. Both the relative increase in rates of severe maternal and neonatal morbidity and mortality after attempted vaginal birth after cesarean delivery compared with elective repeat cesarean delivery and the absolute difference in these rates need to be weighed carefully before a decision is made about whether the excess risks are acceptable or high. In addition, women planning large families need to be cognizant of the risks of morbid placentation in subsequent pregnancies, because such risks increase with repeated cesarean deliveries.⁹ These inputs into decision-making may also be affected by desire for vaginal birth, the severity of the outcomes in question and other personal valuations. Health care providers need to help women to contextualize risks better so that they are able to make informed and personalized decisions.

Limitations

The limitations of our study include reliance on data from a large perinatal database, which may contain some transcription and other errors. Although codes for major diagnoses and procedures in our data source have been validated and found to be accurate, misclassification of some women scheduled for elective repeat cesarean delivery is possible. However, this would have served to minimize differences between elective repeat cesarean delivery and attempted vaginal birth after cesarean delivery, and sensitivity analyses restricted to women at 40 weeks or more gestation support this assumption.

Conclusion

Attempted vaginal birth after cesarean delivery is associated with low absolute rates of severe maternal and infant morbidity and mortality, although relative rates of such adverse outcomes

are higher than for elective repeat cesarean delivery. Temporal trends in the effects of attempted vaginal birth after cesarean delivery on serious neonatal morbidity and mortality have shown a concerning increase in recent years, and further study is required to identify the cause of this unexpected development. Attempts at ensuring the safety of attempted vaginal birth after cesarean delivery must continue to focus on appropriate selection of candidates and careful monitoring of labour and delivery among women with a previous cesarean delivery.

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