OPERATIVE DELIVERY OPTIONS IN THE SECOND STAGE OF LABOUR: OPTIMIZING MATERNAL AND PERINATAL SAFETY

by

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Abstract

Increased operative vaginal delivery, using obstetric forceps and/or vacuum, has been recommended in an effort to curb the rising rate of cesarean delivery. However, the comparative perinatal and maternal safety of operative vaginal delivery and cesarean delivery is not clear. This dissertation aimed to quantify rates of severe perinatal and maternal morbidity and mortality following operative vaginal delivery and cesarean delivery.

The studies in this dissertation were based on information from Canadian national and provincial population-based health databases and included women who delivered a singleton term infant by operative vaginal or cesarean delivery between 2003 and 2014. Study sizes varied from 10,901 to 1,938,913. Logistic regression, propensity score analysis and ecological Poisson regression were used to estimate adjusted rate ratios (ARR) with 95% confidence intervals (CI).

Midpelvic operative vaginal delivery was associated with an increased risk of severe perinatal morbidity/mortality compared with cesarean delivery, although this association varied based on instrument applied and indication for operative delivery. For example, among deliveries with dystocia, midpelvic operative vaginal delivery was associated with higher rates of severe perinatal morbidity/mortality compared with cesarean delivery (forceps ARR 2.11, 95% CI 1.46-3.07; vacuum ARR 2.17, 95% CI 1.49-3.15). Among deliveries with fetal distress, the risk of severe maternal morbidity/mortality was higher with midpelvic

forceps and lower with midpelvic vacuum. However, rates of obstetric trauma were high following operative vaginal delivery, irrespective of instrument or indication.

Rates of birth trauma and obstetric trauma were significantly increased after operative vaginal delivery at all pelvic stations. Further, the population (ecological) rate of operative vaginal delivery was positively associated with the rate of obstetric trauma and the rate of severe birth trauma: a one percent increase in the operative vaginal delivery rate resulted in over 700 additional cases of obstetric trauma per year among nulliparous women.

Encouraging higher rates of operative vaginal delivery as a strategy to prevent cesarean delivery may result in higher rates of perinatal and maternal morbidity/mortality, especially birth trauma and obstetric trauma. The risks and benefits of both operative vaginal and cesarean delivery should be clearly communicated to women, ideally in the antepartum period.

Lay Summary

The rate of operative vaginal deliveries (forceps- and vacuum-assisted deliveries) has declined in Canada as the cesarean delivery rate has risen to levels considered unacceptably high. Recommendations for the increased use of operative vaginal delivery as a strategy to reduce the cesarean delivery rate have gained traction. However, the relative safety of operative vaginal and cesarean delivery is unclear. This dissertation aimed to quantify the safety/harm for mothers and babies associated with operative vaginal and cesarean delivery. The results indicate that encouraging operative vaginal delivery as an alternative to cesarean delivery will result in increased rates of complications for mothers and babies, especially, severe birth trauma and obstetric trauma. Maternity care providers should ensure that pregnant women understand all the risks of both operative vaginal delivery and cesarean delivery, ideally before labour begins, to allow women to make fully informed choices about mode of delivery.

Preface

This statement certifies that the work presented in this dissertation was conceived, conducted, and written by Giulia Muraca. All studies were conducted after receipt of ethics approval from The University of British Columbia Clinical Research Ethics Board (Certificate No.: H12-0277; H14-02746).

Chapters 2 to 6 of the dissertation are each composed of manuscripts, which have been published or have been submitted for publication in a peer-reviewed journal. I was responsible for developing the study proposal, conceptual framework, and analytic approaches for all analyses. For this, I received assistance from my thesis supervisor, Dr. K.S. Joseph, my thesis committee members Dr. Geoffrey Cundiff, Dr. Rollin Brant, and Dr. Yasser Sabr and my research collaborators Dr. Sarka Lisonkova, and Dr. Amanda Skoll.

I conducted all analyses, and wrote all of the statistical analysis code. I wrote the first draft of all manuscripts. My supervisor, thesis committee members and research collaborators made contributions to the study design, analysis and interpretation of data and revised each article for intellectual content. My contribution was greater than 90% for each manuscript of this dissertation.

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List of Abbreviations

ACOG – American College of Obstetricians and Gynecologists

AOR – Adjusted odds ratio

ARD – Adjusted rate difference

ARR – Adjusted rate ratio

BCPDR – British Columbia Perinatal Data Registry

CCI – Canadian Classification of Interventions

CI – Confidence interval

CIHI – Canadian Institute for Health Information

CIHR – Canadian Institutes of Health Research

DAD – Discharge Abstract Database

ICD-10-CA – International Statistical Classification of Diseases and Related Health

Problems – Tenth Revision, Canadian version

NICU – Neonatal intensive care unit

NNT – Number needed to treat

NOS – Not otherwise specified

OR – Odds ratio

PSBC – Perinatal Services British Columbia

RD – Rate difference

SMFM – Society for Maternal-Fetal Medicine

SOGC – Society of Obstetricians and Gynaecologists of Canada

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Dedication

To my Gioia-belle and Lilajune-bug for making me a mom, reminding me of the real reasons for it all, and increasing my study size.

To my Awndy for braving the journey into the mystic with me.

To my incredible mother who set me up for every success and simply made my whole life.

And for you, Papà, for inspiring wonder and humanity and for believing that I could grow higher than the soul can hope or the mind can hide.
i carry your heart (i carry it in my heart)

Chapter 1: Introduction

1.1. The rising rate of cesarean delivery

Childbirth and the actions surrounding it, whether they are medical or otherwise, evoke strong emotions. In industrialized settings, where obstetric intervention has increased significantly in recent decades,[1] the prevailing discourse surrounding contemporary birth practices is often framed ideologically as a matter of nature versus technology, or in stark political, feminist, or economic terms. The rise in cesarean delivery rates, in particular, is at the very centre of this discourse and has become a controversial issue. Only about 5% of Canadian women delivered by cesarean delivery in the 1960s, but cesarean deliveries account for approximately 28% of deliveries currently.[2,3]

Several possible explanations for the secular increase in cesarean delivery rates have been proposed, including changes in maternal and obstetric practice-related factors (summarized in Figure 1.1). There is a higher risk of cesarean delivery for women who are older,[4-6] obese,[7] having their first child or expecting a multiple birth.[8] In Canada, the number of deliveries to older mothers has increased in recent years, as has the proportion of women having their first child at an older age.[9] Multiple births have also increased, mainly due to the increased use of fertility treatments, and increases in pre-pregnancy weight have paralleled the general population increase in obesity.[10] Women who previously delivered a baby by cesarean delivery are more likely to give birth by cesarean delivery in subsequent pregnancies. Some obstetric practice patterns have also increased the frequency of cesarean delivery, including increased use of fetal monitoring, epidural anesthesia and declining rates of forceps-assisted delivery.[11,12]

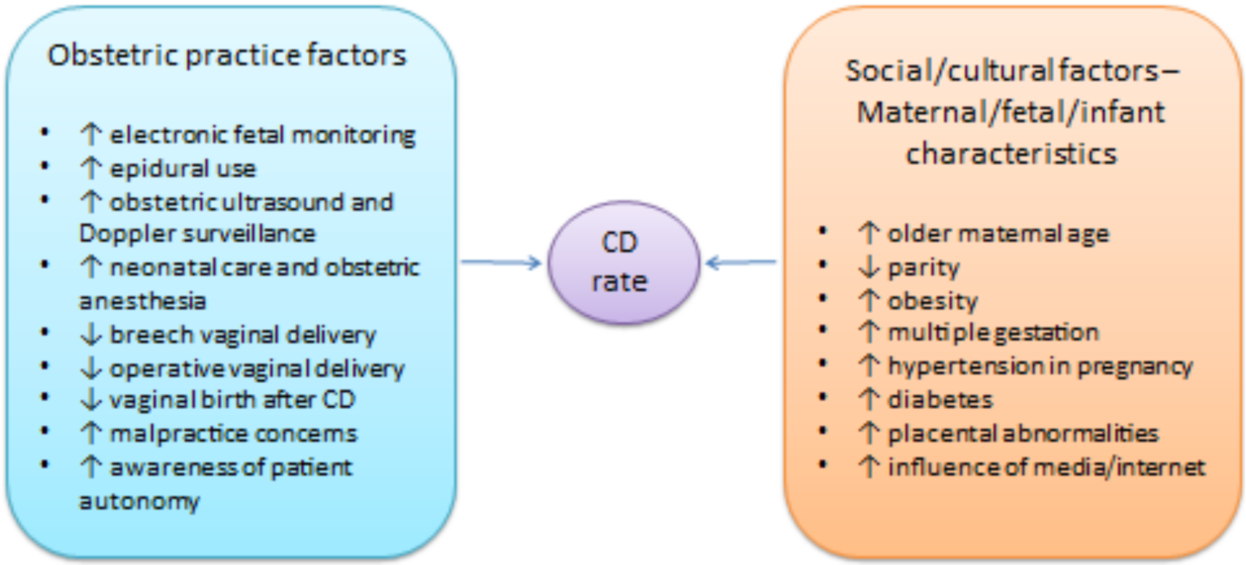

Figure 1.1. Contributors to rising cesarean delivery rates in industrialized settings

There is considerable interest in determining the driving forces behind the global rise in cesarean delivery rates. This focus on cesarean delivery rates is motivated primarily by a widespread desire to halt and reverse unnecessary increases in cesarean delivery rates that do not contribute to improvements in maternal, fetal or infant health.[11,13-18] There is often an implied presumption that any increase in cesarean delivery rates represents an adverse change which needs to be remedied partly because such intervention increases maternal and/or perinatal morbidity and also because it interferes with natural childbirth. The alternative perspective on this issue is that any increase in cesarean delivery rates needs to be set against potential improvements in maternal, fetal and infant health. Increases in cesarean delivery rates that lead to declines in adverse maternal, fetal and infant morbidity and mortality can be justified given improvements in health. On the other hand, increases in cesarean delivery rates without simultaneous declines in maternal, fetal or infant adverse outcomes would imply that the increase in cesarean delivery rates is without health benefits at both the individual and population level.

1.2. Operative vaginal delivery as a strategy to reduce cesarean delivery

A recent Obstetrical Care Consensus statement developed jointly by the American College of Obstetricians and Gynecologists (ACOG) and the Society for Maternal-Fetal Medicine (SMFM) recommended a set of strategies to reduce cesarean delivery rates.[11] Among this list of suggested alternatives to cesarean delivery was operative vaginal delivery. Operative vaginal delivery refers to forceps- and/or vacuum-assisted delivery used to facilitate vaginal birth when there are is an arrest in labour or when there are fetal or maternal concerns.[19] The indications for operative vaginal delivery most commonly include fetal distress, dystocia (abnormal forces of labour), maternal exhaustion and pre-existing maternal complications such as cardiac or cerebrovascular disease. In 2015-2016, the rates of all operative vaginal delivery, vacuum-assisted delivery, forceps-assisted delivery, and delivery with sequential application of vacuum and forceps among vaginal deliveries in Canada were 13.2%, 9.2%, 3.4%, and 0.6%, respectively.[3]

An evaluation of approaches to increase population rates of operative vaginal delivery is underway[20] and the current discourse surrounding these procedures centres around methods to promote the skills required to effect such intervention.[21-23] However, there is substantial uncertainty in the literature[24-31] regarding the balance of perinatal and maternal risks and benefits between operative vaginal delivery and cesarean delivery.

1.3. Is operative vaginal delivery safer than cesarean delivery?

Seeking to compare maternal and neonatal safety following operative vaginal delivery and cesarean delivery, Majoko and Gardner carried out a Cochrane Systematic Review in October 2008 (updated in August 2012). The authors set out to review randomized controlled trials that appeared in the Cochrane Pregnancy and Childbirth Group's Trials Register but found no studies that met their inclusion criteria at either point in time. Consequently, they were unable to synthesize any randomized trial evidence to guide clinical decision-making when choosing between operative vaginal and cesarean delivery.

There are several inconsistencies in the results of previous observational studies comparing perinatal and maternal outcomes following operative vaginal delivery with those following cesarean delivery. With respect to perinatal morbidity, some studies have found higher rates of assisted ventilation with forceps[28] while others have found higher rates with cesarean delivery.[24,32] Higher rates of neonatal convulsions have been reported following cesarean delivery,[26,32] while more recent studies have found no difference in neonatal convulsion rates between operative vaginal and cesarean delivery groups.[25,33] Higher rates of admission to the NICU has been associated with operative vaginal delivery in some studies[28] and cesarean delivery in others.[27,32] However, there has been agreement from several studies regarding higher rates of birth trauma following operative vaginal delivery compared with cesarean.[24,26-28,30,32] The use of sequential instruments is also associated with higher rates of perinatal morbidity such as intracranial hemorrhage, convulsions and central nervous system depression.[24]

Some studies comparing maternal morbidity between operative vaginal and cesarean delivery have found higher rates of maternal blood loss after cesarean delivery,[27-29] while others have found either no difference between the groups[34,35] or higher rates following operative vaginal delivery.[36] Higher rates of endometritis, wound complications and postpartum infection have been associated with cesarean delivery,[29,32,35] while obstetric trauma (cervical, sulcal and severe perineal lacerations) have also been associated with operative vaginal delivery as compared with cesarean delivery.[32]

The inconsistencies in the extant literature on perinatal and maternal morbidity following operative vaginal delivery compared with cesarean delivery are attributable to the fact that previous research on this topic has been compromised by:

a) clinically inappropriate comparison groups (e.g., all cesarean delivery or cesarean delivery in first stage of labour);[24,26,30,36]
b) a failure to stratify analyses by instrument applied (combining outcomes of forceps and vacuum delivery)[27,34,36]
c) no longer relevant to contemporary obstetric practice as the studies were undertaken 25 to 30 years ago.[28-30,34]
d) a lack of adjustment for known confounders such as maternal age, parity, birth weight,[24,25,28-30,33,34] indication for operative delivery,[24-28,32,34-36] and pelvic station.[24-26,33,36]

A list of all the studies comparing perinatal and maternal morbidity and mortality in operative vaginal deliveries and cesarean deliveries is included in Table 1.1. Characteristics of each study are also included in Table 1.1 with study limitations highlighted in red text.

Table 1.1. Description of studies comparing perinatal and maternal morbidity/mortality following operative vaginal and cesarean delivery

First author (journal, year)	No. of deliveries Study design	Instrument type	Reference group	Results	Adjusted for potential confounders (Yes/No)	Adjustment for indication (Yes/No)	Adjustment for pelvic station (Yes/No)
1) Dierker[30] (Am J Obstet Gynecol, 1985)	262 Retrospective cohort	Forceps	Cesarean	Perinatal: ↑ cephalohematoma with forceps ↑ 5-min Apgar<7 with cesarean	No	Yes	Yes (restricted to midpelvic station)
2) Lowe[34] (BJOG, 1987)	225 Retrospective cohort	Operative vaginal delivery (either instrument)	Cesarean in second stage of labour	Perinatal: No difference in birth hypoxia. Not powered to detect differences in trauma, mortality, abnormal neurologic behaviour. Maternal: No difference in pyrexia, transfusions, injury.	No	No	Yes (restricted to midpelvic station)
3) Bashore[29] (Am J Obstet Gynecol, 1990)	844 Retrospective cohort	Forceps	Cesarean in second stage of labour	Perinatal: No difference in neonatal morbidity (Apgar score, cord blood gas values, admission to the NICU, birth trauma) Maternal: ↑ Maternal morbidity (intraoperative and postoperative complications, blood transfusion, hospital stay) with cesarean	No	Yes	Yes (restricted to midpelvic station)
4) Robertson[28] (Am J Obstet Gynecol, 1990)	1769 Retrospective cohort	Forceps, vacuum	Cesarean in second stage of labour	Perinatal: ↑ Neonatal resuscitation, cord arterial pH <7.10, increase in base deficit, admission to NICU, birth trauma with midpelvic forceps ↓ Neonatal resuscitation with low vacuum Maternal: ↑ Maternal morbidity, hospital stay, estimated blood loss with cesarean	No	No	Yes (restricted to low and midpelvic station)

Table 1.1 Description of studies comparing perinatal and maternal morbidity/mortality following operative vaginal and cesarean delivery

First author **(journal, year)**	**No. of deliveries** **Study design**	**Instrument type**	**Reference group**	**Results**	**Adjusted for potential confounders (Yes/No)**	**Adjustment for indication (Yes/No)**	**Adjustment for pelvic station (Yes/No)**
5) Towner[24] (N Engl J Med, 1999)	162,533 Retrospective cohort	Forceps, vacuum, sequential	Cesarean with labour	Perinatal: ↑ facial-nerve injury with forceps ↑ convulsions, mech. ventilation w/ cesarean ↑ ICH, birth injury, convulsions, CNS depression in sequential grp	No	No	No
6) Murphy[27] (Lancet, 2001)	393 Prospective cohort	Operative vaginal (either instrument)	Cesarean in second stage of labour	Perinatal: ↑ trauma with operative vaginal delivery ↑ NICU admission with cesarean Maternal: ↑ Blood loss with cesarean	Yes	No	Yes
7) Burrows[36] (Obstet Gynecol, 2004)	9,042 Retrospective cohort	Operative vaginal (either instrument)	Cesarean with labour	Maternal: ↑ PPH and transfusion with operative vaginal	Yes	No	No
8) Contag[33] (Am J Perinatol, 2010)	990 Retrospective cohort	Forceps, vacuum	Cesarean in second stage of labour	Perinatal: No differences detected (5-min Apgar<3, 5-min Apgar<7, pH<7.0, base excess>-12, brachial plexus injury, seizures, NICU admission)	No	Yes	No
9) Werner[26] (Obstet Gynecol, 2011)	120,541 Retrospective cohort	Forceps, vacuum	Cesarean	Perinatal: ↑ fracture, facial nerve palsy, brachial plexus injury, subdural hemorrhage with forceps ↑ cephalohematoma, scalp laceration, fracture, brachial plexus injury, subdural hemorrhage with vacuum ↑ Seizures, neurologic complication with cesarean	Yes	No	No
10) Walsh[25] (Obstet Gynecol, 2013)	10.933 Retrospective Cohort	Forceps, vacuum	Cesarean in second stage of labour	Perinatal: No differences in neonatal mortality or encephalopathy (including seizures)	No	No	No

Table 1.1 Description of studies comparing perinatal and maternal morbidity/mortality following operative vaginal and cesarean delivery

First author (journal, year)	No. of deliveries Study design	Instrument type	Reference group	Results	Adjusted for potential confounders (Yes/No)	Adjustment for indication (Yes/No)	Adjustment for pelvic station (Yes/No)
11) Halscott[32] (Obstet Gynecol, 2015)	2,518 Retrospective cohort	Forceps, vacuum	Cesarean in second stage of labour	<u>Perinatal</u>: ↓ neonatal morbidity composite (5-min Apgar<4, resp. morbidity, NICU admission, birth trauma, sepsis) with forceps in nulliparous women <u>Maternal</u>: ↑ endometritis and wound complications with cesarean ↑ cervical/sulcal lacerations with forceps High rates of severe perineal lacerations (22% with forceps, 15.4% with vacuum)	Yes	No	Yes (restricted to deliveries at low station)
12) Bailit[35] (Am J Obstet Gynecol, 2016)	2,531 Retrospective cohort	Forceps, vacuum	Cesarean in second stage of labour	<u>Perinatal</u>: No difference in severe neonatal composite outcome <u>Maternal</u>: ↑ postpartum infection in the cesarean group No difference in postpartum hemorrhage	Yes	No	Yes (restricted to deliveries at outlet and low station)

ICH, intracranial hemorrhage; CNS, central nervous system; NICU, Neonatal Intensive Care Unit; PPH, postpartum hemorrhage.

1.4. Pelvic station

Not all operative vaginal deliveries are comparable in terms of the risk of morbidity and the likelihood of failure.[37,38] Differences in outcomes following operative vaginal delivery arise because of several factors with pelvic station at which operative vaginal delivery is attempted being a key issue.

Operative vaginal deliveries include forceps- and vacuum-assisted deliveries carried out at different pelvic stations. Pelvic station measures descent of the fetus in the birth canal by identifying the location of the leading point of the fetal skull in relation to the maternal pelvis, specifically the ischial spines.

In 1988, ACOG redefined the original 1965 classification system for operative vaginal deliveries and proposed the -5 to +5 cm Classification According to Station and Rotation, and this currently serves as the standard for the Society of Obstetricians and Gynaecologists of Canada (SOGC) and ACOG (Table 1.2).[38] Zero station refers to the situation where there leading point of the fetal skull is at the level of the maternal ischial spines. If the leading point of the fetal skull is above zero station operative vaginal delivery is contraindicated (Figure 1.2). Midpelvic operative vaginal delivery is defined as an operative vaginal delivery performed when the presenting part of the fetal head is between 0 and plus 2 cm below the ischial spines - referred to as between 0 station and +2 station.[19,39] On the other hand, operative vaginal delivery performed when the fetal station is at +2 station or lower is referred to as low (pelvic) forceps delivery or low (pelvic) vacuum delivery. Once the fetal head has descended enough to have reached the pelvic floor and is on the perineum, the station is defined as outlet (pelvic) station.

Table 1.2. Classification according to station and rotation[38]

Procedure	**Criteria**
Outlet	• Scalp is visible at the introitus without separating the labia • Fetal skull has reached pelvic floor • Fetal head is at or on perineum • Sagittal suture is in anteroposterior diameter or right or left occiput anterior or posterior position, and • Rotation does not exceed 45 degrees (for forceps deliveries only)
Low-pelvic	Leading point of fetal skull is at station ≥ +2 cm, and not on the pelvic floor and for forceps deliveries only: a. Rotation is ≤45 degrees *or* b. Rotation is > 45 degrees

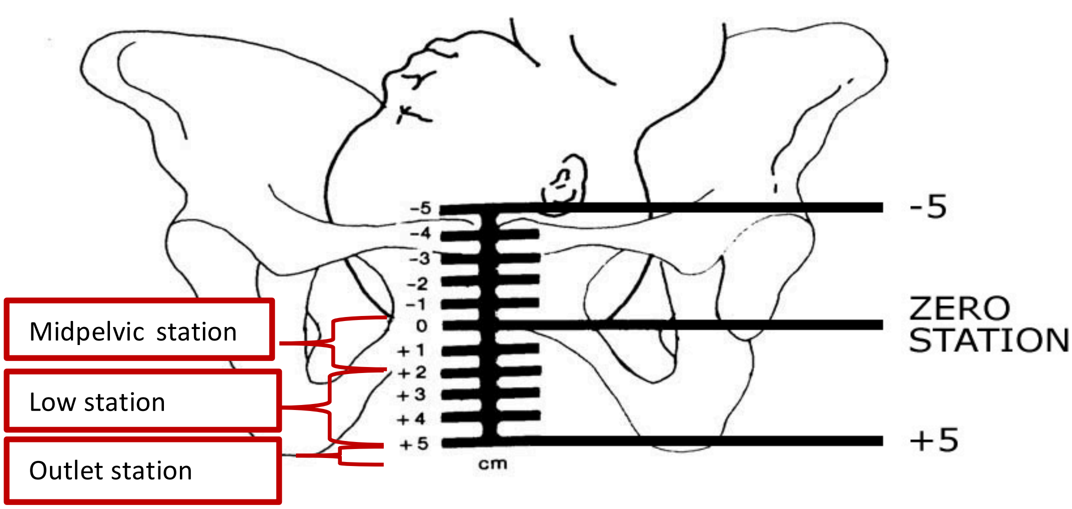

Figure 1.2. Measurement of pelvic station.
Adapted from: http://www.pregnancysymptomsweekbyweek.org.

In 1991, a prospective study was published that aimed to validate the new system. The authors compared maternal and neonatal outcomes following 357 forceps deliveries at outlet, low, and midpelvic stations and validated the new classification system by showing that it successfully stratified maternal and fetal risks (Table 1.3).[37] Thus, inconsistencies in previous study results that did not account for pelvic station are not surprising since combining all operative vaginal deliveries into a single category, without regard for pelvic station, likely masks significant differences in rates of perinatal and maternal outcomes at outlet, low and midpelvic stations.

Table 1.3. Neonatal and maternal outcomes following forceps deliveries stratified by Classification according to station and rotation (1988)[37]

Outcome	**Outlet n=116 (%)**	**Low n=178 (%)**	**Mid n=63 (%)**	**P-value**
Maternal				
Obstetric trauma	12.9	25.3	36.5	<0.001
3^{rd} and 4^{th} degree perineal laceration	8.6	16.3	21.0	<0.05
Vaginal laceration	5.1	12.4	22.2	<0.01
Neonatal				
Umbilical arterial acidemia (pH <7.2)	17.2	25.8	36.5	<0.05
Birth trauma	5.2	10.1	19.0	<0.01

A cesarean delivery performed when the fetal head is at low or outlet pelvic station can be traumatic for the mother and baby because of an increased risk for a variety of obstetric and birth injuries such as fetal skull fracture and extension of the uterine incision.[40-42] The well-known risks of trauma following cesarean delivery with a deeply impacted fetal head generally implies that operative vaginal delivery is the safer option. On the other hand, at midpelvic station, when the fetal head is not as deeply engaged in the maternal pelvis, operative vaginal delivery would require significant operator skill and experience if a safe delivery is to be effected.[19,39] Cesarean delivery in this circumstance would pose less of a challenge as the fetal head is not impacted in the pelvis. Thus, it is an arrest in labour when the fetal head is at midpelvic station that the decision between operative vaginal delivery and cesarean delivery presents a serious challenge. Consequently, it is an increase in operative vaginal deliveries at midpelvic station that would have the greatest potential to reduce the cesarean delivery rate.

Understanding the relative safety of midpelvic operative vaginal delivery and cesarean delivery is critical if midpelvic operative vaginal delivery is to be advocated as an alternative to cesarean delivery. Such information will serve two purposes; it will address whether
1) midpelvic operative vaginal delivery is a safe alternative to cesarean delivery and
2) provide women and their maternity care providers with information on the risks associated with each mode of delivery so that they can make informed choices. I, therefore, conducted a systematic review of studies comparing perinatal and maternal outcomes following operative vaginal delivery at midpelvic station compared with cesarean delivery.

1.5. Systematic review of studies comparing perinatal and maternal outcomes following midpelvic operative vaginal delivery versus cesarean delivery

1.5.1. Review of existing reviews

A review of the risks and benefits of midpelvic forceps delivery was conducted by Friedman in 1987[31] in which 14 observational studies were included. The results focused on the fetal risks of midforceps procedures and did not address any maternal outcomes. All of the studies included in the review found increased rates of fetal adverse outcomes following midpelvic forceps delivery compared with the control group and 11 of the increases were statistically significant increases. The review concluded that there was a preponderance of clinical evidence suggesting that midpelvic forceps delivery exposes the fetus to harm and recommended that the procedure be abandoned. However, the studies included in the review, published between 1967 and 1985, likely do not reflect current obstetric practice and recent technological advances in the management of difficulties during the second stage of labour. Additionally, and as previously mentioned, a Cochrane Systematic Review of randomized controlled trials comparing neonatal and/or maternal outcomes following operative vaginal delivery and cesarean delivery was conducted in 2008[43] and updated in 2012.[44] The authors of the Cochrane Review found no studies that met their inclusion criteria at either point in time.

1.5.2. Objective

The objective of this review was to determine rates of perinatal and maternal morbidity and mortality associated with attempted midpelvic operative vaginal delivery, compared with cesarean delivery, in women with an arrest in the second stage of labour.

1.5.3. Methods

I conducted a systematic review of the literature to synthesize the evidence on perinatal and maternal outcomes following midpelvic operative vaginal delivery compared with cesarean delivery in order to guide clinical practice regarding the safest mode of delivery for a woman with an arrest in the second stage of labour. Studies were considered eligible for the review if they were randomized controlled trials, controlled clinical trials, or quasi-random studies comparing midpelvic operative vaginal versus cesarean delivery. Cohort and case-control studies comparing these two modes of delivery were also considered. Studies were included in the review if the study population included women who delivered by midpelvic operative vaginal delivery, using forceps, vacuum, or sequential instrumentation, compared with those delivered by cesarean delivery. The perinatal and maternal outcomes relevant to this review are listed in Table 1.4.

Table 1.4. Outcomes relevant to the review

Perinatal	**Maternal**
Perinatal death	Death
Admission to NICU	Postpartum hemorrhage
Duration of admission to NICU	Blood transfusion
Neonatal convulsions	Puerperal infection
Need for active resuscitation	Sepsis
Need for assisted ventilation	Shock
Apgar score <4 at 5-minutes	Obstetric trauma
Apgar score <7 at 5-minutes	Obstetric embolism
Asphyxia	Cardiac complications
Acidemia	Febrile morbidity
Birth trauma	Admission to intensive care unit

NICU, Neonatal Intensive Care Unit

Search methods for identification of studies

The research question included three main components: 1) complications such as failure to progress or fetal distress in the second-stage labour with presenting part of the fetal head at midpelvic station; 2) attempted operative vaginal delivery and/or cesarean delivery; and 3) experimental or observational study design. Appendix Figure 1.1 depicts the conceptual model for specific components of the question and how these concepts informed the selection of search terms and strategies. A search was conducted within the Cochrane Central Register of

Controlled Trials, MEDLINE (1946 to present, including in-process citations), CINAHL (1982 to present), Embase (1974 to present), and the Science Citation Index (1900 to present). The detailed terms that were employed in each of these databases, as well as the number of results associated with each keyword or free-text combination are listed in Appendix 1.2. Since the definition of pelvic station and the techniques employed to conduct operative vaginal deliveries have changed since the middle of the 20th century, only articles published after 1950 were considered for inclusion. In addition, while articles published in non-English languages were included as part of the abstract review process, only studies in English were considered for the final review.

Data collection and extraction

Eligible studies had to clearly mention a) midpelvic operative vaginal delivery (employing midpelvic forceps, midpelvic vacuum, or the sequential application of midpelvic vacuum and midpelvic forceps); b) cesarean delivery performed during the second stage of labour; and c) include a calculation of relative risks or odds ratios and their corresponding confidence intervals, or provide enough data to compute these parameters for at least one of the adverse outcome measures of interest (listed in Table 1.4). Two separate authors (N.R., E.R.) independently reviewed titles and abstracts of all identified studies to determine which publications should be included in the full-text review. Conflicting opinions regarding a study's exclusion were discussed by all three members of the review team (G.M.M., N.R., E.R.) in order to achieve consensus. Finally, this process was repeated based on the full text of selected articles in order to identify studies suitable for inclusion in the final analysis. A detailed justification of the decision to exclude a study at this second stage was recorded, and all disagreements were resolved via consensus, as with the earlier stages.

Once a study was deemed eligible for inclusion, two independent reviewers entered data into the predesigned form (see Appendix 1.3). The form was piloted in order to ensure all relevant details were captured and reviewers were in concordance regarding instructions and coding rules. Any discrepancy regarding a particular component of the study was resolved through discussion between the two principal reviewers, consulting a third member of the review team if necessary. Details were entered into Review Manager 5.1 software (RevMan 2012) and checked for accuracy.

Assessment of quality

I planned to use the Cochrane Risk of Bias tool to appraise the quality of any randomized controlled trials, controlled clinical trials, or quasi-randomized controlled trials that met the study's inclusion criteria. For observational and epidemiological study designs, there is currently a lack of consensus regarding the most appropriate methodology for assessing quality in the context of a systematic review,[45] and many published reviews fail to include any appropriate analysis.[46] I considered a number of pre-existing tools and checklists previously employed when conducting systematic reviews of epidemiologic studies – including the Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines;[47] the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist for cohort, case-control, and cross-sectional studies;[48] and the Newcastle-Ottawa Scale for assessing the quality of nonrandomised studies in meta-analyses.[49] However, in light of the deficiencies of these tools, I chose to adapt components from the Graphic Appraisal Tool for Epidemiology (GATE) and supplement these sections with topic-specific criteria.[50] The GATE tool, which was first described by Martin and Srihari in 2006, includes specific questions related to the broad categories of population selection, exposure and comparison definitions, outcome assessments, follow-up time, analytic methods, and other components related to both internal and external validity.

Data analysis and synthesis

A meta-analysis was carried out for a specific pre-specified outcome if a sufficient number of pertinent observations were available in more than one study; in some instances, outcomes were aggregated in order to allow for adequate power. For example, third- and fourth-degree perineal lacerations, cervical and high vaginal lacerations, and uterine incision extensions were combined into one obstetric trauma outcome. Similarly, all types of birth trauma were aggregated into one outcome. For the meta-analysis, the study-specific odds ratios were weighted by the inverse of their variances. Both fixed and random effect models were used to estimate the pooled odds ratio. The random effects models are presented because they represent a more conservative approach. Statistical heterogeneity between studies was evaluated with the Tau^2, Cochran's Q, and I^2 statistical tests.[51] RevMan 5.1 was employed to carry out all statistical analyses and to create all graphs.

1.5.4. Results

After identifying a comprehensive search strategy (Appendix 1.2) and applying inclusion and exclusion criteria in a multistage process (Figure 1.2), four studies were included in the systematic review. These studies contained a total of 1,892 subjects whose information was included in the meta-analysis. All four studies were observational in nature (three retrospective and one prospective cohort) and were appraised to be of moderate quality. Globally, the pooled results between groups of studies were homogeneous, with $Tau^2 < 1$ and $I^2 < 50\%$ for NICU admission, umbilical cord arterial blood pH, and birth trauma. However, the remaining outcomes demonstrated substantial heterogeneity (neonatal resuscitation Tau^2 0.79, I^2 90%; maternal transfusion Tau^2 0.37, I^2 65%; obstetric trauma Tau^2 0.78, I^2 89%; and maternal febrile morbidity Tau^2 2.14, I^2 93% (Appendix Figure 1.2A-G). Only three studies were selected for the meta-analysis, and hence the Cochran Q test was not carried out (due to the test's lack of power to detect heterogeneity when only a few studies are available).[51]

Selection of studies

A total of 692 citations were compiled in a reference manager, with 502 remaining after removing exact duplicates. After independent review of each abstract by two separate researchers, a few disagreements arose regarding the inclusion of studies in the review of the complete articles; these were resolved via discussion by all three members of the study team. Following this process of resolution, 57 abstracts were selected for full review (Appendix Table 1.4 provides the full list of publications).

Following further assessment, 26 studies were excluded because they did not focus on midpelvic deliveries, seven studies were excluded because they were editorials, commentaries, or reviews, five studies were published in a language other than English (including Danish, French, German, Italian, and Turkish), seven studies were removed due to a failure to assess both operative vaginal delivery and cesarean delivery as primary interventions, four lacked information on a pre-specified outcome of interest, and two were excluded because the intervention did not take place during the second stage of labour. In addition, one article met all of the inclusion criteria but reported on data that was also presented in a subsequent publication; only the latter was included in the full review in order to avoid duplication. Applying these criteria resulted in a total of five studies that were included in the full review. However, after two authors thoroughly reviewed a publication by Al-Kadri et al.,[52] it was determined that it failed to meet the requirement to include results for both cesarean delivery and operative vaginal delivery. As a result, four studies are presented in the narrative and quantitative analysis included in this systematic review. Appendix Table 1.5 contains details on the methods, participants, intervention and comparisons, and outcomes of each of the three studies included in the full review. A summary of the study characteristics appears below in Table 1.5.

Table 1.5. Summary of study characteristics

Author	Year	Study Design	Sample Size	Country	Study Setting	Outcomes Measured
Bashore[29]	1990	Retrospective cohort	844	USA	Hospital	Admission to NICU, arterial cord blood pH, birth trauma, Apgar score, obstetric trauma, febrile morbidity, pulmonary embolism, deep vein thrombosis, transfusion.
Lowe[34]	1987	Retrospective cohort	225	UK	Hospital	Admission to NICU, resuscitation, birth trauma, transfusion, perineal injury,
Murphy[53]	2003	Prospective cohort	393	UK	Hospital	Admission to NICU, arterial cord blood pH, birth trauma, transfusion, perineal injury,
Robertson[28]	1990	Retrospective cohort	430	USA	Hospital	Admission to NICU, arterial cord blood pH, resuscitation, birth trauma

NICU, Neonatal Intensive Care Unit.

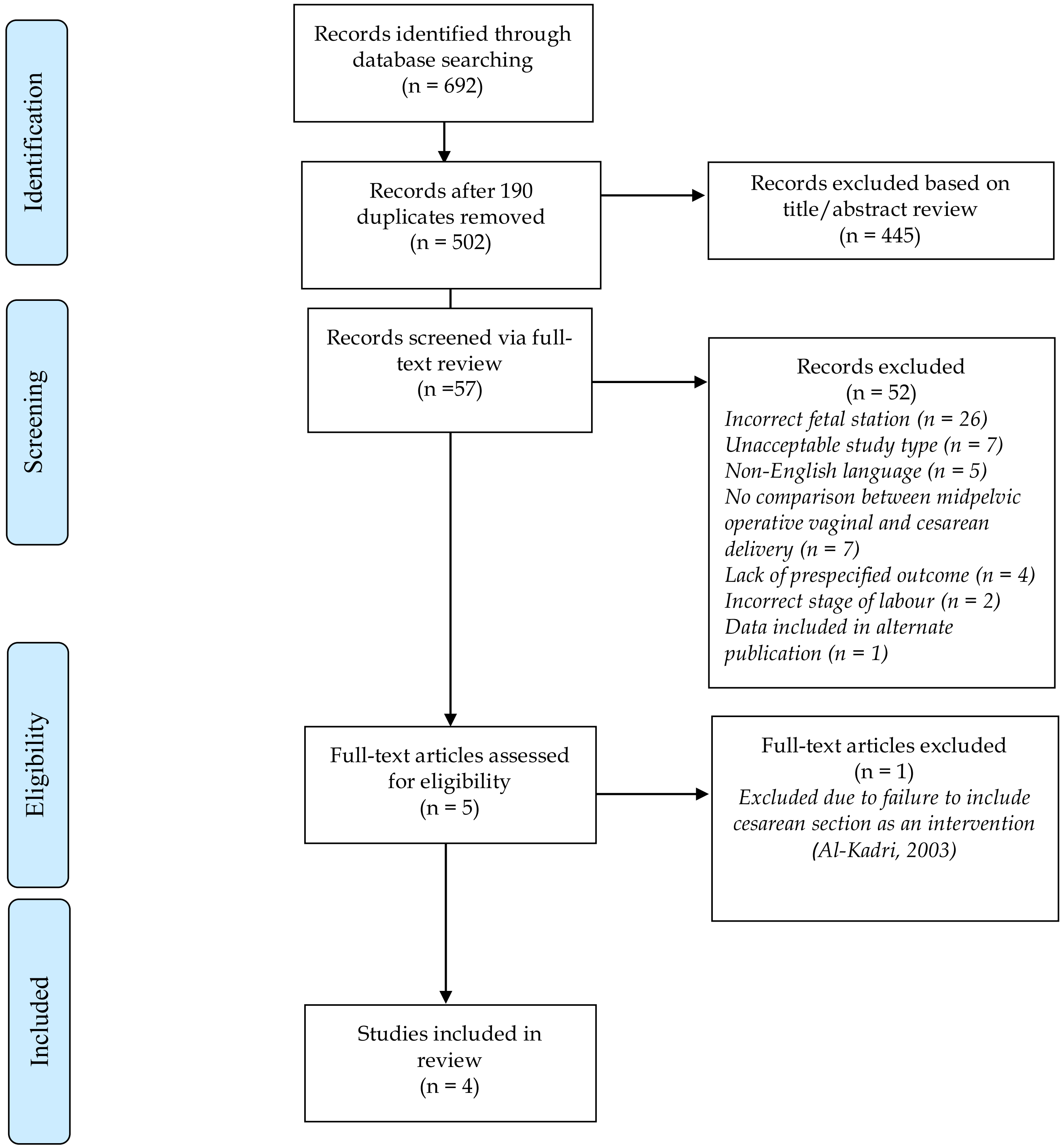

Figure 1.3. Search results for literature review

Quality appraisal for included studies

While no standard exists for conducting quality appraisals for observational studies in the context of a systematic review, the most commonly employed criteria cover methods of choosing participants and comparison groups, the measurement of study variables (including both exposures, or interventions, and outcomes), appropriate selection of analytic methods, and control of confounding.[45] The GATE criteria adapted for use in this review addressed all of these domains, as well as the generalizability of each study's findings. The data extraction form included in Appendix 1.3 details the specific questions employed to ascertain quality within each broad area. Reviewers provided a narrative description for each question, and then created an overall summary score for the category based on these results.

Overall, the four studies included in the final analysis were judged to be of moderate quality. Across the board, there was a lack of sufficient demographic information to assess the generalizability of each study's findings, a characteristic compounded by that fact that each study took place in either a single hospital or two hospitals serving the same population. Another common failing was the fact that the analyses were not adjusted for potential confounders, and in many cases the most appropriate measures of association were not reported, nor was sufficient detail provided on the precision of effect estimates.

The study by Bashore et al.[29] evaluated several important neonatal and maternal outcomes and the largest study size. This study included 358 midpelvic forceps deliveries and 486 cesarean deliveries in the second stage of labour. However, women who had midpelvic vacuum deliveries were not included in the study. The study population was well defined, thereby permitting an evaluation regarding generalizability. Another strength of this study was the stratification of the study population by indication for operative delivery: operative deliveries indicated due to dystocia and those indicated due to fetal distress. The greatest limitation of this analysis is the lack of adjusted estimates for any of the outcomes of interest. Although data on potential confounding factors were collected (i.e., information on maternal age, parity, birth weight, length of second stage of labour), only crude rates were provided in the publication and statistical significance was tested using the t-test or Fisher's exact test.

The biggest threat to the internal validity of the study by Lowe et al.[34] was the lack of clarity regarding the actual method used to identify cases and the overall participation rate. In addition, with the exception of the "resuscitation score" outcome, no information on specific components or definitions of outcomes was presented. With respect to the analysis, similar to the approach by Bashore et al.,[29] only the t-test and χ^2 tests were employed, rather than the more appropriate measures that provided a measure of the strength of the association. Further, no potential confounders were included in the analysis, and trials of successful and unsuccessful operative vaginal delivery were analyzed separately (rather than combining them into a single 'intention-to-treat' type analysis).

Similar issues arose with the publication by Murphy et al.[53] Again, there was a complete lack of information on study participants and the broader patient population, including a lack of information on important covariates such as parity, underlying medical conditions, or even the mean age of study members. Another failing was the exclusion of outcomes among women who had a failed operative vaginal delivery and then proceeded to cesarean delivery, which may have resulted in a bias toward a lower risk of harm among individuals in the operative vaginal delivery group. Among the factors that resulted in the study receiving an overall quality appraisal of moderate are the study's 100% participation rate and the fact that all outcome data were recorded by an obstetrician, with the expertise necessary to properly classify clinical findings.

Like the analysis by Lowe et al.,[34] the study by Robertson and colleagues[28] also lacked sufficient detail regarding the selection of eligible participants. No data were provided on relevant demographic, medical, or obstetric factors among the study subjects. Simple bivariable comparisons were reported, rather than a multivariable analysis with control for confounders such as maternal age, maternal body-mass-index, and indication for intervention. In addition, only crude means, proportions, and p-values were calculated. However, notable strengths of this study were the clearly delineated nature of the intervention and the detailed definitions of all outcomes. A summary of the quality appraisal of each study by category is presented in Table 1.6.

Table 1.6. Quality appraisal by category

Study	Comparisons	Interventions	Outcomes	Analytic Methods	Confounding	Generalizability
Bashore	Low	High	High	Low	Low	Moderate
Lowe	Unclear	High	High	Low	Unclear	Low
Murphy	Low	Low	Unclear	High	Low	Low
Robertson	Low	High	High	Low	Low	Low

Summary of results

After carrying out a qualitative appraisal and description of the four studies selected for review, a meta-analysis was conducted for the two maternal and four neonatal outcomes for which an adequate number of pertinent observations were available across studies. In two instances, more granular outcomes were aggregated in order to allow for adequate power. Specifically, composite outcomes for birth trauma and obstetric trauma were created from their respective component outcomes. The composite birth trauma outcome included bruising, scalp and facial lacerations, cephalohematoma, cerebral hemorrhage, facial nerve palsy, brachial plexus injury, skull fracture, clavicular fracture. Composite obstetric trauma included cervical and high vaginal lacerations, third- and fourth-degree perineal lacerations, uterine incision extension, and inadvertent cystotomy. Forest plots illustrating the relative strength of intervention effects for specific outcomes appear in Appendix Figure 1.2 (A-G).

The results of the current meta-analysis suggest that there is no difference in the risk of admission to the NICU among neonates delivered by midpelvic operative vaginal delivery or those delivered by cesarean delivery (pooled OR 1.37, 95% CI 0.78-2.39). Data provided by the four studies also showed no significant difference in the rate of fetal acidosis (umbilical cord blood pH <7.10) in either group (pooled OR 1.10, 95% CI 0.81-1.49). Additionally, there was no significant difference between the two groups in the need for neonatal resuscitation (pooled OR 1.43, 95% CI 0.39-5.20). However, infants born following midpelvic operative vaginal delivery had a significantly higher rate of birth trauma compared with those delivered by cesarean (pooled OR 12.7, 95% CI 5.37-29.9). In absolute terms, the rate difference for birth trauma was 10% (95% CI 6%-14%) higher following midpelvic operative vaginal delivery than following cesarean delivery.

Table 1.7. Summary of findings

	Pooled Odds Ratio (95% CI)	Pooled Rate Difference (95% CI)	No. of participants (No. of studies)
Neonatal outcomes			
Admission to NICU	1.37 (0.78-2.39)	0.02 (-0.00-0.04)	1899 (4)
Umbilical cord arterial blood pH <7.10	1.10 (0.81-1.49)	0.00 (-0.02-0.03)	1674 (3)
Resuscitation	1.43 (0.39-5.20)	0.09 (-0.22-0.39)	662 (2)
Birth trauma	12.7 (5.37-29.9)	0.10 (0.06-0.14)	1892 (4)
Maternal outcomes			
Blood transfusion	0.65 (0.28-1.54)	-0.03 (-0.06-0.00)	1462 (3)
Obstetric trauma	1.11 (0.36-3.39)	0.04 (-0.12-0.20)	1462 (3)
Febrile morbidity	0.34 (0.04-2.80)	-0.11 (-0.32, 0.10)	1069 (2)

With respect to maternal morbidity, the rate of obstetric trauma was similar following midpelvic operative vaginal delivery and cesarean delivery (pooled OR 1.11, 95% CI 0.36-3.39). Similarly, there was no significant difference in the pooled rate of blood transfusion or febrile morbidity across the two intervention groups (Table 1.7).

1.5.5. Discussion

No published randomized controlled trials, controlled clinical trials, or quasi-random studies comparing midpelvic operative vaginal delivery with cesarean delivery were identified as part of this systematic review. No prospective, controlled clinical experimental research study comparing midpelvic operative vaginal and cesarean delivery has ever been published. Moreover, it is extremely unlikely that such a study will ever be done in light of ethical restraints and feasibility issues. Because no “gold standard” evidence of this type exists, one can only draw conclusions from the existing observational studies, which include the prospective and retrospective cohort studies mentioned in this analysis.

Even among observational studies, only four studies satisfied the inclusion criteria and the main reason for the lack of relevant studies was the reclassification of the definition of midpelvic delivery mandated by the ACOG in 1988.[54] Prior to this change, midpelvic deliveries were classified as those where the fetal head was engaged but the conditions for outlet delivery were not met (conditions for outlet delivery included the criteria that the fetal skull had to have reached the pelvic floor and there had to be no rotation of the head greater than 45 degrees). As a result, prior to 1988, midpelvic operative vaginal delivery was an excessively broad category that included relatively simpler procedures (at what would now be referred to ‘low pelvic station’) and those of great difficulty requiring consummate skill by the practitioner. Most of the studies comparing midpelvic operative vaginal delivery to cesarean delivery were published before the 1988 reclassification, and because their results regarding midpelvic operative vaginal deliveries included outcomes that would now be classified as low-pelvic deliveries, they were deemed to be not relevant for this review.

Due to the clinical heterogeneity of cases included in the older studies that employed the original pelvic station classification, the literature is full of conflicting reports. Some studies concluded that midpelvic operative vaginal delivery should be abandoned due to the high rates of birth trauma associated with the procedure,[28,31] while others inferred that these procedures were safe and should continue to have a place in obstetrical care.[55,56] However, even the four studies included in this review that used the 1988 criteria, yielded conflicting results. The only consistent finding in all four studies was an increased rate of birth trauma following midpelvic operative vaginal delivery. Bashore et al.[29] found significantly higher rates of obstetric trauma (OR 2.44, 95% CI, 1.82-3.27) and significant lower rates of febrile morbidity (OR 0.12, 95% CI 0.07-0.22) and blood transfusion (OR 0.31, 95% CI 0.14-0.73) following midpelvic operative vaginal delivery. Aside from the positive association between operative vaginal delivery and birth trauma, Lowe et al.[34] and Murphy et al.[53] found no significant differences in neonatal or maternal morbidity once both successful and failed operative vaginal delivery were collapsed into one category (to reflect the outcome estimates following a trial of midpelvic operative vaginal delivery). Finally, Robertson et al.[28] found a significantly increased rate of required neonatal resuscitation (OR 2.68, 95% CI 1.78-4.04).

For this analysis, we combined extensions of uterine incisions and perineal injury into a single maternal injury outcome. The rate of severe perineal tears after midpelvic operative vaginal delivery has been a cause for concern, and the comparable morbidity at cesarean delivery was an extension of the uterine incision into the cervix, vagina, or broad ligaments. Perineal trauma has been associated with long-term pelvic floor dysfunction leading to fecal and urinary incontinence.[36,57] Extension of the uterine incision at full dilation has been reported in up to 35% of women undergoing cesarean section[58] and has been associated with an increased risk of cesarean hysterectomy[59] and febrile morbidity.[60] Long-term follow-up could establish whether extensions of the uterine incision subsequently lead to difficult deliveries or an increased risk of uterine rupture. For the purposes of this review, these two groups of injuries were aggregated into a single outcome to provide a clinically useful indicator of maternal injury that can be considered by obstetricians and communicated to women facing the decision between midpelvic operative vaginal delivery and cesarean delivery.

The meta-analysis showed a significant increase in birth injury following midpelvic operative vaginal delivery, concurring with the results of several other studies.[61-73] It is important to note that due to the way that birth trauma was reported in the four studies included in the review, the types of injuries that were included in the birth injury composite outcome were heterogeneous and ranged from mild bruising to severe subarachnoid hemorrhage. As a result, the utility of this information is limited.

Perhaps the most meaningful information regarding birth injury for both women and their care providers would be the long-term effects of birth injuries. Unfortunately, studies examining the long-term neonatal outcomes of midpelvic operative vaginal delivery compared with cesarean delivery have yet to be performed. One study[74] examined long-term outcomes among infants in the different operative intervention groups two years after delivery. However, this study was conducted prior to the ACOG classification changes described above, and was therefore not included in this review. During the five-year study period covered by Lowe et al.,[34] the researchers documented one case of birth injury that occurred after a trial of midpelvic operative vaginal delivery and in which the child suffered from spastic quadriparesis at the age of 23 months. As a single observation, this example is inadequate to reach any valid conclusion regarding the long-term effects of mode of delivery.

Based on the studies included in this review, we can only deduce that short-term birth injury is significantly greater among infants delivered following a trial of midpelvic operative vaginal delivery compared with those delivered by immediate cesarean section. Finally, due to the small number of studies that met the review's inclusion criteria, I was not able to conduct any subgroup or sensitivity analyses based on distinct groups (i.e., by instrument applied or by indication for operative delivery).

This review has several limitations highlighted as part of the quality assessment process, including many weaknesses resulting from the observational nature of the studies included. Since all four studies included in the review were cohort studies, the failure to identify and control for potentially important confounding factors cannot be ignored. In addition, two of the four studies included in the review did not describe any participant characteristics. This lack of detail makes it impossible to determine potential were differences in the composition of the study arms that may have impacted the findings, and, therefore, challenging to assess both internal and external validity. The use of unblinded data collection also increases the potential for reporting bias, because members of the study team may have been more vigilant in documenting outcome data for specific participants depending on the intervention received. Many of these issues could be addressed by a randomized clinical trial, though a randomized trial will likely never be carried out due to ethical concerns and issues with recruitment. Perhaps the greatest limitation of this review is that all the studies that were eligible for inclusion were carried out 15 to 30 years ago. Given the substantial shifts in the obstetric population and obstetric practice over this time period, the data included in these studies are likely no longer relevant to the contemporary obstetric setting.

It was not possible to assess publication bias in this review due to the small number of studies that met the inclusion criteria. We do anticipate there being some publication bias due to our selection criteria being limited to English-language publications, although only five studies that otherwise satisfied our inclusion criteria were excluded due to this reason.

Additional studies comparing midpelvic operative delivery and cesarean delivery are necessary in order to provide clinicians and their patients with evidence on which to base decisions regarding the safest, most effective intervention, and to inform evidence-based practice guidelines in this area.

1.6. Dissertation rationale

The systematic review described above indicates that individual studies have produced conflicting evidence regarding the relative safety of operative vaginal delivery and cesarean delivery and that there is currently a lack of robust data to guide practice. There is a gap in our understanding of the maternal and perinatal risk/benefit equation when comparing a trial of operative vaginal delivery and cesarean delivery. Quantifying the perinatal and maternal morbidity and mortality associated with a midpelvic operative vaginal delivery compared with cesarean delivery is critical to support evidence-based obstetric practice.

Currently, the decision to attempt midpelvic operative vaginal delivery or cesarean delivery as the first-line intervention for complications during the second stage of labour is predominantly dependent on the training of the physician.[75] However, instruction and training in utilizing the two intervention options is unevenly distributed across institutions and training programs: studies show that the opportunities for obstetricians to receive training in operative vaginal delivery have declined as the training in cesarean delivery has increased.[22,23,76-78] For example, Hankins et al.[75] studied forceps and vacuum training practices in North American obstetrical residency programs and maternal-fetal medicine fellowship programs and reported that only 47% of fellowship program directors expected midpelvic forceps proficiency among their graduates, and this proportion was even lower among residency program directors (38%). For midpelvic vacuum extraction, proficiency was expected by 73% of fellowship program directors and 69% of residency program directors. Younger medical professionals in industrialized countries are increasingly reluctant to perform midpelvic operative procedures because of the sharp learning curve, and inadequate opportunities for training, and therefore turn to cesarean delivery for addressing intrapartum challenges.[23,79,80] This shift in training practices has not necessarily been guided by evidence, however, and determining the impact of these changes in obstetrical training on neonatal and maternal outcomes is necessary to minimize harm to mothers and babies and to ensure the provision of the most effective care possible. Maternal and perinatal outcome-based evidence is needed to support women and their maternity care providers in choosing the most appropriate mode of operative delivery if and when intervention is required.

Certainly, the most robust study design to address this question would a randomized trial. However, as mentioned such a trial is unlikely to be carried out for ethical and feasibility reasons and in any case would take many years to accrue sufficient participation to provide meaningful results. Thus, rigorous observational studies are needed to provide evidence on this issue in a timely manner. The issue of timeliness is particularly pressing especially given that changes in practice have already been encouraged with operative vaginal delivery being advocated as an option to reduce rising rates of cesarean delivery.[11]

1.7. Conceptual framework

This dissertation is based on an evidence-informed shared decision-making conceptual framework. The evidence-based approach[81] and collaborative decision-making framework[82] requires the integration of a) the best available research evidence, b) practitioner characteristics, preferences and values, and c) the values, characteristics, needs, and preferences of those who will be affected by the intervention.

Core to obstetrical practice is determining the approach to mode of delivery across a range of clinical situations, while considering the wishes and expectations of the women in their care. Assessing the relative merits of different modes of delivery, such as operative vaginal delivery and cesarean delivery, is challenging and often controversial. For example, the strict guidelines on vaginal delivery after prior cesarean (VBAC),[83] along with the increasing rates of cesarean delivery, have raised concerns about women's access to vaginal delivery[84] and the movement away from physiological birth.[85] On the other hand, whether women should have access to cesarean delivery on demand (i.e., in the absence of medical indications) is also hotly debated.[86-89]

The studies in this dissertation aim to provide women and maternity care providers with robust relative and absolute estimates of maternal and perinatal morbidity and mortality to support informed decisions about mode of delivery for women who require intervention in the second stage of labour. Such estimates are not currently available, and as a result, the factors governing practitioner and women's decision-making are based on opinion and weak evidence regarding the benefits and safety of the operative interventions.

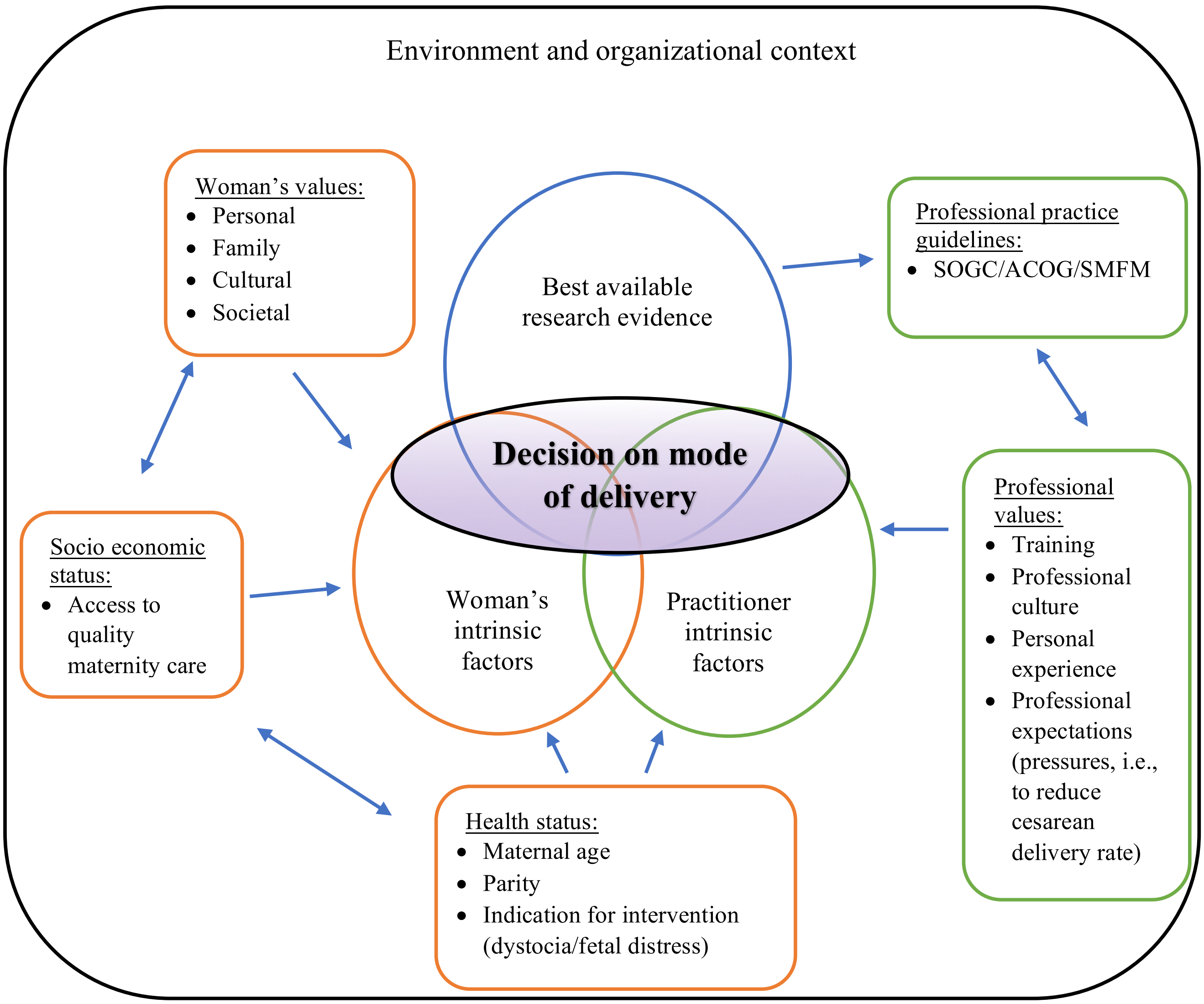

Figure 1.4. Conceptual framework for optimizing maternal and perinatal safety when choosing mode of operative delivery given complications in the second stage of labour. SOGC, Society of Obstetricians and Gynaecologists of Canada; ACOG, American College of Obstetricians and Gynecologists; SMFM, Society for Maternal-Fetal Medicine.

1.8. Dissertation objectives

The primary purpose of this doctoral dissertation was to quantify perinatal and maternal morbidity and mortality associated with all possible modes of delivery (operative vaginal delivery with forceps, vacuum, a combination of vacuum and forceps, or cesarean delivery) when spontaneous vaginal delivery is not an option and intervention is required for women with complications in the second stage of labour.

The specific objectives of the dissertation were to:

1) Describe temporal and regional trends in the use of operative vaginal delivery, by pelvic station, and by instrument applied, in Canada.
2) Quantify the perinatal and maternal morbidity and mortality associated with attempted operative vaginal delivery at midpelvic station compared with cesarean delivery in the second stage of labour (when the decision between cesarean delivery and operative vaginal delivery is most uncertain).
3) Estimate rates of severe perinatal and maternal morbidity and mortality associated with operative vaginal delivery at all pelvic stations compared with cesarean delivery and to determine whether these associations differ by pelvic station.
4) Quantify the relationship between population rates of operative vaginal delivery, obstetric trauma and birth trauma.

1.9. Data sources

The data sources used for analyses in this dissertation were the British Columbia Perinatal Data Registry (BCPDR) and the Canadian Institute for Health Information's Discharge Abstract Database (DAD). The BCPDR contains information on approximately 99% of births in British Columbia, from approximately 60 hospitals and health centres across the province and also includes home births attended by registered midwives. The DAD includes all hospital deliveries in Canada (excluding Quebec) that resulted in a live birth or stillbirth, and includes approximately 98% of all Canadian births (excluding Quebec).[90] Both databases register stillbirths and live births at 20 weeks of gestation or greater. Diagnoses and procedures in these databases were coded using the International Statistical Classification of Diseases and Related Health Problems, version 10, Canadian edition (ICD-10-CA), and the Canadian Classification of Interventions (CCI). These and additional data were abstracted from antenatal records, labour and delivery records, and birth records using standardized forms filled out by care providers. Both the DAD and the BCPDR were abstracted from the women's medical records by trained data abstractors.

1.9.1. Validity of the data sources

A validation study[91] comparing perinatal information from the DAD with information from the Nova Scotia Atlee Perinatal Database (a small, clinically focused population-based database) serving as the gold standard, showed that most obstetric, maternal and neonatal indicators in the DAD were accurate. Some key results are tabulated below. In particular, cesarean delivery had very high sensitivity (99.8%, 95% CI 99.5-100) and specificity (98.7%, 95% CI 98.3-99.0). Maternal morbidity, such as postpartum hemorrhage, also had high sensitivity and specificity (90.2%, 95% CI, 86.2-93.3; 98.2%, 95% CI 97.8-98.5, respectively) as did severe perineal lacerations (third-degree: 97.1%, 95% CI 92.7-99.2 and 99.9%, 95% CI 99.8-100, respectively; fourth-degree: 94.7%, 95% CI 74.0-99.7 and 99.9%, 95% CI 99.8-100, respectively). The accuracy of other important neonatal morbidity varied with sensitivity ranging from 88.9% for severe intraventricular hemorrhage to 67.4% for bacterial sepsis. The specificities for these two conditions were 100% and 99.6%, respectively.[91]

Furthermore, a 2015/2016 Discharge Abstract Database reabstraction study found high agreement for obstetric hemorrhage indicators (89.5% agreement, 95% CI 86.3%–92.7%) and very high agreement for obstetric trauma indicators (97.0% agreement 95% CI 95.4%–98.6%).[92]

Table 1.8. Validity of perinatal diagnoses and procedures in the Discharge Abstract Database, Canadian Institute for Health Information[91]

Indicator	Sensitivity (95% CI)	Specificity (95% CI)
Obstetric factors		
Cesarean delivery	99.8 (99.5-100)	98.7 (98.3-99.0)
Induction of labour	89.2 (87.7-90.6)	96.9 (96.4-97.4)
Maternal complications		
Postpartum hemorrhage	90.2 (86.2-93.3)	98.2 (97.8-98.5)
Blood transfusion	85.7 (42.1-99.6)	99.8 (99.6-99.9)
Perineal lacerations		
1st degree	91.7 (89.7-93.3)	97.9 (97.4-98.4)
2nd degree	97.7 (96.8-98.3)	99.1 (98.7-99.4)
3rd degree	97.1 (92.7-99.2)	99.9 (99.8-100)
4th degree	94.7 (74.0-99.7)	99.9 (99.8-100)
Chronic hypertension	83.3 (73.6-90.6)	99.9 (99.8-100)
Any gestational hypertensive disorder	87.9 (85.0-90.4)	99.6 (99.4-99.8)
Neonatal complications		
Severe respiratory distress syndrome	100 (95.5-100)	99.6 (99.4-99.8)
Intraventricular hemorrhage	88.9 (51.8-99.7)	100 (99.9-100)
Fracture of clavicle	91.7 (61.5-99.8)	100 (99.3-100)
Bacterial sepsis	67.4 (56.5-77.2)	99.6 (99.4-99.8)

CI, confidence interval.

The BCPDR incorporates routine quality checks for the data, including programmed logic and consistency checks and validation rules to ensure that the measures entered are plausible.[93] The data are also reviewed at the hospital-level and through the analyses of key indicators. A provincial chart re-abstraction study[94] showed overall high quality of data contained in the BCPDR. Maternal, antenatal, labour and delivery, obstetric trauma, postpartum, and newborn information had a high degree of completion and high levels of accuracy. The sensitivity, specificity, and positive predictive value of selected maternal indicators from the BCPDR are summarized in Table 1.9.

Table 1.9. Validity of selected maternal diagnoses and procedures in the British Columbia Perinatal Database Registry[94]

Variable	Sensitivity (95% CI)	Specificity (95% CI)	Positive predictive value (95% CI)
Labour position			
Anterior	89.8 (85.8 - 92.9)	90.8 (86.1 - 94.3)	81.4 (75.8 - 86.3)
Posterior	66.9 (50.9 - 80.6)	98.5 (97.3 - 99.2)	77.5 (67.0 - 86.0)
Transverse	79.9 (71.8 - 86.5)	98.5 (97.5 - 99.2)	87.2 (79.5 - 92.8)
Labour presentation			
Vertex	96.0 (93.7 - 97.6)	82.2 (75.2 - 88.0)	94.7 (92.8 - 96.2)
Stage of labour			
First stage start date	95.4 (93.7 - 96.8)	95.3 (92.4 - 97.3)	98.4 (97.3 - 99.2)
First stage start time	98.8 (97.8 - 99.5)	93.9 (89.2 - 97.0)	97.6 (95.9 - 98.7)
Second stage start date	97.9 (96.5 - 98.8)	97.9 (90.5 - 99.9)	99.0 (95.6 - 99.9)
Second stage start time	99.2 (97.6 - 99.9)	100.0 (99.2 -100.0)	100.0 (99.4 -100.0)
Obstetric trauma			
Perineum/Vagina/Cervix - Laceration	97.3 (94.8 - 98.8)	98.9 (97.8 - 99.6)	98.6 (96.8 - 99.5)
Perineal laceration			
3rd degree	90.1 (70.9 - 98.4)	99.8 (98.7 -100.0)	92.9 (59.0 -100.0)
4th degree	100.0 (-)	100.0 (-)	100.0 (-)
Cesarean delivery type			
Primary Elective	96.0 (83.8 - 99.7)	99.8 (99.4 - 100.0)	95.3 (82.3 - 99.6)
Primary Emergency	99.1 (97.1 - 99.8)	99.8 (99.2 - 100.0)	99.2 (97.3 -99.9)
Repeat Elective	94.9 (86.7 - 98.8)	99.2 (98.0 - 99.8)	90.7 (76.0 -97.9)
Repeat Emergency	90.2 (78.9 - 96.7)	99.6 (99.0 - 99.9)	94.7 (87.9 - 98.3)

CI: confidence interval

1.10. Dissertation structure

The second chapter of this dissertation provides a descriptive analysis of the temporal and regional trends in operative vaginal delivery in Canada by pelvic station and instrument applied. The third and fourth chapters provide detailed population-based analyses of perinatal and maternal outcomes following midpelvic operative vaginal delivery compared with cesarean delivery using national and provincial databases. The fifth chapter presents the results of an analysis quantifying severe perinatal and maternal morbidity and mortality associated with operative vaginal delivery at outlet, low-pelvic, and midpelvic stations compared with cesarean delivery in the second stage of labour, to determine whether these associations differ by pelvic station. The sixth chapter presents an ecological analysis exploring the associations between operative vaginal delivery, obstetric trauma, and birth trauma at the population level. Finally, Chapter 7 synthesizes the findings of the different studies, proposes future research directions for research, adds context to the implications of this work and highlights the significance of this thesis.

Chapter 2: Temporal and Regional Trends in Operative Vaginal Delivery in Canada[1]

2.1. Synopsis

Background: To describe temporal and regional variation in the use of operative vaginal delivery by pelvic station in Canada from 2004 to 2013 in term, singletons.

Methods: Operative vaginal delivery rates among term, singletons in Canada (excluding Quebec) were estimated using information from the Discharge Abstract Database of the Canadian Institute for Health Information between 2004 and 2012 (n=2,284,109). Operative vaginal deliveries were stratified by pelvic station. Temporal trends were assessed using the Cochran-Armitage test for linear trend in proportions by year. Geographic variation was assessed by calculating the rate and 95% confidence interval of each mode of delivery from 2010-2012 for each province/territory.

Results: Among singletons at term, the operative vaginal delivery rate decreased from 12.0% in 2004 to 10.7% in 2012 (P<0.0001), while cesarean delivery rates (excluding those following failed operative vaginal deliveries) increased from 24.9% to 26.7%. Forceps deliveries decreased from 3.1% to 2.5%, primarily due to decreases in midpelvic forceps delivery. Vacuum delivery also decreased from 7.8% in 2004 to 7.4% in 2012, however, vacuum delivery increased significantly at outlet and low stations (by 26.0% and 15.1%, respectively) and remained stable at midpelvic station. The failed operative vaginal delivery

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[1] A version of this chapter has been published as Muraca GM, Sabr Y, Brant R, Cundiff GW, Joseph KS. (2016) Temporal and regional variations in operative vaginal delivery in Canada by pelvic station, 2004-2012. *J Obstet Gynaecol Canada* 38:627-35.

rate was 0.3% and decreased by 23.7% ($P<0.0001$). Large variations were noted in operative vaginal delivery rates by province.

Conclusion: Temporal trends in operative vaginal delivery rates varied by pelvic station, with outlet and low operative vaginal deliveries increasing and midpelvic and failed operative vaginal deliveries decreasing. Vacuum extraction is increasingly replacing forceps deliveries at outlet and low stations, while cesarean deliveries are replacing forceps deliveries at midpelvic stations. Variations in operative vaginal delivery rates across provinces suggest differences in instrument preference and/or an evolution in standards of practice.

2.2. Background and objectives

In contrast to the increasing cesarean delivery rate, the operative vaginal delivery rate has declined over the last 25 years and varies markedly worldwide.[10,77,95-97] The United States reported an operative vaginal delivery rate of 3.2% of all deliveries in 2014 compared to 9.4% in 1995.[95] In Canada, overall rates of operative vaginal delivery are substantially higher but follow the same downward trajectory from 17.4% of all vaginal deliveries in 1991 to 13.2% in 2014.[10,96] These trends are concerning because operative vaginal deliveries can potentially prevent cesarean deliveries. As previously mentioned, a recent consensus statement endorsed by the American College of Obstetricians and Gynecologists (ACOG) and the Society for Maternal-Fetal Medicine, advocated an increase in the use of operative vaginal deliveries as a strategy to safely lower the primary cesarean delivery rate.[11]

Operative vaginal deliveries include both forceps and vacuum assisted deliveries carried out at different pelvic stations (i.e., after the fetal head has descended to a different extent). Quantifying pelvic station-specific operative vaginal delivery rates is important because midpelvic, low pelvic, and outlet operative vaginal deliveries are associated with significantly different rates of neonatal and maternal trauma. However, such rates are rarely, if ever, reported in population-based studies, making reported temporal and regional variation in overall operative vaginal delivery rates less meaningful. Another critical factor responsible for maternal and fetal safety relates to the sequential use of forceps, vacuum and cesarean delivery, with combined and sequential use of these interventions associated with the highest rates of neonatal mortality and morbidity. We, therefore, carried out a study to describe temporal and regional variation in the use of operative vaginal delivery by pelvic station in Canada from April 2004 to March 2013 in term, singletons.

2.3. Methods

The study was carried out among all hospital deliveries in Canada between April 2004 and March 2013 with data obtained from the Canadian Institute for Health Information's (CIHI) Discharge Abstract Database. This database contains information on approximately 98% of all deliveries in Canada (excluding Quebec).[90] Trained health records personnel abstracted information into the database using standardized definitions, and data consistency and accuracy were ensured through routine quality assurance checks. Maternal, fetal and neonatal information in the database included details regarding medical history, maternal characteristics, labour and delivery, neonatal condition, and details of diagnoses and interventions/procedures. Diagnoses in the database were coded using the Canadian version of the International Classification of Diseases (ICD-10-CA) throughout the study period, while interventions and procedures were coded using the Canadian Classification of Interventions (CCI). The accuracy of the perinatal information in the database has been demonstrated in validation studies.[91,92]

All term hospital deliveries between 37 and 41 weeks gestation in Canada (excluding Quebec) that resulted in a singleton live birth (Z37.0) or a singleton stillbirth (Z37.1) between April 1, 2004, and March 31, 2013 (hereafter referred to as fiscal years 2004 to 2012) were included in the study. Missing gestational age data precluded the inclusion of deliveries from Prince Edward Island in 2004 and 2005 as well as deliveries from the territories in 2004.

Forceps deliveries were identified using CCI codes 5.MD.53.^^, vacuum deliveries were identified using CCI code 5.MD.54.^^ and deliveries involving the sequential use of instruments were identified using the CCI code 5.MD.55.^^. Forceps deliveries were grouped into five categories: outlet, low, midpelvic, double forceps application (e.g., Scanzoni maneuver) and forceps rotation with manually assisted delivery. Outlet, low and midpelvic forceps deliveries were defined based on the Classification According to Station and Rotation.[39] Outlet forceps delivery was defined as forceps delivery in cases where the scalp was visible at the introitus without separating the labia, the fetal skull had reached the pelvic floor, the fetal head was at or on the perineum, the sagittal suture was in anteroposterior diameter, or the position was right or left occiput anterior or posterior and rotation did not exceed 45 degrees. Low forceps delivery was defined as forceps delivery in cases where the leading point of the fetal skull was at pelvic station ≥ +2 cm, not on the pelvic floor, and rotation was either 45 degrees or less, or greater than 45 degrees. Midpelvic forceps delivery was defined as forceps delivery in cases where the head was engaged and the leading point of the fetal skull was above station +2 cm. Forceps deliveries with unspecified pelvic station were included in the low forceps category.

Delivery by vacuum extraction was grouped into four pelvic categories: outlet, low, mid, and not otherwise specified (NOS). The outlet, low and midpelvic vacuum groups were defined with the same descent/station criteria used for the forceps groups except that details about rotation did not apply. Deliveries that used both instruments sequentially were grouped into the same four categories as vacuum extractions: outlet, low, mid, and NOS. Information about the sequence in which the instruments were applied was not available; such cases could have represented a failed trial of vacuum extraction that proceeded to a successful trial of forceps delivery or vice versa.

Information on pelvic station was not available for failed trials of operative vaginal delivery (unless the failed trial with one instrument was followed by a successful trial with another instrument). Consequently, failure rates were grouped into three categories: failed trial of forceps delivery, failed trial of vacuum extraction, and failed trial of sequential instrumentation. In the latter group, details on the sequence in which the instruments were used were not available. To qualify as a failed operative vaginal delivery, deliveries required a CCI code indicating a cesarean delivery in combination with instrumentation, as well as a diagnosis code for a failed instrument (O66.5).

Temporal trends were assessed using the Cochran-Armitage test for a linear trend in proportions by year, and by comparing rates in 2012 with those in 2004. Geographic variation was assessed by calculating the rate and 95% confidence interval (CI) of each mode of delivery over the last three years of study (2010-2012) for each province and territory. All analyses were conducted using SAS version 9.4 for Windows (SAS Institute Inc., Cary, NC). Ethics approval for the study was obtained from the Clinical Research Ethics Board at the University of British Columbia.

2.4. Results

There were 2,284,109 singleton deliveries at 37 to 41 weeks gestation during the study period and these resulted in 2,280,044 live births and 4,065 stillbirths; the stillbirth rate was 1.7 per 1,000 total births. The mean maternal age was 29.3 years, and most women were nulliparous (44%) or had one previous delivery (35%). Women with previous cesarean deliveries accounted for 10.4% of the population and 2.3% were vaginal births after cesarean delivery.

Figure 2.1 shows the distribution of mode of delivery among all term, singleton deliveries from 2004 to 2012. The overall cesarean delivery rate (not including failed operative vaginal deliveries) was 26.2% (95% CI 26.1, 26.2) and the overall operative vaginal delivery rate was 11.2% (95% CI 11.2, 11.2). Among the operative vaginal delivery group, 92.0% of deliveries were successful after the use of a single instrument and consisted of a 3:1 ratio of vacuum extraction to forceps delivery (successful forceps delivery rate 2.7 per 100 deliveries; successful vacuum delivery rate 7.5 per 100 deliveries). The remaining deliveries in the operative vaginal delivery group were achieved with the use of a second instrument (sequential instrument delivery rate 0.6 per 100 deliveries) or with a cesarean delivery (failed instrument(s) followed by cesarean delivery rate 0.3 per 100 deliveries). Forceps (40.3%) and vacuum (44.6%) use were similarly distributed among the failed operative vaginal deliveries that resulted in a cesarean delivery. The remaining 15.1% of cesarean deliveries following failed operative vaginal delivery took place after the use of both instruments.

Temporal trends in mode of delivery are presented in Table 2.1. The overall operative vaginal delivery rate decreased significantly by 10.8%, from 120.1 per 1,000 deliveries in

2004 to 107.1 per 1,000 in 2012 (P<0.0001), while the cesarean delivery rate (not including failed operative vaginal deliveries) increased significantly from 249.0 to 266.9 per 1,000 deliveries (7.2% increase, P<0.0001). The rate of forceps delivery decreased significantly by 20% from 31.4 per 1,000 in 2004 to 25.1 in 2012 (P<0.0001).

Vacuum extraction rates decreased from 77.5 to 74.4 per 1,000 deliveries (4% decrease, P=0.006), while the sequential use of vacuum and forceps decreased from 7.3 to 4.7 per 1,000 deliveries (36.0% decrease, P<0.0001).

Figure 2.2 presents the temporal trends in operative vaginal delivery rates from 2004 to 2012 stratified by pelvic station at which the instrument was applied. The rates for all types of forceps delivery decreased over the study period (Figure 2.2, Panel A and Table 2.1). Low forceps accounted for the most forceps deliveries and despite an overall decline, rates increased in the most recent years. Midpelvic forceps deliveries were the second most common type of forceps delivery and use decreased steadily over the study period from 13.0 per 1,000 deliveries in 2004 to 9.3 per 1,000 deliveries in 2012 (P<0.0001, Table 2.1).

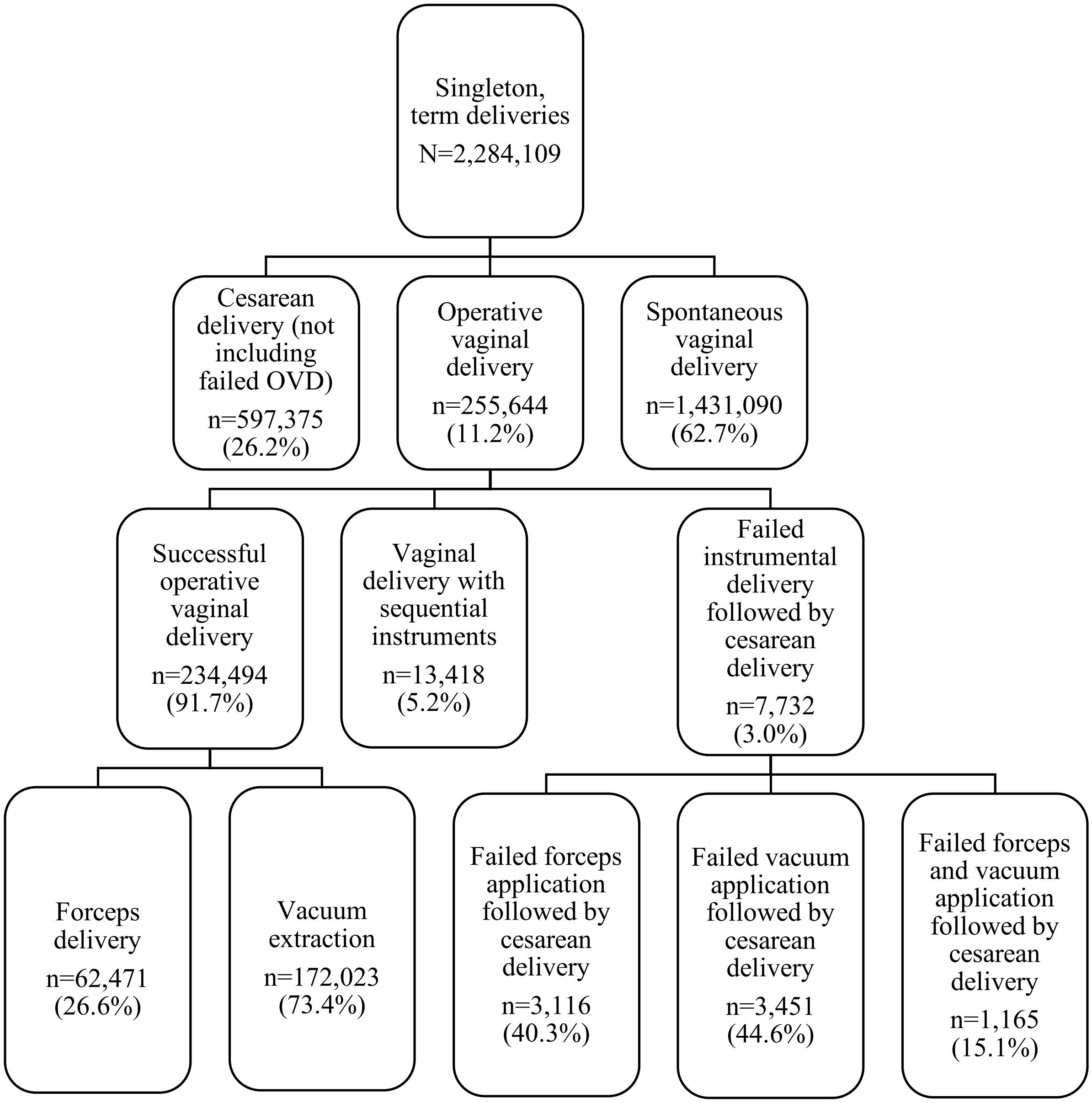

Figure 2.1. Schematic diagram showing the mode of delivery of term singletons, Canada, 2004-2012. OVD, operative vaginal delivery.

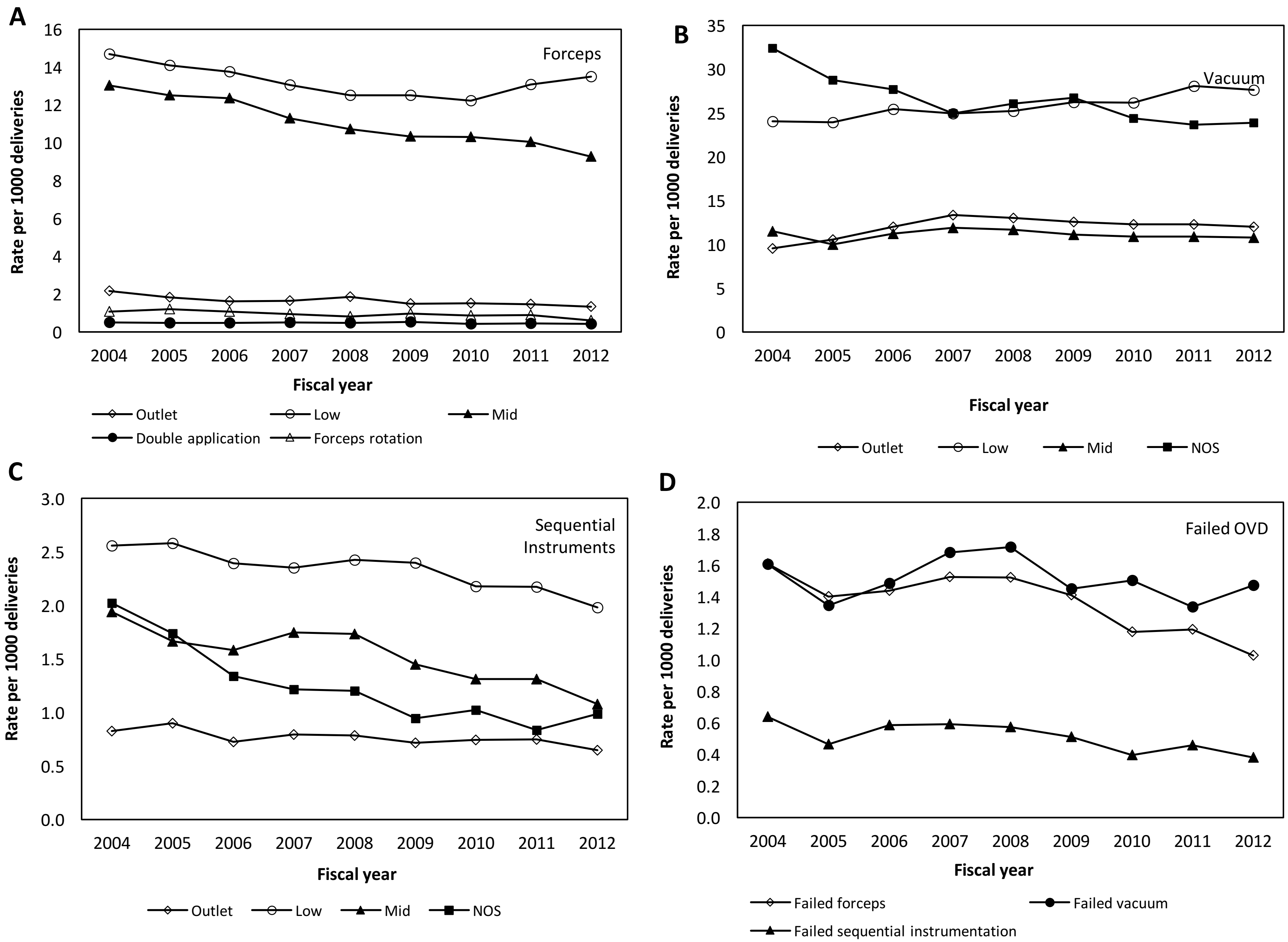

Figure 2.2. Temporal trends in forceps delivery (A), vacuum extraction (B), sequential instrumentation (C), and failed trial of operative vaginal delivery (D) among singleton, term deliveries in Canada (excluding Quebec), 2004-2012

Vacuum extraction with the station of application unspecified (NOS) constituted the largest proportion of all vacuum extractions until 2010, after which low vacuum delivery was the most common. The frequency of vacuum deliveries without specification of station decreased over the study period, while outlet and low vacuum delivery rates significantly increased (26.0% increase, $P<0.001$ and 15.1% increase, $P<0.0001$, respectively) between 2004 and 2012. The rate of midpelvic vacuum delivery was stable ($P=0.23$, Table 1.1).

Rates of sequential instrument use and failed operative vaginal deliveries decreased significantly over the study period (Figure 2.2, Panel C and D). The sequential use of instruments at low station was most common, followed by sequential use at midpelvic station. Attempted forceps deliveries that ended in a cesarean delivery decreased from 1.6 per 1,000 deliveries in 2004 to 1.0 per 1,000 deliveries in 2012 ($P<0.0001$). Similarly, the sequential use of instruments resulting in a cesarean delivery decreased from 0.6 to 0.4 per 1,000 deliveries ($P<0.0001$). The rate of attempted vacuum delivery ending in a cesarean delivery did not change appreciably over the study period (from 1.6 to 1.5 per 1,000 deliveries, $P=0.19$). Failed forceps rates (as a proportion of successful and failed forceps deliveries), failed vacuum rates (as a proportion of successful and failed vacuum deliveries) and failed sequential instrument application rates were 4.8%, 2.5% and 8.0%, respectively. Figure 2.3 shows temporal trends in these rates, with significant decreases in the proportions of failed forceps and failed vacuum attempts between 2004 and 2012($P=0.03$ and $P=0.003$, respectively).

Table 2.1. Numbers and rates of spontaneous vaginal delivery, operative vaginal delivery and cesarean delivery, term singletons, Canada, 2004-2012

Mode of delivery	All years			2004	2005	2006	2007	2008	2009	2010	2011	2012	% change	P for trend
	N	rate	95% CI											
Number of deliveries	2284109	-	-	236556	241059	249120	258802	260224	261659	257405	259138	260146	-	-
Operative vaginal delivery	255644	111.9	(111.5, 112.3)	120.1	113.5	115.3	112.5	112.2	111.3	107.5	108.9	107.1	-10.8	<.0001
Forceps delivery	62471	27.4	(27.1, 27.6)	31.4	30.1	29.3	27.4	26.3	25.8	25.3	25.9	25.1	-20.1	<.0001
Outlet forceps	3763	1.6	(1.6, 1.7)	2.2	1.8	1.6	1.6	1.9	1.5	1.5	1.5	1.3	-38.4	<.0001
Low forceps	30241	13.2	(13.1, 13.4)	14.7	14.1	13.7	13.0	12.5	12.5	12.2	13.1	13.5	-8.0	<.0001
Midpelvic forceps	25249	11.1	(10.9, 11.2)	13.0	12.5	12.4	11.3	10.7	10.3	10.3	10.1	9.3	-28.9	<.0001
Double application	1083	0.5	(0.4, 0.5)	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	-18.1	0.07
Forceps rotation	2135	0.9	(0.9, 1.0)	1.1	1.2	1.1	0.9	0.8	1.0	0.9	0.9	0.6	-42.1	<.0001
Vacuum extraction	172023	75.3	(75.0, 75.7)	77.5	73.3	76.4	75.1	75.9	76.6	73.8	74.9	74.4	-4.0	0.006
Outlet vacuum	27408	12.0	(11.9, 12.1)	9.5	10.5	12.0	13.3	13.0	12.6	12.3	12.3	12.0	26.0	<.0001
Low vacuum	58877	25.8	(25.6, 26.0)	24.0	23.9	25.4	24.9	25.2	26.2	26.2	28.1	27.7	15.1	<.0001
Midpelvic vacuum	25370	11.1	(11.0, 11.2)	11.5	10.0	11.2	11.9	11.7	11.1	10.9	10.9	10.8	-6.3	0.23
Vacuum, unspecified	60368	26.4	(26.2, 26.6)	32.4	28.8	27.7	25.0	26.0	26.7	24.4	23.7	23.9	-26.2	<.0001
Sequential instruments	13418	5.9	(5.8, 6.0)	7.3	6.9	6.0	6.1	6.1	5.5	5.3	5.1	4.7	-36.0	<.0001
Outlet sequential	1745	0.8	(0.7, 0.8)	0.8	0.9	0.7	0.8	0.8	0.7	0.7	0.7	0.6	-21.2	0.005
Low sequential	5331	2.3	(2.3, 2.4)	2.6	2.6	2.4	2.4	2.4	2.4	2.2	2.2	2.0	-22.4	<.0001
Midpelvic sequential	3497	1.5	(1.5, 1.6)	1.9	1.7	1.6	1.8	1.7	1.4	1.3	1.3	1.1	-44.3	<.0001
Sequential, unspecified	2845	1.2	(1.2, 1.3)	2.0	1.7	1.3	1.2	1.2	0.9	1.0	0.8	1.0	-51.2	<.0001
Failed operative vaginal delivery*	7732	3.4	(3.3, 3.5)	3.9	3.2	3.6	3.8	3.8	3.4	3.1	3.0	2.9	-23.7	<.0001
Failed forceps	3116	1.4	(1.3, 1.4)	1.6	1.4	1.5	1.5	1.5	1.4	1.2	1.2	1.0	-37.5	<.0001
Failed vacuum	3451	1.5	(1.5, 1.6)	1.6	1.3	1.5	1.7	1.7	1.5	1.5	1.3	1.5	-6.3	0.19
Failed sequential	1165	0.5	(0.5, 0.5)	0.6	0.5	0.6	0.6	0.6	0.5	0.4	0.5	0.4	-33.3	<.0001
Cesarean delivery (not including failed OVDs)	597375	261.5	(261.0, 262.1)	249.0	257.6	257.3	261.9	265.0	262.5	265.2	266.2	266.9	7.2	<.0001
Spontaneous vaginal delivery	1431090	626.5	(625.9, 627.2)	630.6	628.8	627.6	625.7	622.7	626.1	627.2	624.9	625.9	-0.7	<.0001

*These deliveries refer to cases with two codes, 1) for the combined use of instrument(s) and cesarean delivery and 2) for failed instrument.
Data not available for PEI and NWT/NT/YT for 2004 and for PEI in 2005. CI, confidence interval; OVD, operative vaginal delivery.

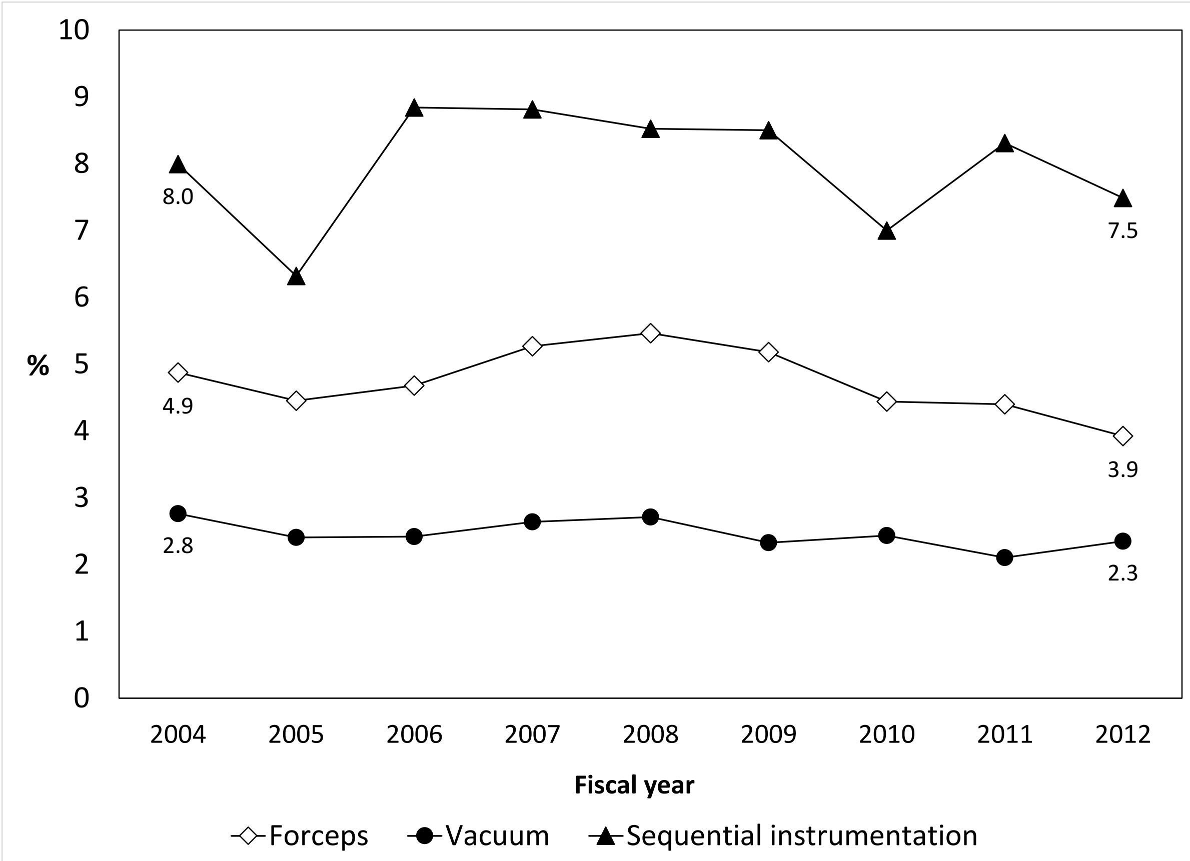

Figure 2.3 Failure rates among trials of forceps, vacuum and sequential instrumentation in term singleton deliveries, Canada (excluding Quebec), 2004-2012.

Figure 2.4 presents the distribution of operative vaginal delivery by pelvic station, including failures, from 2004 to 2012. Operative vaginal deliveries at the outlet and low pelvic stations increased over the study period. Outlet operative vaginal deliveries increased by 11.8% ($P<0.0001$) from 12.5 in 2004 to 14.0 per 1,000 deliveries in 2012, low operative vaginal deliveries increased by 4.4% ($P<0.0001$) from 41.3 to 43.1 per 1,000 deliveries. Midpelvic operative vaginal deliveries decreased from 26.5 in 2004 to 21.1 per 1,000 deliveries in 2012 (20% decrease, $P<0.0001$) as NOS deliveries and operative vaginal delivery failures decreased by 28% and 24%, respectively.

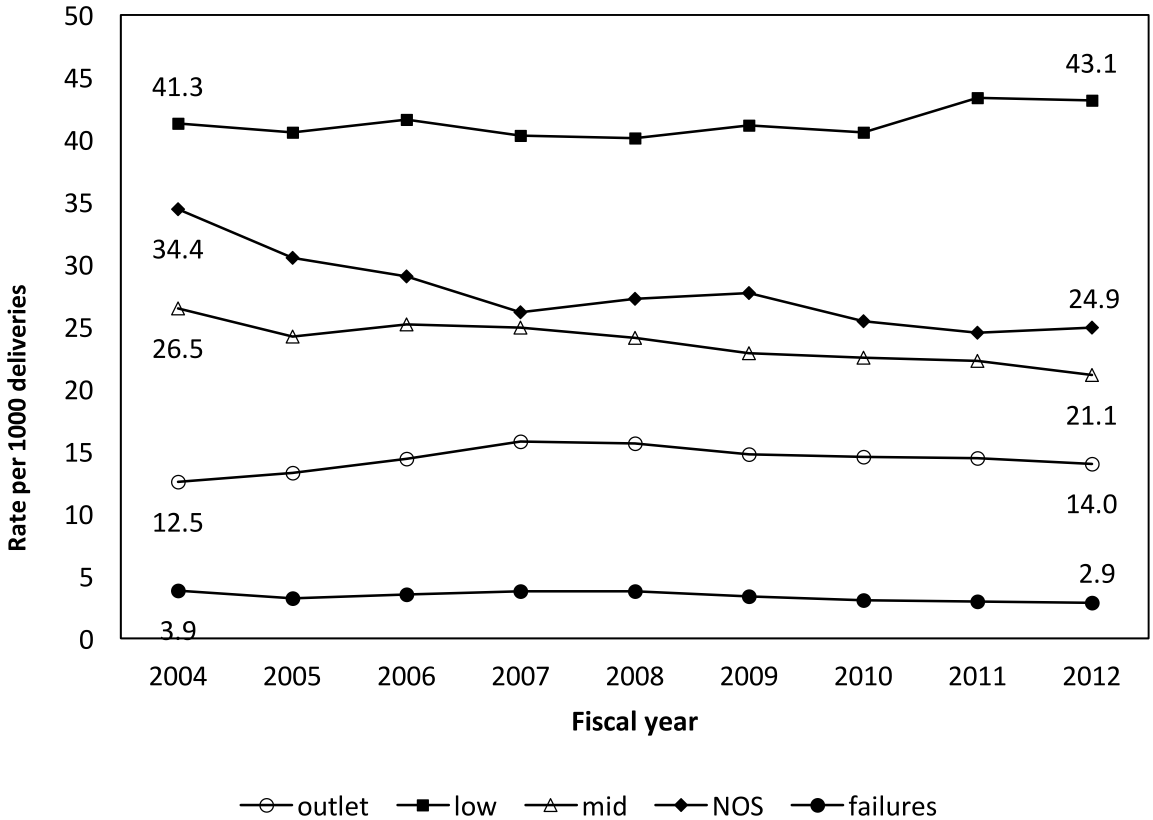

Figure 2.4. Distribution of operative vaginal delivery by pelvic station, including failures, Canada (excluding Quebec), 2004-2012

Geographic variations in operative vaginal delivery rates in 2010 to 2012 are depicted in Figure 5. Nova Scotia had a low forceps rate of 22.9 per 1,000 deliveries that was much higher than the national rate (12.9 per 1,000 deliveries; Figure 2.5, Panel A). Alberta's midpelvic forceps rate was 17.6 per 1,000 deliveries compared with a rate of 9.9 per 1,000 deliveries nationally. The territories had relatively low rates of forceps deliveries. Saskatchewan had elevated rates of all types of vacuum delivery except midpelvic vacuum (Figure 2.5, Panel B). The rate of outlet vacuum use in Saskatchewan was double the Canadian rate and the rate of low vacuum extraction was 40.4 per 1,000 (95% CI 38.5, 42.4) compared to the national rate of 27.3 per 1,000 (95% CI 26.9, 27.7). Alberta had the highest rate of midpelvic vacuum delivery (31.8 per 1,000 deliveries, 95% CI 30.9, 32.8). British Columbia had a notably high rate of vacuum delivery at unspecified pelvic station (41.9 per 1,000, 95% CI 40.7, 43.0). Sequential instrumentation rates were highest in Saskatchewan (Figure 2.5, Panel C) at outlet, low and unspecified station, while Alberta had the highest rate of midpelvic sequential instrumentation. Failed forceps delivery rates were highest in Prince Edward Island and Nova Scotia while failed vacuum delivery was most common in British Columbia and Saskatchewan (Figure 2.5, Panel D).

2.5. Discussion

Our study showed that rates of operative vaginal delivery declined, while rates of cesarean delivery increased in Canada from 2004 to 2012. Temporal changes in operative vaginal delivery rates were dependent on pelvic station, with operative vaginal deliveries at the outlet and low stations showing significant increases, whereas midpelvic operative vaginal deliveries showed significant declines. Forceps use at all stations decreased from 2004 to 2012, while rates of low and outlet vacuum extraction increased and midpelvic vacuum rates were stable. Rates of sequential instrument use, as well as failed operative vaginal deliveries decreased significantly over the study period. Nova Scotia had the highest low forceps rate in 2010-12, Alberta had the highest rates of midpelvic forceps, midpelvic vacuum, and midpelvic sequential instrumentation, Saskatchewan had the highest rates of outlet and low vacuum deliveries, the highest rates of sequential instrumentation at outlet, low and unspecified stations and the highest failed sequential instrumentation rate, and British

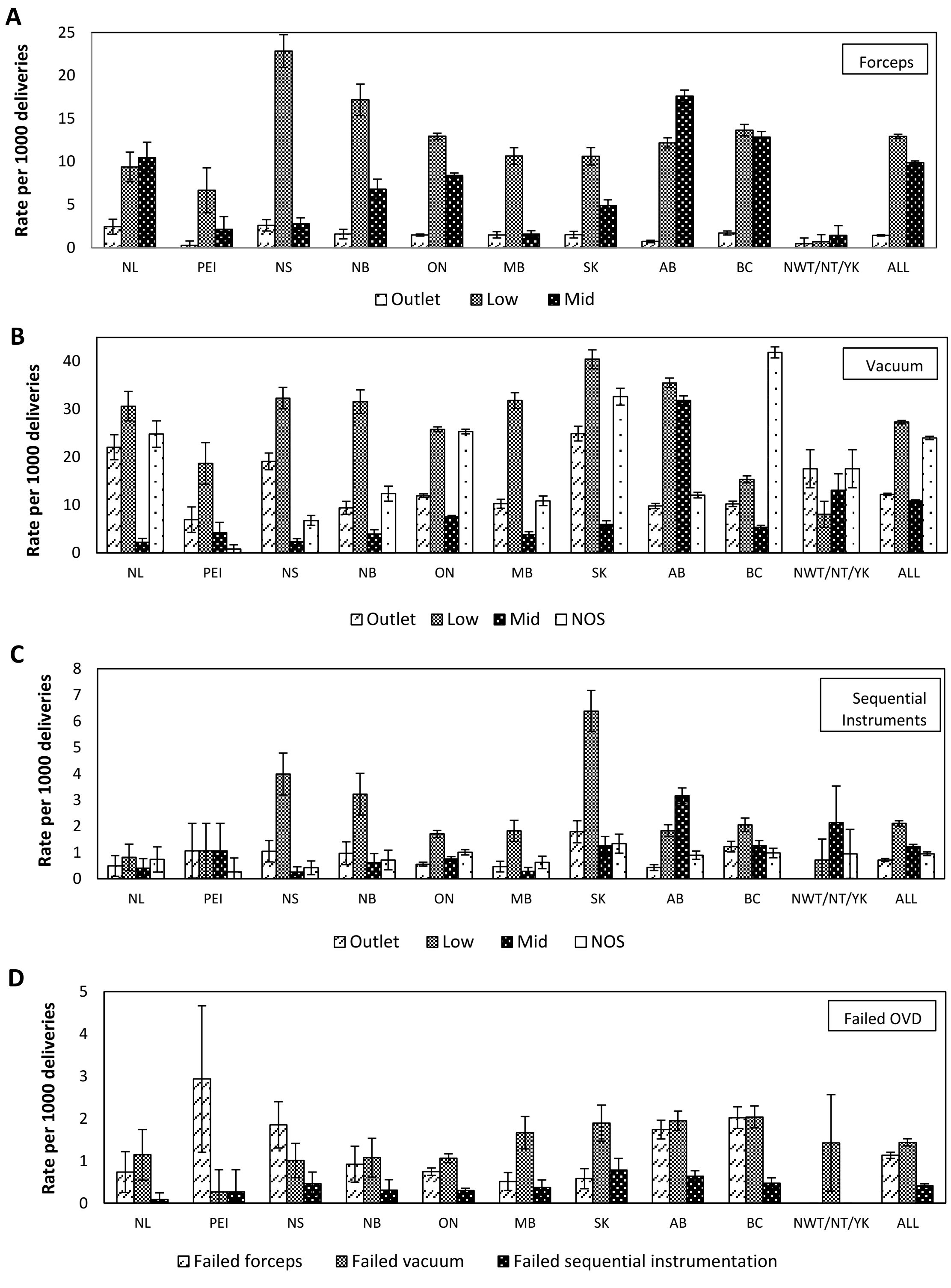

Figure 2.5. Geographic variations in rates of forceps delivery (A), vacuum extraction (B), sequential instrumentation (C), and failed trials of OVD (D) among term singleton deliveries, Canada (excluding Quebec), 2010-2012. OVD, operative vaginal delivery.

Columbia had the highest vacuum rate with station of application unspecified and the highest failed vacuum rate.

As in other settings,[98,99] forceps delivery rates in Canada declined significantly between 2004 and 2012 and this can be largely attributed to the decrease in the use of midpelvic forceps. Midpelvic operative vaginal delivery requires considerably more operator skill than low or outlet procedures.[39] The potential for maternal and neonatal trauma associated with midpelvic operative vaginal deliveries, a decrease in obstetricians skilled in midpelvic operative vaginal delivery and an increase in malpractice concerns have contributed to the reduction of midpelvic forceps delivery in favour of cesarean delivery.[22,23,76,80,100-102] A population-based study from Nova Scotia[103] showed that an absolute 1% decrease in midpelvic forceps deliveries was associated with a relative 2% increase (95% CI 1%, 3%, P=0.001) in primary cesarean delivery between 1988 and 2000. The impact of this shift from operative vaginal delivery to cesarean delivery on maternal and neonatal outcomes is unclear.[43] Some studies suggest that midpelvic operative vaginal deliveries significantly increase both maternal and neonatal morbidity when compared to cesarean delivery.[28-30,74,104,105] However, these studies were carried out 25 to 30 years ago and are difficult to interpret in the current obstetric context with lower operative vaginal delivery rates and an enhanced culture of safety. Further research is required to quantify maternal and neonatal risks and benefits associated with operative vaginal delivery and cesarean delivery.

The vacuum extraction rate also decreased in Canada between 2004 and 2012 albeit at a slower rate than the decline in forceps deliveries. However, in contrast to the overall trend in vacuum deliveries, there were significant increases in the outlet and low vacuum deliveries and no change in rates of midpelvic vacuum. This suggests that vacuum extraction is increasingly replacing forceps deliveries at outlet and low pelvic stations, while cesarean deliveries are replacing forceps deliveries at midpelvic stations.

Our study showed a 36% reduction in the sequential use of instruments for operative vaginal delivery from 2004 to 2012. This decrease is expected given recommendations against such intervention[19,100] because of the significantly increased risk of maternal and neonatal trauma associated with sequential instrument use.[24] Studies need to assess if there is any correlation between regional variations in operative vaginal deliveries, sequential operative vaginal deliveries and failed operative vaginal deliveries and rates of maternal and neonatal trauma.

Although the operative vaginal deliveries failure rates observed in our study are consistent with those reported in other studies, these are likely underestimates due to data constraints. CCI codes indicating a cesarean delivery in combination with instrumentation do not distinguish instrument use during the cesarean operation (through the incision) from instrument use for attempting a vaginal delivery. Deliveries were classified as cases of failed operative vaginal deliveries only if they had both a procedure code for instrument use and a separate ICD-10 code indicating failed instrument use. The failure to distinguish between forceps or vacuum use during cesarean delivery from their attempted use for effecting a vaginal delivery needs to be addressed by CIHI in order to facilitate more accurate estimations of operative vaginal deliveries failure rates and any potential variation in these rates in Canada.

The strengths of our study include a comprehensive database that collected information on approximately 98% of births in Canada (excluding Quebec).[29] Hospitalization data was abstracted by trained medical records archivists using standard definitions and the data have been subject to periodic validation studies.[7] The limitations of our study include the possibility of some transcription errors that are inevitable in large databases. Although assessment of pelvic station is a potentially subject to error, it is unlikely that the extent of such errors changed over the study period or that there were large geographic differences in clinical skills required to accurately assess pelvic station. Data source constraints included a lack of detail on the sequence of instrument use in deliveries involving both forceps and vacuum use and ambiguity in connection with forceps use prior to and during cesarean delivery.

In summary, rates of operative vaginal delivery decreased and cesarean delivery rates increased in Canada (excluding Quebec) from 2004 to 2012 among term, singletons. This decrease was driven chiefly by declines in the use of midpelvic forceps delivery. Increases in vacuum extraction rates were observed at outlet and low stations but not at midpelvic station. Wide variations in operative vaginal delivery rates were observed across the provinces and territories at all pelvic stations suggesting large variations in instrument preference and/or an evolution in standards of practice. Contemporary studies quantifying the risks and benefits of operative vaginal deliveries versus cesarean deliveries with regard to maternal and neonatal trauma and other perinatal outcomes are required before guidelines can endorse a specific mode of delivery for appropriate fetal or maternal indications.

Note: The shift in operative vaginal delivery use from forceps to vacuum at outlet and low-pelvic stations, and from forceps to cesarean delivery at midpelvic station, suggest that increasing the use of operative vaginal delivery at midpelvic station would offer the greatest potential impact as a strategy to reduce cesarean delivery. I therefore carried out a study to examine whether midpelvic operative vaginal delivery was a safe and acceptable alternative to cesarean delivery. This study is presented in Chapter 3.

Chapter 3: Perinatal and maternal morbidity and mortality following midpelvic operative vaginal delivery versus cesarean delivery in labour: a retrospective cohort study[2]

3.1. Synopsis

Background: Increased use of operative vaginal delivery, 20% of which occurs at midpelvic station, has recently been advocated as a strategy to reduce the cesarean delivery rate. This study aimed to quantify the severe perinatal and maternal morbidity and mortality associated with attempted midpelvic operative vaginal delivery.

Methods: I studied all term, singleton deliveries in Canada between 2003 and 2013 by attempted midpelvic operative vaginal delivery or cesarean delivery with labour (with and without prolonged second stage). The primary outcomes were composite severe perinatal morbidity and mortality (convulsions, assisted ventilation, severe birth trauma, and perinatal death) and composite severe maternal morbidity and mortality (e.g., severe postpartum hemorrhage, shock, sepsis, cardiac complications, acute renal failure, and death). Logistic regression was used to estimate adjusted odds ratios (AOR).

Results: The study population included 187,234 deliveries. Among women with dystocia and prolonged second stage, midpelvic operative vaginal delivery was associated with higher rates of severe perinatal morbidity and mortality compared with cesarean delivery (forceps, adjusted OR 1.81, 95% CI 1.24-2.64; vacuum, adjusted OR 1.81, 95% CI 1.17-2.80; sequential instruments, adjusted OR 3.19, 95% CI 1.73-5.88) and especially with higher rates

[2] A version of this chapter has been published as Muraca GM, Sabr Y, Lisonkova S, Skoll A, Brant R, Cundiff GW, Joseph KS. (2017) Perinatal and maternal morbidity and mortality after attempted operative vaginal delivery at midpelvic station. CMAJ 2017;189:E764-72.

of severe birth trauma. Rates of severe maternal morbidity and mortality were not significantly different following operative vaginal delivery, though rates of obstetric trauma were higher (forceps, adjusted OR 4.51, 95% CI 4.04-5.02; vacuum, adjusted OR 2.70, 95% CI 2.35-3.09; sequential instruments, adjusted OR 4.24, 95% CI 3.46-5.19). Among women with fetal distress, similar associations were seen for severe birth trauma and obstetric trauma, although vacuum was associated with lower rates of severe maternal morbidity and mortality (adjusted OR 0.52, 95% CI 0.33-0.80). Associations tended to be stronger in women without a prolonged second stage.

Conclusion: Midpelvic operative vaginal delivery is associated with higher rates of severe birth trauma and obstetric trauma, while rates of severe perinatal and maternal morbidity and mortality overall vary by indication and operative instrument.

3.2. Background and objectives

When the fetal head is at midpelvic station during the second stage of labour, mode of delivery and perinatal and maternal outcomes are largely dependent on the urgency to expedite delivery and operator skill with midpelvic operative vaginal delivery.[38,106] Operative vaginal delivery provides a temporal advantage over cesarean delivery, although midpelvic forceps or vacuum application requires skill and experience. On the other hand, while cesarean delivery generally decreases the risk of birth trauma compared to instrument use, engagement of the fetal head in the pelvis means the risk of trauma is not eliminated by an emergency cesarean delivery.[40,41,107,108] Assessments of the balance of risks and benefits between midpelvic operative vaginal delivery and cesarean delivery have tended to favor the latter option in recent decades and this has contributed to a rising rate of cesarean delivery worldwide.[38] More recently, a consensus statement endorsed by the American College of Obstetricians and Gynecologists and the Society for Maternal-Fetal Medicine[11] recommended operative vaginal delivery as a strategy to reduce the rate of cesarean delivery. Midpelvic operative vaginal delivery accounts for over 20% of all operative vaginal deliveries and approximately 2-3% of term, singleton deliveries in Canada.[109]

The literature on perinatal and maternal mortality/morbidity following operative vaginal delivery compared with cesarean delivery is inconsistent.[24-30,32,35,110] Also, studies on the risks and benefits of these two options have been compromised by a lack of information on pelvic station, a key determinant of perinatal and maternal outcomes.[37] We, therefore, carried out a study aimed at quantifying the perinatal and maternal morbidity and mortality associated with attempted operative vaginal delivery at midpelvic station (compared with cesarean delivery in labour), when the decision between cesarean delivery and operative vaginal delivery is most uncertain.

3.3. Methods

The study population included all hospital deliveries in Canada between April 2003 and March 2013 with data obtained from the Canadian Institute for Health Information's Discharge Abstract Database. Details regarding this database, such as the information contained, the validity, and the methods of data abstraction are detailed in the Methods section of Chapter 2.

All midpelvic operative vaginal and cesarean deliveries with labour between 37 and 41 weeks gestation that resulted in a singleton live birth or stillbirth were included. Deliveries were excluded if the infant had a congenital anomaly or if the mother had a hypertensive disorder, diabetes mellitus, or a placental abnormality. Analyses contrasting midpelvic operative vaginal deliveries with cesarean deliveries were carried out after stratifying by indication (viz., dystocia or fetal distress). Deliveries at midpelvic station included operative vaginal delivery in cases where the head was engaged and the leading point of the fetal skull was above station +2 cm but below zero station.[38] An intention-to-treat framework was used i.e., successful and failed forceps (or vacuum) deliveries were included in the attempted midpelvic forceps (or vacuum) category.

I proposed to compare outcomes among women following midpelvic operative vaginal delivery versus those among women following cesarean delivery carried out in the second stage labour. However, our data source identified cesarean deliveries with and without labour but not cesarean deliveries carried out in the second stage of labour (except for those carried out after a prolonged second stage). Since second stage cesarean delivery is generally associated with greater morbidity than cesarean delivery in the active phase of labour,[108] I carried out analyses comparing midpelvic operative vaginal delivery versus cesarean delivery in labour after stratifying the analyses based on prolonged second stage of labour (using ICD-10-CA code O631). I anticipated that the contrast among women with a prolonged second stage would potentially favour midpelvic operative vaginal delivery (since a deeply engaged head can complicate cesarean delivery), while comparisons among women without prolonged second stage would potentially favour cesarean delivery (because of the inclusion of women not in second stage).

The study included two primary outcomes, composite severe perinatal morbidity and mortality and composite severe maternal morbidity and mortality. Severe perinatal morbidity and mortality included neonatal convulsions, assisted ventilation by endotracheal intubation, severe birth trauma (intracranial laceration and hemorrhage, skull fracture, severe injury to the central or peripheral nervous systems, long bone injury, subaponeurotic hemorrhage, and injury to the liver/spleen), stillbirth or neonatal death. Severe maternal morbidity and mortality included severe postpartum hemorrhage (postpartum hemorrhage requiring transfusion), obstetric shock, sepsis, cardiac complications (cardiac arrest, cardiac failure, myocardial infarction and pulmonary embolism), acute renal failure, obstetric embolism, evacuation of incisional hematoma or death. Secondary outcomes included the components of the composite outcomes as well as respiratory morbidity, outcomes related to asphyxia, severe cerebral morbidity, all birth trauma, maternal postpartum infection, maternal postpartum hemorrhage, and obstetric trauma. Diagnosis and procedure codes used to define the study cohort are listed in Appendix Table 3.1.

Multivariable logistic regression models were used to estimate adjusted odds ratios (AOR) and 95% confidence intervals (CIs) expressing the relationship between mode of delivery and the composite outcomes. The final models controlled for maternal age, parity, birth weight, previous cesarean delivery, maternal province of residence and year of birth. Modification of the effect of mode of delivery on composite perinatal and maternal morbidity and mortality by fiscal year, provider type (obstetrician/non-obstetrician), success/failure of operative vaginal delivery attempt, and institutional delivery volume (high/medium/low) was examined by introducing interaction terms into a mixed-effects regression model with a logit link function that accounted for clustered observations within institutions. The magnitude of absolute effects was quantified by calculating adjusted rate differences and the adjusted number needed to treat (NNT). The adjusted NNT reflects the average number of operative vaginal deliveries that would have had to be delivered by cesarean to avoid one case of the outcome of interest.

Sensitivity analyses were carried out by estimating the association between attempted mode of delivery and composite perinatal and maternal morbidity and mortality assuming that all sequential instrument applications involved a failed vacuum delivery attempt followed by an attempted forceps delivery. All statistical analyses were performed using SAS 9.4. The study was approved by the University of British Columbia's Clinical Research Ethics Board.

3.4. Results

The study population included 187,234 deliveries; 76,755 midpelvic operative vaginal or cesarean deliveries for dystocia and 110,479 midpelvic operative vaginal or cesarean deliveries for fetal distress (Figure 3.1). Of these, 28,923 deliveries occurred following a prolonged second stage of labour (17,484 with dystocia and 11,439 with fetal distress). Nulliparous women, older women (≥35 years), and those who delivered at later gestational ages were more likely to have had a cesarean delivery. Midpelvic forceps was more commonly used in nulliparous women compared with midpelvic vacuum, while the reverse was true among parous women (Table 3.1). Operative vaginal delivery was more common in institutions with high delivery volume, while cesarean delivery was more frequent in low delivery volume centers (Appendix Table 3.2).

3.4.1. Operative vaginal versus cesarean delivery among women without prolonged second stage

Perinatal outcomes in deliveries with dystocia

In the dystocia cohort, midpelvic operative vaginal delivery was associated with higher rates of severe perinatal morbidity/mortality (forceps AOR 3.57, 95% CI 2.72-4.69; vacuum AOR 3.83, 95% CI 2.83-5.18; and sequential AOR 4.89, 95% CI 3.00-7.99). Differences in severe birth trauma and its components were particularly noteworthy (forceps AOR 20.0, 95% CI 12.5-31.9; vacuum AOR 23.9, 95% CI 14.7-38.7; and sequential AOR 26.2, 95% CI 13.2-52.2). Midpelvic forceps was also associated with significantly higher rates of respiratory distress, other respiratory conditions, intracranial hemorrhage due to hypoxia, and severe cerebral morbidity. Midpelvic vacuum was associated with significantly higher rates of birth asphyxia and intracranial hemorrhage due to hypoxia. Sequential instrumentation was associated with higher rates of assisted ventilation via endotracheal intubation, respiratory distress, and severe cerebral morbidity (Table 3.2). Rates of birth trauma (all) were higher in all operative vaginal delivery groups compared with cesarean delivery (Appendix Table 3.3).

<u>Maternal outcomes in deliveries with dystocia</u>

Among women with dystocia, I found no differences in the rates of composite severe maternal morbidity/mortality following attempted midpelvic operative vaginal delivery and cesarean delivery (Table 3.2). However, rates of severe postpartum hemorrhage were higher following midpelvic forceps delivery (AOR 1.65, 95% CI 1.24-2.19). Attempted midpelvic vacuum extraction was not associated with higher rates of composite severe maternal morbidity/mortality but was associated with higher rates of postpartum hemorrhage and lower rates of postpartum infection.

Obstetric trauma rates were notably higher following attempted midpelvic operative vaginal delivery compared with cesarean delivery (forceps AOR 13.0, 95% CI 11.8-14.2; vacuum AOR 5.85, 95% CI 5.18-6.59; sequential AOR 11.2, 95% CI 9.40-13.4). Rates of third and fourth degree perineal lacerations were particularly high (approximately 17% following midpelvic forceps, 10% following midpelvic vacuum, and 17% following sequential instrumentation (Table 3.2). Extension of the uterine incision occurred in approximately 1% of cesarean deliveries.

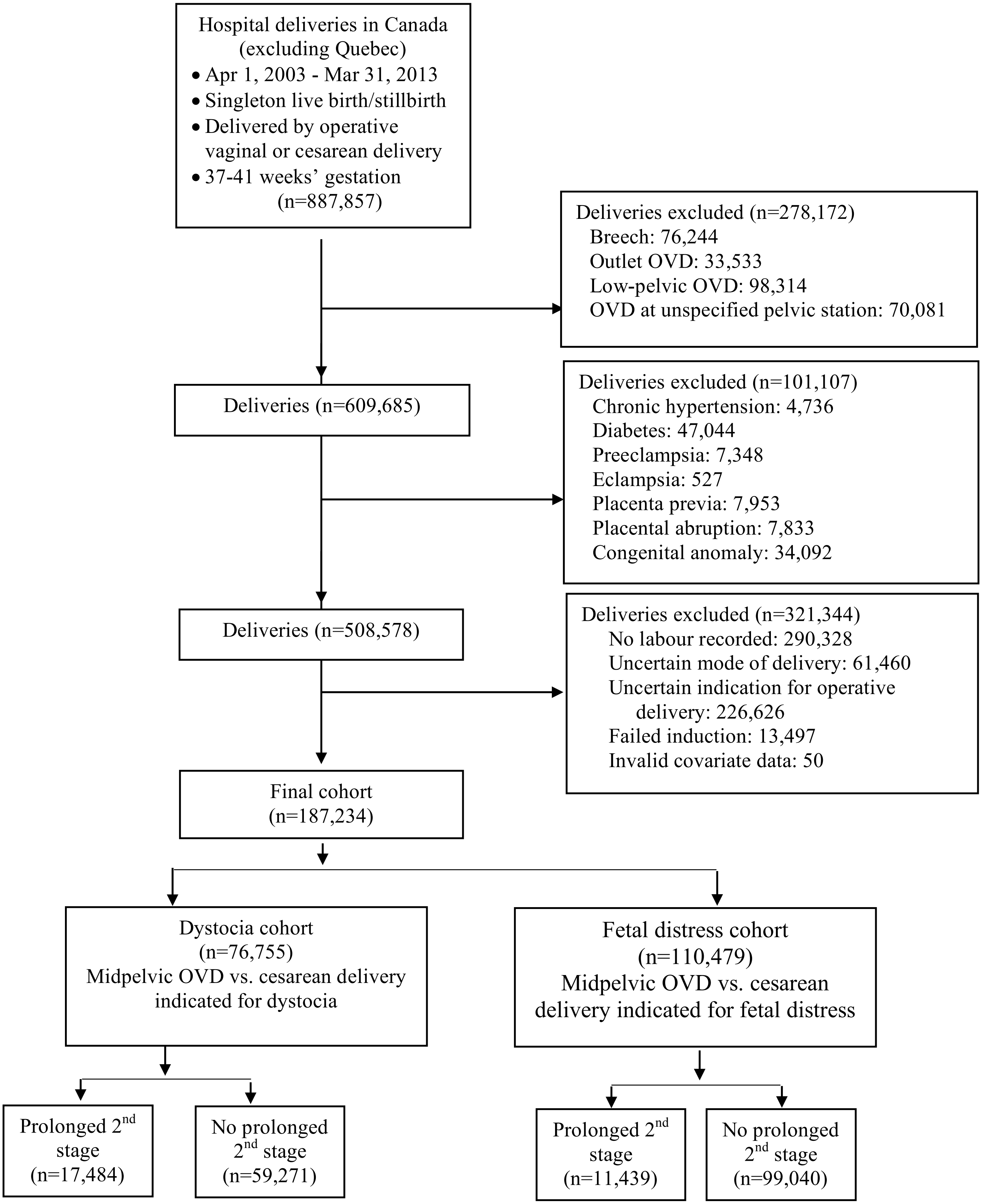

Figure 3.1. Derivation of study cohort. The sum of individual exclusions may exceed the total at each point as a result of deliveries being excluded for multiple reasons.

Table 3.1. Frequency of mode of delivery by maternal, infant and obstetric factors among women delivering term singletons by midpelvic operative vaginal delivery (OVD) or cesarean delivery with labour, Canada (excluding Quebec), 2003-2013 (N=187,234)

Maternal/neonatal characteristic	Attempted midpelvic forceps (n=24,274)	Attempted midpelvic vacuum (n=23,525)	Attempted sequential midpelvic OVD (n=4,012)	Cesarean delivery (n=135,423)	P-value
	No. (%)	No. (%)	No. (%)	No. (%)	
Maternal age (year)					<0.0001
< 20	888 (11.3)	1001 (12.8)	199 (2.5)	5758 (73.4)	
20-24	3359 (11.8)	3545 (12.5)	676 (2.4)	20821 (73.3)	
25-29	7850 (13.6)	7242 (12.6)	1376 (2.4)	41198 (71.4)	
30-34	8144 (13.5)	7670 (12.7)	1236 (2.1)	43194 (71.7)	
35-39	3447 (12.6)	3413 (12.5)	437 (1.6)	20070 (73.3)	
≥40	586 (10.3)	654 (11.5)	88 (1.5)	4382 (76.7)	
Parity					<0.0001
0	15881 (13.6)	13905 (11.9)	2673 (2.3)	84561 (72.3)	
1	2310 (10.8)	4765 (22.2)	415 (1.9)	13970 (65.1)	
2-3	577 (8.6)	1783 (26.5)	128 (1.9)	4253 (63.1)	
≥4	67 (6.0)	282 (25.1)	17 (1.5)	759 (67.5)	
Missing	5439 (13.3)	2790 (6.8)	779 (1.9)	31880 (78.0)	
Previous cesarean					<0.0001
Yes	51 (2.1)	49 (2.0)	17 (0.7)	2297 (95.2)	
No	24223 (13.1)	23476 (12.7)	3995 (2.2)	133126 (72.0)	
Gestational age (weeks)					<0.0001
37-38	4007 (14.5)	4347 (15.7)	587 (2.1)	18675 (67.6)	
39-41	20267 (12.7)	19178 (12.0)	3425 (2.1)	116748 (73.1)	
Birth weight (g)					<0.0001
<2500	208 (8.1)	354 (13.8)	26 (1.0)	1979 (77.1)	
2500-2999	2671 (14.1)	3310 (17.3)	367 (1.9)	12641 (66.6)	
3000-3999	17868 (13.8)	16927 (13.1)	3001 (2.3)	91849 (70.8)	
≥4000	3527 (9.8)	2934 (8.1)	618 (1.7)	28954 (80.4)	
Epidural					<0.0001
Yes	20924 (15.3)	16747 (12.2)	3159 (2.3)	95941 (70.2)	
No	3350 (6.6)	6778 (13.4)	853 (1.7)	39482 (78.2)	
Indication					<0.0001
Dystocia	10017 (13.1)	6401 (8.3)	1572 (2.1)	58765 (76.6)	
Fetal distress	14257 (12.9)	17124 (15.5)	2440 (2.2)	76658 (69.4)	
Prolonged 2nd stage					<0.0001
Yes	7855 (32.4)	4887 (16.9)	1147 (4.0)	15034 (52.0)	
No	16419 (10.4)	18638 (11.8)	2865 (1.8)	120389 (76.1)	
Successful OVD* trial (% of all OVD)					<0.0001
Dystocia	8611 (86.0)	4849 (75.8)	1094 (69.6)	-	
Fetal distress	12836 (90.0)	15549 (90.8)	1874 (76.8)	-	

*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/fetal distress).

Perinatal outcomes in deliveries with fetal distress

In the fetal distress cohort, rates of composite perinatal morbidity/mortality were higher in the midpelvic forceps group (AOR 1.38, 95% CI 1.18-1.60) and the sequential midpelvic instrumentation group (AOR 2.25, 95% CI 1.72-2.94). Similar to deliveries with dystocia, severe birth trauma was substantially higher following all types of operative vaginal delivery. Midpelvic forceps and vacuum deliveries were associated with lower rates of fetal asphyxia (forceps AOR 0.75, 95% CI 0.62-0.90; vacuum AOR 0.71, 95% CI 0.60-0.84), while midpelvic vacuum deliveries were associated with lower rates of assisted ventilation by endotracheal tube (AOR 0.65, 95% CI 0.53-0.80). Sequential midpelvic operative vaginal delivery was associated with significant increases in several adverse neonatal outcomes (Table 3.3).

Maternal outcomes in deliveries with fetal distress

Composite maternal morbidity/mortality in the fetal distress cohort was higher in the midpelvic forceps group (AOR 1.35, 95% CI 1.14-1.60) and the sequential midpelvic instrumentation group (AOR 1.63, 95% CI 1.17-2.27) and lower in the midpelvic vacuum group (AOR 0.55, 95% CI 0.45-0.68; Table 3.3). Midpelvic forceps was associated with significantly higher rates of postpartum hemorrhage and severe postpartum hemorrhage and lower rates of sepsis and postpartum infection compared with cesarean delivery. Lower rates of severe postpartum hemorrhage, sepsis and cardiac complications were observed following midpelvic vacuum delivery.

Table 3.2. Perinatal and maternal outcomes among attempted midpelvic operative vaginal deliveries and cesarean deliveries in labour with dystocia and without prolonged second stage of labour (n=59,271)

Outcome	Cesarean (n=49,465)		Attempted midpelvic forceps (n=5,276)			Attempted midpelvic vacuum (n=3,621)			Attempted sequential OVD (n=909)		
	n	%	n	%	AOR (95% CI)	n	%	AOR (95% CI)	n	%	AOR (95% CI)
Perinatal											
Severe perinatal morbidity/mortality	214	0.43	74	1.4	3.57 (2.72-4.69)	58	1.60	3.83 (2.83-5.18)	18	1.98	4.89 (3.00-7.99)
Stillbirth	8	0.02	<5	<0.09	-	0	0.00	-	0	0.00	-
Neonatal death	0	0.00	0	0.00	-	0	0.00	-	0	0.00	-
Neonatal convulsions	59	0.12	5	0.09	0.82 (0.33-2.06)	<5	<0.14	0.91 (0.33-2.54)	0	0.00	-
Asst. ventilation (endotracheal)	129	0.26	16	0.30	1.26 (0.74-2.13)	9	0.25	1.03 (0.52-2.03)	6	0.66	2.77 (1.21-6.33)
Severe birth trauma*	29	0.06	51	0.97	20.0 (12.5-31.9)	47	1.30	23.9 (14.7-38.7)	12	1.32	26.2 (13.2-52.2)
Respiratory distress†	2051	4.15	243	4.61	1.12 (0.98-1.28)	139	3.84	1.01 (0.84-1.20)	47	5.17	1.31 (0.97-1.77)
Fetal asphyxia	136	0.27	20	0.38	1.40 (0.87-2.25)	9	0.25	1.06 (0.54-2.10)	<5	<0.55	1.64 (0.60-4.46)
Birth asphyxia	63	0.13	12	0.23	1.79 (0.96-3.32)	8	0.22	1.74 (0.83-3.63)	<5	<0.55	1.73 (0.42-7.08)
Intracranial h'hage due to hypoxia	7	0.01	5	0.09	-	0	0.00	-	<5	<0.55	-
Severe cerebral morbidity‡	46	0.09	10	0.19	2.08 (1.04-4.14)	9	0.25	2.77 (1.35-5.72)	<5	<0.55	3.65 (1.13-11.8)
Birth trauma	693	1.40	342	6.48	4.72 (4.12-5.40)	400	11.1	7.65 (6.70-8.74)	120	13.2	9.65 (7.83-11.9)
Meconium aspiration syndrome	99	0.20	16	0.30	1.52 (0.89-2.60)	9	0.25	1.47 (0.74-2.94)	<5	<0.55	0.62 (0.09-4.46)
Bacterial sepsis	326	0.66	31	0.59	0.87 (0.60-1.26)	10	0.28	0.51 (0.27-0.95)	6	0.66	1.07 (0.48-2.42)
Maternal											
Severe maternal morbidity/mortality	639	1.29	75	1.42	1.12 (0.88-1.43)	46	1.27	0.92 (0.68-1.25)	12	1.32	0.99 (0.56-1.76)
Severe postpartum hemorrhage‖	350	0.71	58	1.10	1.65 (1.24-2.19)	36	0.99	1.31 (0.92-1.87)	9	0.99	1.39 (0.71-2.70)
Obstetric trauma	1063	2.15	1108	21.0	13.0 (11.8-14.2)	440	12.2	5.85 (5.18-6.59)	183	20.1	11.2 (9.40-13.4)
Perineal laceration-3rd/4th degree	0	0.00	901	17.1	-	365	10.1	-	152	16.7	-

OVD, operative vaginal delivery; AOR, adjusted odds ratio; CI, confidence interval. Adjusted odds ratios estimated using logistic regression with cesarean delivery as the reference group. All models adjusted for maternal age, parity, birth weight, previous cesarean delivery, and year of birth.

*Severe birth trauma includes intracranial laceration and hemorrhage, skull fracture, severe injury to CNS, severe injury to PNS, long bone injury, subaponeurotic (subgaleal) hemorrhage, injury to liver, and injury to spleen.

†Respiratory distress includes hyaline membrane disease, idiopathic respiratory distress syndrome, transient tachypnoea of newborn and other neonatal respiratory distress.

‡ Severe cerebral morbidity includes hypoxic ischemic encephalopathy, cerebral ischemia, cerebral irritability, and cerebral depression.

|| Severe postpartum hemorrhage includes a combination of postpartum hemorrhage and transfusion codes.

§ Assisted ventilation includes resuscitation, chest compression, endotracheal respiratory assistance, mechanical respiratory assistance, forced oxygenation, intubation, mechanical ventilation, drugs for resuscitation.

** Cardiac complications include cardiac arrest, cardiac failure, myocardial infarction and pulmonary embolism.

Sequential instrument application was associated with significantly higher rates of postpartum hemorrhage and severe postpartum hemorrhage (Table 3.3). Adjusted rate differences and NNTs are listed in Appendix Table 3.4.

Modifiers of the effect of mode of delivery

Among deliveries with fetal distress, the association between midpelvic forceps delivery and composite maternal morbidity/mortality was weaker in the first three years of the study (AOR 1.04, 95% CI 0.76-1.29) compared with the last three years (AOR 1.58, 95% CI 1.25-2.00; P for interaction=0.04). This was also true for sequential midpelvic instrumental delivery.

In deliveries with dystocia, the AOR for composite perinatal morbidity/mortality following midpelvic forceps delivery was significantly lower in institutions with a high delivery volume compared with institutions with a medium or low delivery volume (high delivery volume AOR 1.71, 95% CI 1.02-2.88; medium delivery volume AOR 3.60, 95% CI 2.42-5.35; low delivery volume AOR 3.02, 95% CI 2.23-4.09; P for interaction=0.04; Appendix Table 3.5). Among deliveries with fetal distress, the magnitude of the association between midpelvic vacuum delivery and composite maternal morbidity/mortality was significantly different in low, medium and high volume institutions (high delivery volume AOR 0.32, 95% CI 0.19-0.52; medium delivery volume AOR 0.63, 95% CI 0.42-0.95; low delivery volume AOR 0.76, 95% CI 0.60-0.97;P for interaction=0.01; Appendix Table 3.5).

The association between midpelvic operative vaginal delivery and composite perinatal and maternal morbidity/mortality was dependent on the success of instrumentation (Appendix Table 3.6). Inclusion of sequential instrumentation in the attempted midpelvic vacuum group did not significantly increase severe perinatal or maternal morbidity/mortality in the midpelvic vacuum group for either indication (Appendix Table 3.7).

3.4.2. Operative vaginal versus cesarean delivery among women with prolonged second stage

Perinatal outcomes in deliveries with dystocia

Midpelvic operative vaginal delivery was associated with higher rates of composite severe perinatal morbidity and mortality (forceps, adjusted OR 1.81, 95% CI 1.24-2.64, NNT 188, 95% CI 93-635; vacuum, adjusted OR 1.81, 95% CI 1.17-2.80, NNT 188, 95% CI 85-897; sequential instruments, adjusted OR 3.19, 95% CI 1.73-5.88, NNT 70, 95% CI 31-209; Table 3.4).

Differences in severe birth trauma and its components were particularly noteworthy (forceps, adjusted OR 5.01, 95% CI 2.75-9.15, NNT 145, 95% CI 71-332; vacuum, adjusted OR 4.47, 95% CI 2.27-8.80, NNT 168, 95% CI 75-458; sequential instruments, adjusted OR 9.46, 95% CI 4.11-21.8, NNT 69, 95% CI 28-187). Midpelvic forceps was also associated with significantly higher rates of respiratory distress, severe cerebral morbidity and bacterial sepsis. Midpelvic vacuum was associated with significantly higher rates of birth asphyxia, intracranial hemorrhage due to hypoxia and meconium aspiration syndrome. Sequential instrumentation was associated with higher rates of respiratory distress, cardiac failure or dysrhythmia and severe cerebral morbidity (Table 3.4). Birth trauma rates were significantly

Table 3.3. Perinatal and maternal outcomes among attempted midpelvic operative vaginal deliveries and cesarean deliveries in labour with fetal distress and without prolonged second stage of labour (n=99,040)

Outcome	Cesarean (n=70,924)		Attempted midpelvic forceps (n=11,143)			Attempted midpelvic vacuum (n=15,017)			Attempted sequential OVD (n=1,956)		
	n	%	n	%	AOR (95% CI)	n	%	AOR (95% CI)	n	%	AOR (95% CI)
Perinatal											
Severe perinatal morbidity/mortality	1064	1.50	212	1.90	1.38 (1.18-1.60)	243	1.62	1.13 (0.98-1.31)	59	3.02	2.25 (1.72-2.94)
Stillbirth	7	0.01	<5	<0.04	-	<5	<0.03	-	0	0.00	-
Neonatal death	19	0.03	<5	<0.04	0.34 (0.05-2.50)¶	<5	<0.03	0.50 (0.12-2.13)¶	<5	<0.26	1.91 (0.26-14.3)¶
Neonatal convulsions	201	0.28	34	0.31	1.08 (0.75-1.56)	36	0.24	0.87 (0.60-1.27)	11	0.56	2.00 (1.09-3.70)
Asst. ventilation (endotracheal)	880	1.24	115	1.03	0.91 (0.75-1.11)	113	0.75	0.65 (0.53-0.80)	22	1.12	1.04 (0.68-1.59)
Severe birth trauma*	52	0.07	79	0.71	10.9 (7.62-15.6)	108	0.72	10.2 (7.15-14.5)	32	1.64	24.2 (15.4-38.1)
Asst. ventilation§	2526	3.56	304	2.73	0.82 (0.73-0.93)	431	2.87	0.90 (0.81-1.00)	80	4.09	1.35 (1.07-1.70)
Fetal asphyxia	1160	1.64	133	1.19	0.75 (0.62-0.90)	164	1.09	0.71 (0.60-0.84)	49	2.51	1.67 (1.25-2.23)
Birth asphyxia	257	0.36	39	0.35	0.99 (0.70-1.39)	39	0.26	0.74 (0.52-1.05)	18	0.92	2.56 (1.58-4.17)
Intracranial h'hage due to hypoxia	37	0.05	7	0.06	1.20 (0.54-2.70)	16	0.11	2.04 (1.14-3.67)	<5	<0.26	3.93 (1.40-11.0)
Cardiac failure/dysrhythmia	3220	4.54	751	6.74	1.15 (1.06-1.25)	847	5.64	0.64 (0.59-0.70)	115	5.88	0.78 (0.64-0.95)
Severe cerebral morbidity‡	193	0.27	41	0.37	1.36 (0.96-1.91)	44	0.29	1.02 (0.72-1.44)	13	0.66	2.34 (1.33-4.14)
Birth trauma	1102	1.55	721	6.47	3.99 (3.62-4.40)	1446	9.63	5.44 (4.99-5.93)	322	16.5	10.2 (8.87-11.7)
Meconium aspiration syndrome	1126	1.59	161	1.44	0.95 (0.80-1.12)	158	1.05	0.72 (0.61-0.86)	30	1.53	1.04 (0.72-1.51)
Bacterial sepsis	772	1.09	79	0.71	0.68 (0.54-0.86)	60	0.40	0.50 (0.38-0.65)	10	0.51	0.54 (0.29-1.01)
Maternal											
Severe maternal morbidity/mortality	843	1.19	169	1.52	1.35 (1.14-1.60)	105	0.70	0.55 (0.45-0.68)	38	1.94	1.63 (1.17-2.27)
Severe postpartum hemorrhage‖	421	0.59	136	1.22	2.16 (1.77-2.63)	76	0.51	0.73 (0.57-0.95)	27	1.38	2.28 (1.54-3.39)
Sepsis	182	0.26	9	0.08	0.32 (0.16-0.62)	9	0.06	0.26 (0.13-0.52)	<5	<0.26	0.57 (0.18-1.81)
Cardiac complication**	204	0.29	22	0.20	0.70 (0.45-1.09)	16	0.11	0.33 (0.19-0.55)	9	0.46	1.60 (0.81-3.14)
Obstetric trauma	1975	2.78	2524	22.7	10.6 (9.92-11.3)	1633	10.9	4.15 (3.86-4.47)	448	22.9	10.2 (9.03-11.4)
Perineal laceration-3rd/4th degree	<5	<0.01	2020	18.1	-	1397	9.30	-	364	18.6	-

OVD, operative vaginal delivery; AOR, adjusted odds ratio; CI, confidence interval. Adjusted odds ratios estimated using logistic regression with cesarean delivery as the reference group. All models adjusted for maternal age, parity, birth weight, previous cesarean delivery, and year of birth.

*Severe birth trauma includes intracranial laceration and hemorrhage, skull fracture, severe injury to CNS, severe injury to PNS, long bone injury, subaponeurotic (subgaleal) hemorrhage, injury to liver, and injury to spleen.

‡ Severe cerebral morbidity includes hypoxic ischemic encephalopathy, cerebral ischemia, cerebral irritability, cerebral depression.

|| Severe postpartum hemorrhage includes a combination of postpartum hemorrhage and transfusion codes.

§ Assisted ventilation includes resuscitation, chest compression, endotracheal respiratory assistance, mechanical respiratory assistance, forced oxygenation, intubation, mechanical ventilation, drugs for resuscitation.

** Cardiac complications include cardiac arrest, cardiac failure, myocardial infarction and pulmonary embolism.

¶ Crude odds ratio reported as adjusted odds ratio was undefined due to small numbers.

higher in all midpelvic operative vaginal delivery groups compared with cesarean delivery (Table 3.4 and Appendix Table 3.8). Adjusted rate differences and NNTs restricted to deliveries with prolonged second stage are listed in Appendix Table 3.9.

Maternal outcomes in deliveries with dystocia

Rates of composite severe maternal morbidity and mortality were not significantly different among women following operative vaginal delivery compared with cesarean delivery (Table 3.4). However, midpelvic forceps delivery was associated with significantly higher rates of severe postpartum hemorrhage (adjusted OR 1.51, 95% CI 1.09-2.09) and significantly lower rates of cardiac complications (adjusted OR 0.38, 95% CI 0.17-0.86) and postpartum infection (adjusted OR 0.54, 95% CI 0.37-0.79). Midpelvic vacuum was associated with higher rates of postpartum hemorrhage (adjusted OR 1.61, 95% CI 1.39-1.86) and lower rates of postpartum infection (adjusted OR 0.60, 95% CI 0.38-0.95).

Obstetric trauma rates were significantly higher following operative vaginal delivery (forceps, adjusted OR 4.51, 95% CI 4.04-5.02, NNT, 4 95% CI 4-5; vacuum, adjusted OR 2.70, 95% CI 2.35-3.09, NNT 9, 95% CI 8-12; sequential instruments, adjusted OR 4.24, 95% CI 3.46-5.19, NNT 5, 95% CI 4-6). Rates of third- and fourth-degree perineal lacerations were particularly high (approximately 19% following midpelvic forceps, 12% following midpelvic vacuum, and 20% following sequential instrumentation). Extension of the uterine incision occurred in 2.9% of cesarean deliveries (Table 3.4 and Appendix Table 3.8).

Perinatal outcomes in deliveries with fetal distress

Rates of composite severe perinatal morbidity and mortality were higher among women with fetal distress compared with women who had dystocia (Table 3.5). Deliveries by sequential midpelvic instrumentation were associated with higher rates of composite severe perinatal morbidity and mortality compared with cesarean delivery (AOR 2.62, 95% CI 1.15-4.06, NNT 34, 95% CI 18-371). Rates of assisted ventilation by endotracheal intubation were lower following midpelvic forceps (adjusted OR 0.64, 95% CI 0.42-0.98) and midpelvic vacuum (adjusted OR 0.44, 95% CI 0.25-0.76). Severe birth trauma was substantially higher following all types of operative vaginal delivery (forceps, adjusted OR 10.4, 95% CI 4.84-22.5, NNT 68, 30-166; vacuum, adjusted OR 9.05, 95% CI 3.97-20.6, NNT 79, 95% CI 33-215; sequential instruments, adjusted OR 24.3, 95% CI 9.72-60.8, NNT 27, 95% CI 11-73; Table 3.5).

Midpelvic forceps deliveries were associated with lower rates of fetal asphyxia (adjusted OR 0.53, 95% CI 0.32-0.91) and higher rates of cardiac failure or dysrhythmia (adjusted OR 1.54, 95% CI 1.25-1.90).

Table 3.4. Perinatal and maternal outcomes among attempted midpelvic operative vaginal deliveries and cesarean deliveries with dystocia and prolonged second stage of labour (n=17,484)

Outcome	**Cesarean (n=9,300)**		**Attempted midpelvic forceps (n=4,741)**			**Attempted midpelvic vacuum (n=2,780)**			**Attempted sequential OVD (n=663)**		
Dystocia	**n**	**%**	**n**	**%**	**AOR (95% CI)**	**n**	**%**	**AOR (95% CI)**	**n**	**%**	**AOR (95% CI)**
Severe perinatal morbidity/mortality	61	0.66	52	1.10	1.81 (1.24-2.64)	32	1.15	1.81 (1.17-2.80)	13	1.96	3.19 (1.73-5.88)
Stillbirth	0	0.00	0	0.00	-	<5	<0.18	-	0	0.00	-
Neonatal death	0	0.00	<5	<0.11	-	<5	<018	-	0	0.00	-
Neonatal convulsions	16	0.17	8	0.17	0.98 (0.42-2.29)[¶]	6	0.22	1.26 (0.49-3.21)[¶]	<5	<0.75	1.76 (0.40-7.65)[¶]
Asst. ventilation (endotracheal)	35	0.38	10	0.21	0.55 (0.27-1.13)	9	0.32	0.80 (0.38-1.67)	<5	<0.75	0.74 (0.18-3.08)
Severe birth trauma*	16	0.17	35	0.74	5.01 (2.75-9.15)	19	0.68	4.47 (2.27-8.80)	9	1.36	9.46 (4.11-21.8)
Respiratory distress[†]	302	3.25	188	3.97	1.25 (1.04-1.51)	116	4.17	1.29 (1.03-1.61)	47	7.09	2.29 (1.66-3.16)
Assisted ventilation[‡]	140	1.51	63	1.33	0.81 (0.60-1.10)	37	1.33	0.79 (0.54-1.14)	12	1.81	1.12 (0.61-2.05)
Fetal asphyxia	23	0.25	9	0.19	0.77 (0.36-1.66)[¶]	<5	<0.18	0.44 (0.13-1.45)[¶]	<5	<0.75	1.22 (0.29-5.19)[¶]
Birth asphyxia	19	0.20	8	0.17	0.83 (0.36-1.89)[¶]	12	0.43	2.12 (1.03-4.37)[¶]	<5	<0.75	1.48 (0.34-6.36)[¶]
Intracranial h'hage due to hypoxia	<5	<0.05	<5	<0.11	1.96 (0.28-13.9)[¶]	8	0.29	13.4 (2.85-63.2)[¶]	<5	<0.75	14.1 (1.98-100)[¶]
Cardiac failure/dysrhythmia	120	1.29	67	1.41	1.09 (0.80-1.47)	47	1.69	1.14 (0.80-1.62)	18	2.71	1.91 (1.15-3.18)
Severe cerebral morbidity[§]	16	0.17	18	0.38	2.21 (1.13-4.34)[¶]	<5	<0.18	0.42 (0.10-1.82)[¶]	<5	<0.75	3.52 (1.17-10.6)[¶]
Birth trauma[‖]	194	2.09	304	6.41	3.23 (2.68-3.88)	307	11.0	5.40 (4.47-6.52)	100	15.1	7.92 (6.11-10.3)
Meconium aspiration syndrome	11	0.12	9	0.19	1.61 (0.67-3.88)[¶]	10	0.36	3.05 (1.29-7.19)[¶]	<5	<0.75	2.56 (0.57-11.6)[¶]
Bacterial sepsis	29	0.31	28	0.59	1.90 (1.13-3.20)[¶]	6	0.22	0.69 (0.29-1.67)[¶]	0	0.00	-
Severe maternal morbidity/mortality	153	1.65	83	1.75	1.19 (0.91-1.57)	38	1.37	0.87 (0.60-1.25)	13	1.96	1.26 (0.71-2.25)
Maternal death	0	0.00	0	0.00	-	0	0.00	-	0	0.00	-
Severe postpartum hemorrhage**	97	1.04	64	1.35	1.51 (1.09-2.09)	26	0.94	0.92 (0.59-1.44)	13	1.96	2.00 (1.10-3.62)
Shock	<5	<0.05	<5	<0.11	0.98 (0.18-5.36)[¶]	<5	<0.18	0.84 (0.09-7.49)[¶]	0	0.00	-
Sepsis	20	0.22	8	0.17	0.78 (0.35-1.78)[¶]	5	0.18	0.84 (0.31-2.23)[¶]	0	0.00	-
Cardiac complication[††]	36	0.39	7	0.15	0.38 (0.17-0.86)[¶]	6	0.22	0.56 (0.23-1.32)[¶]	0	0.00	-
Acute renal failure	<5	<0.05	<5	<0.11	-	<5	<0.18	-	0	0.00	-
Obstetric embolism	5	0.05	0	0.00	-	<5	<0.18	-	0	0.00	-
Evacuation incisional hematoma	<5	<0.05	<5	<0.11	-	0	0.00	-	0	0.00	-
Obstetric trauma[‡‡]	589	6.33	1085	22.9	4.51 (4.04-5.02)	427	15.4	2.70 (2.35-3.09)	147	22.2	4.24 (3.46-5.19)
Perineal laceration-3rd/4th degree	<5	<0.05	888	18.7	-	341	12.3	-	135	20.4	-
Uterine incision extension	268	2.88	13	0.27	0.11 (0.06-0.19)	21	0.76	0.29 (0.18-0.46)	<5	0.15	0.06 (0.01-0.40)
Postpartum infection[§§]	126	1.35	34	0.72	0.54 (0.37-0.79)	22	0.79	0.60 (0.38-0.95)	8	1.21	0.87 (0.42-1.80)
Postpartum hemorrhage	668	7.18	792	16.7	2.77 (2.48-3.10)	323	11.6	1.61 (1.39-1.86)	111	16.7	2.54 (2.03-3.17)

OVD, operative vaginal delivery AOR, adjusted odds ratio; CI, confidence interval. Adjusted odds ratios estimated using logistic regression with cesarean delivery as the reference group.

All models adjusted for maternal age, parity, birth weight, previous cesarean delivery, province, and fiscal year.

* Severe birth trauma included intracranial laceration and hemorrhage, skull fracture, severe injury to CNS, severe injury to PNS, long bone injury, subaponeurotic (subgaleal) hemorrhage, injury to liver, and injury to spleen.

† Respiratory distress included respiratory distress syndrome, transient tachypnoea of the newborn and other neonatal respiratory distress.

‡ Assisted ventilation includes resuscitation, chest compression, endotracheal respiratory assistance, mechanical respiratory assistance, forced oxygenation, intubation, mechanical ventilation, drugs for resuscitation.

§ Severe cerebral morbidity included hypoxic ischemic encephalopathy, cerebral ischemia, cerebral irritability, and cerebral depression.

|| Birth trauma included intracranial hemorrhage/laceration, injury to CNS/PNS, injury to scalp and injury to skeleton.

¶ Crude odds ratio reported as adjusted odds ratio was undefined due to small numbers.

** Severe postpartum hemorrhage includes a combination of postpartum hemorrhage and transfusion codes.

†† Cardiac complications include cardiac arrest, cardiac failure, myocardial infarction and pulmonary embolism.

‡‡ Obstetric trauma included severe perineal lacerations (3rd/4th degree), cervical laceration, high vaginal laceration, injury to pelvic organ/joint, pelvic hematoma, and extension of uterine incision.

§§ Postpartum infection includes sepsis, infection of obstetric surgical wound, infection of the genital tract following delivery, urinary tract infection following delivery, genitourinary tract infections following delivery, pyrexia of unknown origin following delivery and other specified, puerperal infection.

Maternal outcomes in deliveries with fetal distress

Composite severe maternal morbidity and mortality in deliveries with fetal distress was lower in the midpelvic vacuum group compared with cesarean delivery (adjusted OR 0.52, 95% CI 0.33-0.80, NNH 96, 68-229; Table 3.5). Midpelvic operative vaginal deliveries were associated with significantly higher rates of obstetric trauma (forceps, adjusted OR 3.34, 95% CI 2.94-3.80, NNT 5, 95% CI 4-6; vacuum, adjusted OR 1.99, 95% CI 1.71-2.33, NNT 12, 95% CI 9-17; sequential instruments, adjusted OR 3.23, 95% CI 2.55-4.08], NNT 6, 95% CI 4-8), as well as higher rates of postpartum hemorrhage and lower rates of postpartum infection compared with cesarean delivery. Severe perineal laceration rates following operative vaginal delivery were high, ranging from 13-18%, depending on instrument(s) applied. Extension of the uterine incision occurred in approximately 3.8% of cesarean deliveries (Appendix Table 3.8).

Modifiers of the effect of mode of delivery

The effect of mode of delivery on composite severe perinatal and maternal morbidity and mortality was not modified by institutional delivery volume, type of practitioner, success of the instrumentation, or the inclusion of sequential instrumentation in the attempted midpelvic vacuum delivery group (Appendix Tables 3.10-3.13).

Among women with fetal distress, the association between midpelvic operative vaginal delivery and composite severe perinatal morbidity/mortality was similar among women with and without a prolonged second stage of labour. However, the associations between midpelvic forceps and sequential instrumentation and composite severe maternal morbidity/mortality were significantly weaker among women with a prolonged second stage (P value for difference in AOR=0.01; Figure 3.2). Associations between operative vaginal delivery and obstetric trauma were significantly stronger in deliveries without a prolonged second stage compared with those with a prolonged second stage of labour (Figure 3.2).

3.5. Discussion

Our study showed that rates of severe perinatal morbidity and mortality were higher following attempted midpelvic operative vaginal delivery compared with cesarean delivery among deliveries with dystocia, while rates of severe maternal morbidity and mortality were similar. Among deliveries with fetal distress, rates of severe perinatal morbidity and mortality were higher following attempted sequential midpelvic instrumentation compared with cesarean delivery, while rates of severe maternal morbidity and mortality were lower following attempted midpelvic vacuum delivery.

This difference 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 cesarean delivery group. Attempted midpelvic operative vaginal delivery was associated with substantially higher rates of severe birth trauma and obstetric trauma compared with cesarean delivery.

Table 3.5. Perinatal and maternal outcomes among attempted midpelvic operative vaginal deliveries and cesarean deliveries with fetal distress and prolonged second stage of labour (n=11,439)

Outcome	Cesarean (n=5,734)		Attempted midpelvic forceps (n=3,114)			Attempted midpelvic vacuum (n=2,107)			Attempted sequential OVD (n=484)		
Fetal distress	**n**	**%**	**n**	**%**	**AOR (95% CI)**	**n**	**%**	**AOR (95% CI)**	**n**	**%**	**AOR (95% CI)**
Severe perinatal morbidity/mortality	103	1.80	68	2.18	1.26 (0.92-1.72)	39	1.85	1.01 (0.69-1.48)	21	4.34	2.62 (1.15-4.06)
Stillbirth	0	0.00	0	0.00	-	0	0.00	-	0	0.00	-
Neonatal death	<5	<0.09	<5	<0.16	-	0	0.00	-	0	0.00	-
Neonatal convulsions	23	0.40	7	0.22	0.56 (0.24-1.31)¶	6	0.28	0.71 (0.29-1.74)¶	<5	<1.03	1.03 (0.24-4.38)¶
Asst. ventilation (endotracheal)	80	1.40	29	0.93	0.64 (0.42-0.98)	15	0.71	0.44 (0.25-0.76)	8	1.65	1.13 (0.54-2.37)
Severe birth trauma*	9	0.16	37	1.19	10.4 (4.84-22.5)	22	1.04	9.05 (3.97-20.6)	12	2.48	24.3 (9.72-60.8)
Respiratory distress†	386	6.73	197	6.33	0.95 (0.79-1.13)	133	6.31	0.97 (0.79-1.20)	48	9.92	1.54 (1.12-2.12)
Assisted ventilation‡	198	3.45	67	2.15	0.59 (0.45-0.79)	49	2.33	0.57 (0.41-0.78)	17	3.51	0.91 (0.55-1.51)
Fetal asphyxia	63	1.10	18	0.58	0.53 (0.32-0.91)	17	0.81	0.69 (0.40-1.19)	7	1.45	1.33 (0.60-2.94)
Birth asphyxia	26	0.45	12	0.39	0.85 (0.43-1.69)¶	6	0.28	0.63 (0.26-1.53)¶	<5	<1.03	0.91 (0.22-3.85)¶
Intracranial h'hage due to hypoxia	<5	<0.09	<5	<0.16	0.92 (0.17-5.03)¶	<5	<0.24	1.36 (0.25-7.44)¶	<5	<1.03	2.97 (0.33-26.6)¶
Cardiac failure/dysrhythmia	209	3.64	172	5.52	1.54 (1.25-1.90)	80	3.80	0.90 (0.69-1.18)	38	7.85	2.09 (1.45-3.00)
Severe cerebral morbidity§	17	0.30	7	0.22	0.76 (0.31-1.83)¶	7	0.33	1.12 (0.46-2.71)¶	5	1.03	3.51 (1.29-9.56)¶
Birth trauma‖	154	2.69	253	8.12	3.26 (2.65-4.02)	269	12.8	5.09 (4.13-6.28)	99	20.5	9.47 (7.18-12.5)
Meconium aspiration syndrome	92	1.60	34	1.09	0.70 (0.47-1.04)	43	2.04	1.33 (0.91-1.94)	7	1.45	1.02 (0.47-2.24)
Bacterial sepsis	43	0.75	23	0.74	0.99 (0.59-1.64)	12	0.57	0.76 (0.40-1.44)	<5	<1.03	0.55 (0.13-2.27)
Severe maternal morbidity/mortality	125	2.18	53	1.70	0.78 (0.56-1.09)	26	1.23	0.52 (0.33-0.80)	7	1.45	0.62 (0.29-1.35)
Maternal death	0	0.00	0	0.00	-	0	0.00	-	0	0.00	-
Severe postpartum hemorrhage**	72	1.26	42	1.35	1.09 (0.74-1.61)	21	1.00	0.73 (0.44-1.22)	<5	<1.03	0.61 (0.22-1.69)
Shock	<5	<0.09	0	0.00	-	0	0.00	-	0	0.00	-
Sepsis	21	0.37	5	0.16	0.44 (0.17-1.16)¶	<5	<0.24	0.13 (0.02-0.96)¶	<5	<1.03	0.56 (0.08-4.20)¶
Cardiac complication††	28	0.49	6	0.19	0.41 (0.17-1.00)	<5	<0.24	0.36 (0.12-1.04)	<5	<1.03	0.90 (0.21-3.86)
Acute renal failure	<5	<0.09	0	0.00	-	<5	<0.24	-	0	0.00	-
Obstetric embolism	5	0.09	0	0.00	-	0	0.00	-	0	0.00	-
Evacuation incisional hematoma	<5	<0.09	<5	<0.16	-	0	0.00	-	0	0.00	-
Obstetric trauma‡‡	464	8.09	710	22.8	3.34 (2.94-3.80)	329	15.6	1.99 (1.71-2.33)	111	22.9	3.23 (2.55-4.08)
Perineal laceration-3rd/4th degree	<5	<0.09	567	18.2	-	270	12.8	-	88	18.2	-
Uterine incision extension	219	3.82	16	0.51	0.13 (0.08-0.22)¶	7	0.33	0.08 (0.04-0.18)¶	11	2.27	0.59 (0.32-1.08)¶
Postpartum infection§§	112	1.95	28	0.90	0.46 (0.30-0.70)	16	0.76	0.42 (0.25-0.72)	5	1.03	0.53 (0.21-1.31)
Postpartum hemorrhage	491	8.56	533	17.1	2.20 (1.92-2.51)	262	12.4	1.41 (1.19-1.66)	73	15.1	1.77 (1.35-2.31)

OVD, operative vaginal delivery AOR, adjusted odds ratio; CI, confidence interval.
Adjusted odds ratios estimated using logistic regression with cesarean delivery as the reference group.
All models adjusted for maternal age, parity, birth weight, previous cesarean delivery, province, and fiscal year.
* Severe birth trauma included intracranial laceration and hemorrhage, skull fracture, severe injury to CNS, severe injury to PNS, long bone injury, subaponeurotic (subgaleal) hemorrhage, injury to liver, and injury to spleen.
† Respiratory distress included respiratory distress syndrome, transient tachypnoea of the newborn and other neonatal respiratory distress.
‡ Assisted ventilation includes resuscitation, chest compression, endotracheal respiratory assistance, mechanical respiratory assistance, forced oxygenation, intubation, mechanical ventilation, drugs for resuscitation.
§ Severe cerebral morbidity included hypoxic ischemic encephalopathy, cerebral ischemia, cerebral irritability, and cerebral depression.
|| Birth trauma included intracranial hemorrhage/laceration, injury to CNS/PNS, injury to scalp and injury to skeleton.
¶ Crude odds ratio reported as adjusted odds ratio was undefined due to small numbers.
** Severe postpartum hemorrhage includes a combination of postpartum hemorrhage and transfusion codes.
†† Cardiac complications include cardiac arrest, cardiac failure, myocardial infarction and pulmonary embolism.
‡‡ Obstetric trauma included severe perineal lacerations (3rd/4th degree), cervical laceration, high vaginal laceration, injury to pelvic organ/joint, pelvic hematoma, and extension of uterine incision.
§§ Postpartum infection includes sepsis, infection of obstetric surgical wound, infection of the genital tract following delivery, urinary tract infection following delivery, genitourinary tract infections following delivery, pyrexia of unknown origin following delivery and other specified, puerperal infection

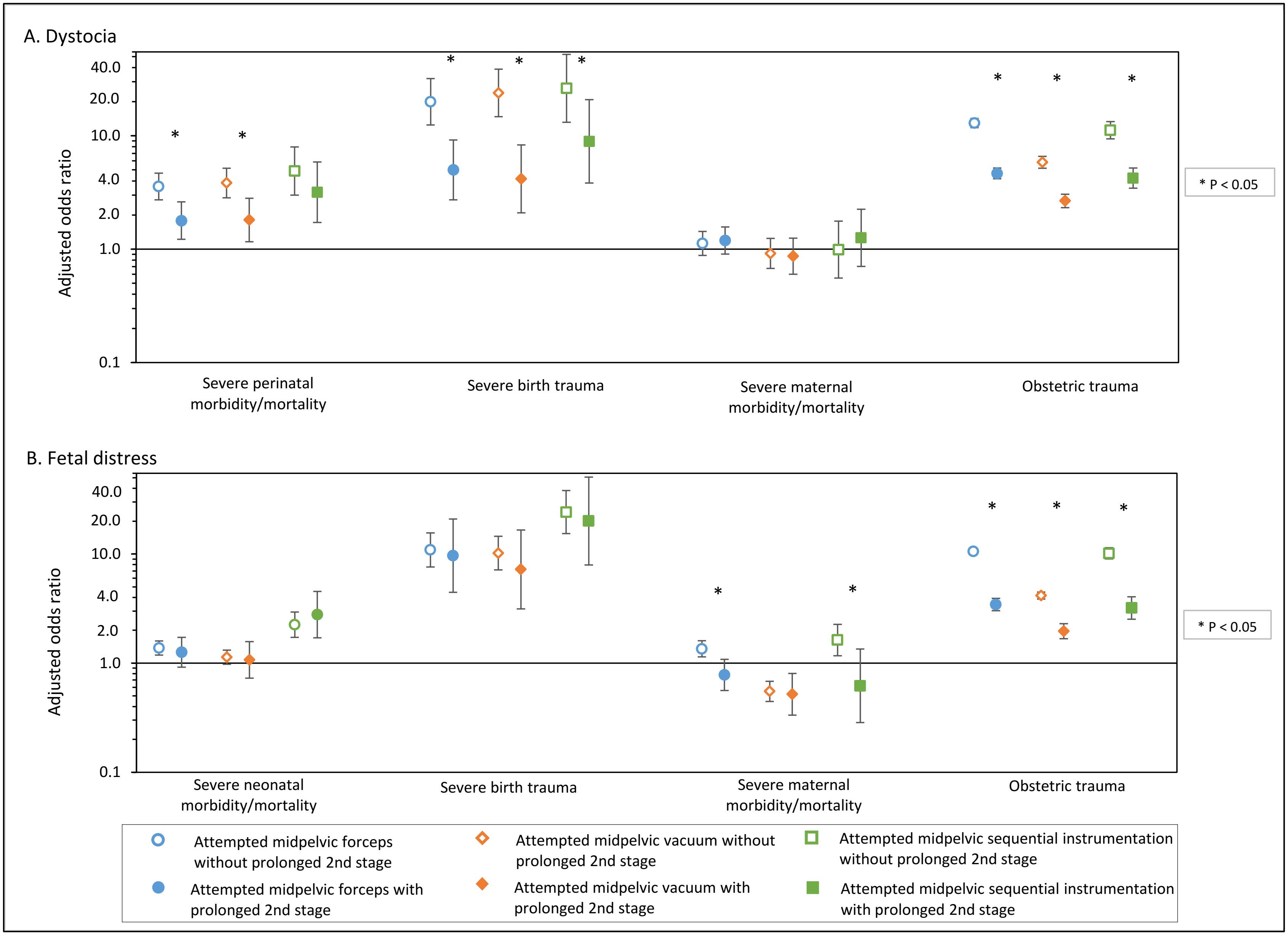

Figure 3.2. Adjusted odds ratios and 95% confidence intervals showing the effects of midpelvic OVD (compared with cesarean delivery in labour) on composite severe perinatal and maternal morbidity/mortality and trauma among women with/without prolonged 2nd stage

In contrast to the conflicting results in the literature,[10,13-15] our study shows higher rates of neurologic injury following midpelvic operative delivery with forceps and sequential instrumentation. Reasons for this difference likely include limited power and lack of adjustment in previous studies[10,13] and considerations related to pelvic station and indication for delivery. The literature also does not provide clarity regarding blood loss following midpelvic operative vaginal delivery.[7,8,15,23-25] Our study showed higher rates of postpartum hemorrhage following attempted midpelvic forceps delivery and attempted sequential instrumentation compared with cesarean delivery. Although uterine atony appeared to be the major contributor, increased rates of hemorrhage likely also reflected perineal and vaginal trauma.[26]

The high rates of third and fourth degree perineal lacerations following attempted midpelvic operative vaginal delivery (12%-19%) are cause for concern. Rates ranging from 14% to 45%, have been reported previously but are discounted because they reflect obstetric practice in the late 20th century.[8,9,17] Nevertheless, recent studies continue to show high rates[27] and operative vaginal delivery is known to increase the risk of pelvic floor disorders five to 10 years after a first delivery.[28] Women need to be informed about the substantially increased risk of anal sphincter trauma following midpelvic instrumental delivery along with the relevant long-term quality-of-life implications.

The limitations of our study include our inability to account for the skill of the operator. However, women delivering in hospital have little understanding of the relevant issues regarding expertise in midpelvic operative vaginal delivery and our data reflect the experience and skills of contemporary practitioners. Although I excluded women with common pregnancy complications, some uncommon complications may have been overrepresented in the cesarean delivery group. Such confounding by indication would have resulted in a bias favouring operative vaginal delivery. Lastly, errors and omissions in coding are inevitable in large administrative databases; however, these would have resulted in non-differential misclassification.

Our study shows that attempted midpelvic operative vaginal delivery is associated with substantially higher rates of severe birth trauma and obstetric trauma. Rates of severe perinatal and maternal morbidity and mortality following midpelvic operative vaginal delivery are also increased, though these associations vary by indication and instrument used. Encouraging higher rates of operative vaginal delivery as a strategy to reduce the cesarean delivery rate could result in increases in severe perinatal and maternal morbidity and mortality, especially birth trauma, severe postpartum hemorrhage, and obstetric trauma.

Note: While the results of this analysis were informative, they were limited in their generalizability due to our inability to include all women in the second stage of labour. In addition, we were unable to account for important potential confounders and effect modifiers such as position of the fetal head at delivery (occiput anterior/posterior), maternal prepregnancy weight, and maternal socio-economic status. Thus, I conducted a similar study including deliveries in the province of British Columbia using a perinatal database with more clinically nuanced information, such as duration of second stage of labour and prepregnancy weight. This study is described in detail in Chapter 4.

Chapter 4: Perinatal and maternal morbidity and mortality following midpelvic operative vaginal delivery versus cesarean delivery in the second stage of labour: a retrospective cohort study[3]

4.1. Synopsis

Background: Increased use of operative vaginal delivery has been advocated as a strategy to curb rising rates of cesarean delivery. The aim of this study was to quantify severe perinatal and maternal morbidity/mortality associated with midpelvic operative vaginal delivery compared with cesarean delivery.

Methods: The study included all term singleton operative vaginal and cesarean deliveries in the second stage of labour in British Columbia from 2004–2014. The primary outcomes were severe perinatal morbidity/mortality (e.g., convulsions, severe birth trauma, and perinatal death) and severe maternal morbidity (e.g., severe postpartum hemorrhage, shock, sepsis and cardiac complications). Generalized boosted regression was used to estimate multinomial propensity scores and weights. Doubly robust logistic models were used to estimate adjusted odds ratios (AOR) and 95% confidence intervals (CI).

Results: The study population included 10,901 deliveries. Among deliveries with dystocia, attempted midpelvic operative vaginal delivery was associated with higher rates of severe perinatal morbidity/mortality compared with cesarean delivery (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). Rates of severe maternal morbidity/mortality were also higher following midpelvic operative

[3] A version of this chapter has been published as Muraca GM, Skoll A, Lisonkova S, Sabr Y, Brant R, Cundiff GW, Joseph KS. (2017) Perinatal and maternal morbidity and mortality among term singletons following midcavity operative vaginal delivery versus caesarean delivery. BJOG 2017; doi:10.1111/1471-0528.14820.

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 midpelvic vacuum (ARR 1.28, 95% CI 1.04-1.61) and in severe maternal morbidity following attempted midpelvic forceps delivery (ARR 2.34, 95% CI 1.54-3.56).

Conclusion: Attempted midpelvic 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.

4.2. Background and objectives

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 cesarean delivery rate.[11] The evaluation of approaches to achieve this end are underway[20] and the current discourse surrounding operative vaginal delivery centres around methods to promote the skills required to effect such intervention.[21,22] However, there is substantial uncertainty in the literature[24-30] regarding the balance of perinatal and maternal risks and benefits between operative vaginal delivery and cesarean 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.[32,38,111]

Operative vaginal deliveries at midpelvic station require the greatest operator skill and experience and consequently, it is at midpelvic station that the decision between operative vaginal delivery and cesarean delivery presents a serious challenge. Midpelvic operative vaginal deliveries account for up to 20% of all operative vaginal deliveries in industrialized settings and 2–3% of term, singleton deliveries overall.[109] The literature on perinatal and maternal outcomes contrasting midpelvic operative vaginal delivery and cesarean delivery is based on studies undertaken 25 to 30 years ago[28-30] that are no longer reflective of the current obstetric practice.

We, therefore, carried out a study aimed at quantifying the effects of operative vaginal delivery at midpelvic station on perinatal and maternal morbidity and mortality compared with cesarean delivery in a cohort of women in the second stage of labour. Although the objective of this study is similar to that described in Chapter 3, this analysis differs from the study presented in Chapter 3 in several ways. Firstly, the use of a specialized perinatal database with more clinical detail than the national hospitalization database allowed me to restrict this analysis to all women in the second stage of labour, not just those with prolonged second stage of labour. Secondly, I used propensity score analysis and was able to adjust for important confounders such as prepregnancy weight and socioeconomic status, variables that were not available in the national database. Lastly, I was able to include an expanded set of outcomes (i.e. Apgar score).

4.3. Methods

I conducted a population-based cohort study including all term (37 to 41 weeks) singletons delivered by midpelvic operative vaginal delivery or cesarean 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 standardized forms and coding rules. Data quality is continually assessed by means of quality and consistency checks, and information in the database has been validated[91,94,112] and used routinely for health planning and research.[93,113]

The study period was restricted to fiscal years from April 1, 2004, to March 31, 2014 (hereafter referred to as years 2004 to 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 cesarean 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).[114]

Deliveries at midpelvic station were defined based on the Classification According to Station and Rotation[38] 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 station +2 cm but below zero station. I used an intention-to-treat framework i.e., both successful and failed forceps deliveries (followed by cesarean delivery) were included in the attempted midpelvic forceps category. Attempted midpelvic 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 Agar score less than 4, severe birth trauma (intracranial hemorrhage, skull fracture, severe injury to the central or peripheral nervous systems, long bone injury, subaponeurotic hemorrhage, and injury to liver or spleen), stillbirth and neonatal death. Severe maternal morbidity included severe postpartum hemorrhage (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 hemorrhage, as well as birth and obstetric trauma. Birth trauma included intracranial hemorrhage, 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 hematoma, 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 Appendix Table 4.1.

The effect of midpelvic 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 (midpelvic operative vaginal or cesarean 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 (midpelvic operative vaginal) and the confounding factors.

Multinomial propensity scores were used to estimate the probability that a woman would have delivered by midpelvic forceps, midpelvic vacuum, sequential midpelvic instrumentation or cesarean 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), pre-pregnancy weight (kg), previous cesarean delivery (Y/N), position of the fetal head at delivery (occiput anterior vs occiput posterior/transverse), birth weight (<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 generalized boosted regression models.[115] This nonparametric model estimates the propensity score by combining several piecewise-constant functions of the covariates using data-adaptive, machine learning techniques. Multiple regression trees were generated and the optimal iteration was chosen as that which best balanced the comparison groups using pre-specified stopping rules. I used the iteration that minimized the mean standardized effect size (ES) difference and the mean Kolmogorov-Smirnov statistic as stopping rules. I considered an absolute ES below 0.2 as indicative of good balance. Box plots were used to assess overlap between the weighted mode of delivery groups. I 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 modeled the same associations using a) logistic regression adjusting for the same eight covariates listed above and b) 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 as 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 vs 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 pre-pregnancy 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 10 imputed datasets. The discriminant function method was used to impute values for categorical variables and linear regression was used for continuous variables.[116] 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 cesarean to avoid one case of the outcome of interest. All analyses were carried out using SAS version 9.4 (SAS Institute Inc.). The study was approved by the University of British Columbia's Clinical Research Ethics Board.

4.4. Results

The study population included 10,901 deliveries; 5,057 attempted midpelvic operative vaginal or cesarean deliveries with dystocia and 5,844 attempted midpelvic operative vaginal or cesarean deliveries with fetal distress (Figure 4.1). The rate of severe perinatal

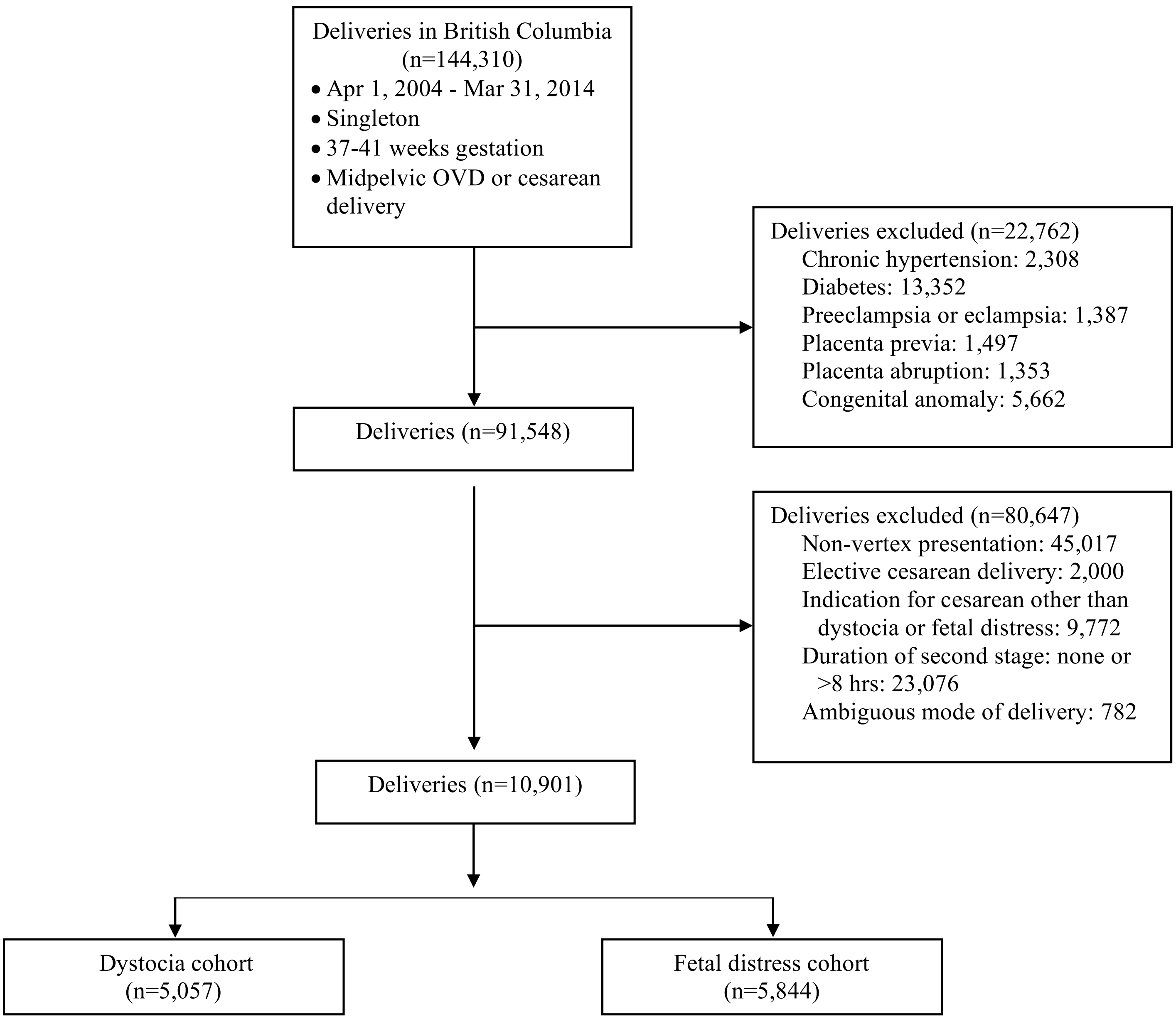

Figure 4.1. Derivation of study cohort

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 pre-pregnancy weight (≥70 kg) and those who delivered at later gestational ages were more likely to have had a cesarean delivery. Attempted midpelvic forceps was more commonly used in nulliparous women compared with attempted midpelvic vacuum, while the reverse was true among multiparous women (Table 4.1). Attempted operative vaginal delivery was more common in deliveries with babies of lower birth weight, while cesarean delivery was more frequent in macrosomic infants (≥4000 g). Women with dystocia had higher rates of cesarean 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% among women with dystocia and fetal distress, respectively; Table 4.1).

Propensity score weighting converged, achieved good balance in the mode of delivery groups, and the overlap of propensity scores in the weighted groups was satisfactory in both the dystocia and fetal distress cohorts (Appendix Figures 4.1-4.4).

4.4.1. Severe perinatal morbidity/mortality

Among deliveries with dystocia, attempted midpelvic operative vaginal delivery was associated with higher rates of severe perinatal morbidity/mortality compared with cesarean delivery (forceps 1.7%, vacuum 2.2%, sequential 3.5%, and cesarean 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 4.2). Rates of severe birth trauma were similarly higher in attempted forceps (1.0%; ARR 4.33, 95% CI 2.31-8.11) and attempted vacuum deliveries (1.0%; ARR 3.16,

Table 4.1. Maternal, infant and obstetric factors among women in the second stage of labour delivering term singletons by attempted midpelvic operative vaginal delivery (OVD) or cesarean delivery, British Columbia, 2004–2014.

(N=10,901)

Maternal/neonatal characteristic	Cesarean delivery (n=4,524)		Attempted midpelvic forceps (n=3,978)		Attempted midpelvic vacuum (n=1,913)		Attempted sequential midpelvic OVD (n=486)		P-value*
	No.	(%)	No.	(%)	No.	(%)	No.	(%)	
Maternal age (yr)									<0.0001
< 20	96	(39.3)	79	(32.4)	51	(20.9)	18	(7.4)	
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									<0.0001
0	3860	(42.6)	3433	(37.9)	1382	(15.2)	388	(4.3)	
≥1	664	(36.1)	545	(29.7)	531	(28.9)	98	(5.3)	
Pre-pregnancy weight (kg)									<0.0001
<55	956	(36.9)	1063	(41.0)	439	(16.9)	133	(5.1)	
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 (wks)									<0.0001
37–38	868	(38.1)	865	(38.0)	448	(19.7)	98	(4.3)	
39–41	3656	(42.4)	3113	(36.1)	1465	(17.0)	388	(4.5)	
Position of fetal head at delivery									<0.0001
Occiput anterior	1063	(19.9)	2777	(51.9)	1222	(22.8)	289	(5.4)	
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)	
Birth weight (g)									<0.0001
<2500	11	(17.2)	30	(46.9)	21	(32.8)	<5	(<8.0)	
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)	
Indication									<0.0001
Dystocia	2405	(47.6)	1763	(34.9)	690	(13.6)	199	(3.9)	
Fetal distress	2119	(36.3)	2215	(37.9)	1223	(20.9)	287	(4.9)	
Income quintile									0.46
1	941	(41.8)	817	(36.3)	384	(17.1)	109	(4.8)	
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†									<0.0001
Dystocia	-	-	1633	(92.6)	552	(80.0)	164	(82.4)	
Fetal distress	-	-	2027	(91.5)	1078	(88.1)	244	(85.0)	

* Chi-square or Fisher exact test

† Successful OVDs express the number (%) of successful OVD in a specific category divided by the number of attempted OVDs in that category stratified by indication (dystocia/fetal distress)

95% CI 1.65-6.05) compared with cesarean delivery (0.3%). Sequential midpelvic 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 cesarean deliveries; ARR 10.2, 95% CI 7.75-13.5; Table 4.2). Attempted midpelvic forceps and vacuum were also associated with significantly higher rates of respiratory distress and all birth trauma (Tables 4.2 and Appendix Table 4.2).

Among deliveries with fetal distress, the rate of severe perinatal morbidity/mortality was similar in the attempted midpelvic forceps, sequential instrument, and cesarean delivery groups. However, it was significantly higher in the attempted midpelvic vacuum group (2.6% versus 1.9% in cesarean group; ARR 1.28, 95% CI 1.04-1.61; Tables 4.3 and Appendix Table 4.2).

Severe birth trauma rates were higher in all the attempted midpelvic 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 cesarean delivery group (0.2%). The rate of assisted ventilation by endotracheal tube was significantly lower among attempted midpelvic forceps deliveries compared with cesarean deliveries (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 cesarean 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 midpelvic forceps, 103 for midpelvic vacuum and 33 for sequential instrumentation in deliveries with dystocia.

Table 4.2. Rate ratios expressing the association between operative vaginal delivery (OVD) vs cesarean delivery and severe perinatal and maternal morbidity/mortality among women with dystocia with adjustment using weighted multinomial propensity scores, British Columbia, 2004–2014

	Cesarean delivery (n=2,405)		**Attempted midpelvic forceps (n=1,763)**		**Attempted midpelvic vacuum (n=690)**		**Attempted sequential midpelvic OVD (n=199)**	
Outcome	**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 hemorrhage	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 hemorrhage	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 ($3^{rd}/4^{th}$ degree)*	0.00	Reference	23.0 (21.1-25.0)		10.3 (8.24-12.8)		21.1 (16.0-27.3)	

ARR, adjusted rate ratios; CI, confidence interval.

Results adjusted for maternal age, parity, previous cesarean delivery, prepregnancy weight, position of fetal head at delivery, birth weight, income quintile, and year of delivery.

* Rate (%) and 95% CI provided for severe perineal lacerations as rate ratios were not estimable due to small numbers (0.00%) in the reference group.

Table 4.3. Rate ratios expressing the association between operative vaginal delivery (OVD) vs cesarean 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	Cesarean delivery (n=2,119)		Attempted midpelvic forceps (n=2,215)		Attempted midpelvic vacuum (n=1,223)		Attempted sequential midpelvic 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 hemorrhage	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 hemorrhage	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 (3rd/4th degree)*	0.00	Reference	19.8 (18.2-21.5)		8.50 (7.07-10.2)		22.0 (17.6-27.1)	

ARR, adjusted rate ratios; CI, confidence interval.
Results adjusted for maternal age, parity, previous cesarean delivery, prepregnancy weight, position of fetal head at delivery, birth weight, income quintile, and year of delivery.
* Rate (%) and 95% CI provided for severe perineal lacerations as rate ratios were not estimable due to small numbers (0.00%) in the reference group.

4.4.2. Severe maternal morbidity

Rates of severe maternal morbidity were higher following midpelvic operative vaginal delivery compared with cesarean delivery in the dystocia group (1.2% and 1.5% following forceps and vacuum, respectively compared with 0.8% following cesarean delivery; forceps ARR 1.57, 95% CI 1.05-2.36; vacuum ARR 2.29, 95% CI 1.57-3.36); Tables 4.2 and Appendix Table 4.2). In deliveries with fetal distress, rates of maternal morbidity were increased following attempted midpelvic forceps (1.5% vs 0.7% in cesarean delivery; ARR 2.34, 95% CI 1.54-3.56) and sequential operative vaginal delivery (1.7%; ARR 2.96, 95% CI 1.94-4.51; Table 4.3). This higher maternal morbidity was mainly due to higher rates of severe postpartum hemorrhage in the midpelvic 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 hemorrhage among midpelvic forceps delivery was 2.46 (95% CI 1.43-4.25), while the same ARR was 4.17 (95% CI 2.50-6.97) with vacuum.

4.4.3. Obstetric trauma

Obstetric trauma rates were high following attempted vacuum delivery (11.6% versus 3.8% following cesarean deliveries; ARR 3.61, 95% CI 3.03-4.29; Tables 4.2 and Appendix Table 4.2) and highest following attempted midpelvic forceps delivery (26.4% versus 3.8%; ARR 8.84, 95% CI 7.22-9.96) among women with dystocia. Obstetric trauma rates among deliveries with fetal distress were similar (Tables 4.3 and Appendix Table 4.2). Severe perineal laceration rates were high among attempted midpelvic operative vaginal deliveries, ranging from 8.5% following attempted vacuum deliveries for fetal distress to 23.0% among attempted forceps deliveries for dystocia. Figures 4.2 and 4.3 show the rates of severe perineal lacerations by indication, instrument, episiotomy type (Figure 4.2), and laceration degree (3^{rd} vs 4^{th} degree; Figure 4.3).

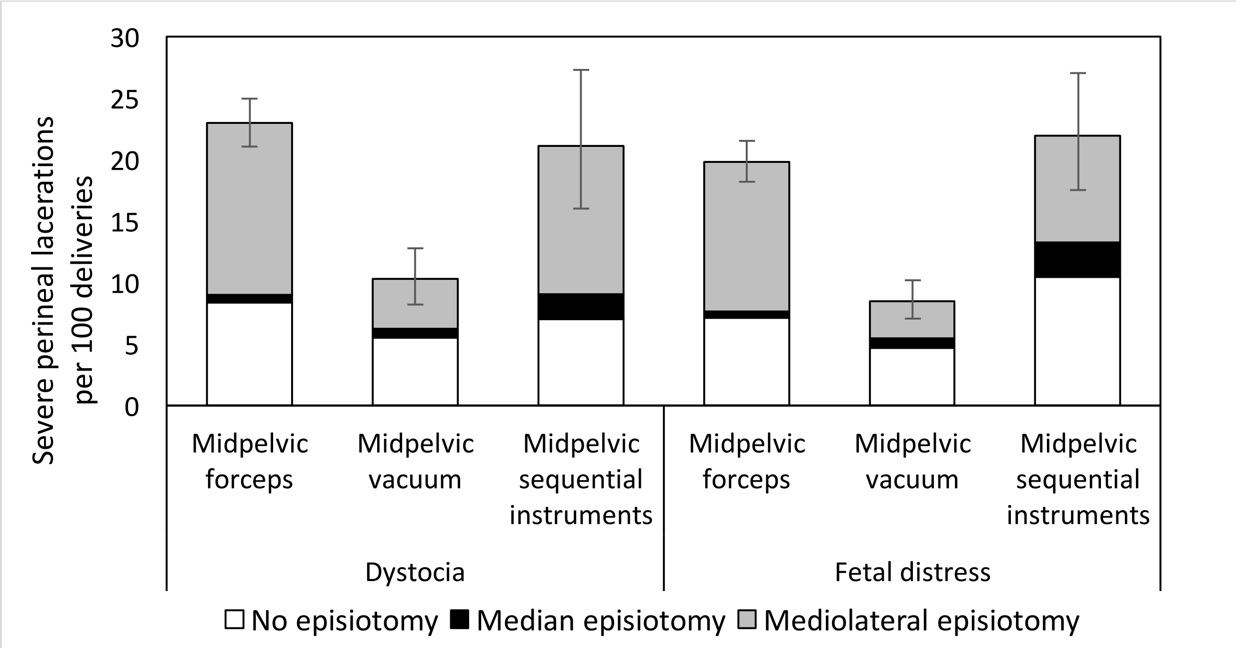

Figure 4.2. Rates (per 100 deliveries) and 95% confidence intervals of third and fourth-degree perineal lacerations following midpelvic operative vaginal delivery by instrument, indication, and type of episiotomy, British Columbia, 2004–2014.

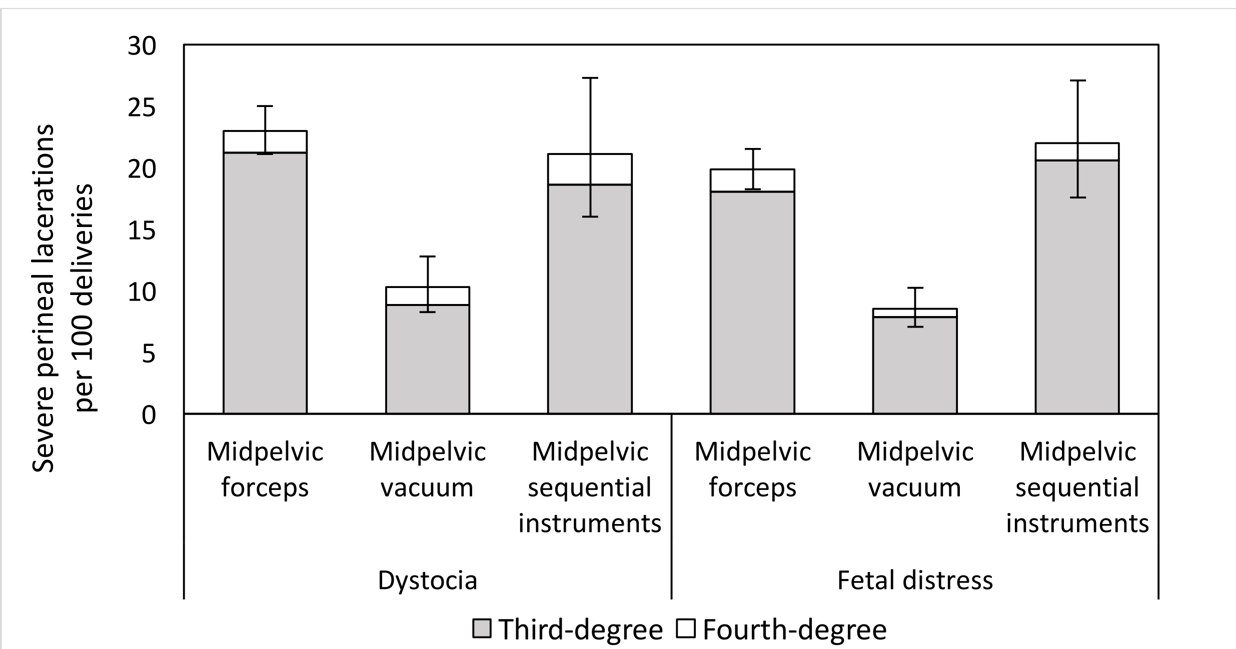

Figure 4.3. Rates (per 100 deliveries) and 95% confidence intervals of third and fourth-degree perineal lacerations following midpelvic operative vaginal delivery by instrument and indication, British Columbia, 2004–2014.

NNT for obstetric trauma was 3 for midpelvic forceps, 10 for midpelvic vacuum and 4 for sequential instrumentation among women with dystocia (Table 4.4).

4.4.4. Sensitivity analyses and effect modification

The associations between attempted midpelvic 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 (Table 4.5). 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 (Table 4.6). The estimates from the data with multiple imputation were very similar to the complete case estimates. The association between attempted midpelvic 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 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; Appendix Table 4.3).

The association between attempted midpelvic operative vaginal delivery and severe perinatal morbidity/mortality was similar among women with and without a prolonged second stage of labour (Appendix Tables 4.4 and 4.5). However, the association between attempted midpelvic 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;

Table 4.4. Adjusted rate differences (per 100 deliveries) and number needed to treat (NNT) for perinatal and maternal outcomes following attempted midpelvic operative vaginal delivery (OVD) compared with cesarean delivery, British Columbia, 2004–2014

Outcome	**Attempted midpelvic forceps**			**Attempted midpelvic vacuum**			**Attempted midpelvic sequential OVD**		
	ARD	95% CI	NNT	ARD	95% CI	NNT	ARD	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 hemorrhage	0.73	(0.22−1.63)	137	1.59	(0.75−2.99)	63	0.39	(0.00−1.10)	256
Postpartum hemorrhage	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	(-0.19−0.85)	353	0.53	(0.08−1.15)	189	0.08	(-0.38−0.66)	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−-0.03)	-285	0.20	(-0.15−0.67)	492	-0.67	(-0.84−0.25)	-150
Respiratory distress	0.50	(-0.50−1.64)	200	0.64	(-0.36−1.85)	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	(-0.36−0.23)	-722	1.29	(0.62−2.32)	77
Severe postpartum hemorrhage	1.05	(0.46−2.10)	95	-0.07	(-0.21−0.24)	-1515	0.98	(0.40−2.02)	102
Postpartum hemorrhage	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 NNTs reflected the average number of women delivered by operative vaginal delivery that would have had to be delivered by cesarean to avoid one case of the outcome of interest.

Adjusted rate differences estimated using cesarean delivery as the reference group. All models adjusted for maternal age, parity, pre-pregnancy weight, previous cesarean delivery, position of the fetal head at delivery, birth weight, income quintile, and year of delivery.

ARD, adjusted rate difference; CI, confidence interval; NNT, number needed to treat.

Appendix Table 4.5). Prolonged second stage similarly attenuated the association between attempted midpelvic forceps delivery and respiratory distress and obstetric trauma among women with dystocia and between attempted midpelvic vacuum delivery and postpartum hemorrhage among deliveries with fetal distress.

Table 4.5. Rate ratios expressing the association between operative vaginal delivery (OVD) vs cesarean 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

	Cesarean delivery	**Attempted midpelvic forceps**	**Attempted midpelvic vacuum**	**Attempted sequential midpelvic OVD**
Outcome	**ARR (95% CI)**	**ARR (95% CI)**	**ARR (95% CI)**	**ARR (95% CI)**
Dystocia cohort				
Severe perinatal morbidity/mortality*	Reference	2.32 (1.24-4.36)	2.94 (1.43-6.05)	4.80 (1.92-12.0)
Severe maternal morbidity†	Reference	1.79 (0.89-3.60)	2.01 (0.89-4.54)	1.59 (0.35-7.16)
Fetal distress cohort				
Severe perinatal morbidity/mortality*	Reference	1.56 (1.00-2.45)	1.43 (0.85-2.42)	1.15 (0.47-2.81)
Severe maternal morbidity†	Reference	2.04 (1.01-4.14)	0.80 (0.30-2.17)	2.62 (0.89-7.74)

ARR, adjusted rate ratio; CI, confidence interval.

Results adjusted for maternal age, parity, pre-pregnancy weight, previous cesarean delivery, position of the fetal head at delivery, birth weight, income quintile, and year of delivery.

* Severe perinatal morbidity/mortality included neonatal convulsions, assisted ventilation by endotracheal tube, 5-minute Apgar score of <4, severe birth trauma (see below for definition), stillbirth that occurred after the onset of labour, and neonatal death.

† Severe maternal morbidity included severe postpartum hemorrhage, shock, sepsis, obstetric embolism, cardiac complication, and acute renal failure.

Table 4.6. Rate ratios expressing the association between operative vaginal delivery (OVD) vs cesarean 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

	Cesarean delivery	**Attempted midpelvic forceps**	**Attempted midpelvic vacuum**	**Attempted sequential midpelvic OVD**
Outcome	**ARR (95% CI)**	**ARR (95% CI)**	**ARR (95% CI)**	**ARR (95% CI)**
Dystocia cohort				
Severe perinatal morbidity/mortality*	Reference	2.26 (1.54-3.32)	2.36 (1.60-3.47)	5.07 (3.54-7.25)
Severe maternal morbidity†	Reference	1.72 (1.13-2.61)	2.44 (1.65-3.62)	1.68 (1.08-2.60)
Fetal distress cohort				
Severe perinatal morbidity/mortality*	Reference	1.20 (0.94-1.53)	1.36 (1.06-1.74)	1.02 (0.77-1.36)
Severe maternal morbidity†	Reference	2.41 (1.58-3.68)	0.79 (0.46-1.36)	3.26 (2.11-5.02)

ARR, adjusted rate ratio; CI, confidence interval.

Results adjusted for maternal age, parity, pre-pregnancy weight, previous cesarean delivery, position of the fetal head at delivery, birth weight, income quintile, and year of delivery.

* Severe perinatal morbidity/mortality included neonatal convulsions, assisted ventilation by endotracheal tube, 5-minute Apgar score of <4, severe birth trauma (see below for definition), stillbirth that occurred after the onset of labour, and neonatal death.

† Severe maternal morbidity included severe postpartum hemorrhage, shock, sepsis, obstetric embolism, cardiac complication, and acute renal failure.

4.5. Discussion

Our study showed that among term singleton deliveries in the second stage of labour, attempted midpelvic operative vaginal delivery was associated with an increased risk of severe perinatal morbidity/mortality compared with cesarean 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 cesarean delivery group. We also found substantially greater risk of birth and obstetric trauma following operative vaginal delivery compared with cesarean 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 cesarean delivery group except for midpelvic vacuum deliveries among women with fetal distress.

The strengths of our data source and analysis include an ability to identify operative vaginal deliveries at midpelvic station and to restrict our cesarean delivery cohort to women in the second stage of labour. Women who had a failed operative vaginal delivery (and eventually delivered by cesarean) 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[117-120] 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 randomized trials for assessing the safety of midpelvic operative vaginal delivery is questionable. More importantly, nonexperimental evaluation of the unintended effects of midpelvic 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).[121] 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 midpelvic 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 midpelvic operative vaginal delivery. Another limitation relates to determination of pelvic station, which can be challenging per se and can be affected by moulding and fetal head position.[122,123] These study findings reflect the average safety of midpelvic operative vaginal delivery as carried out under current norms of diagnosis and available expertise.

Although we restricted cesarean deliveries to those carried out in the second stage of labour, we were constrained by our inability to ascertain information on pelvic station for cesarean deliveries. However, only a small fraction of cesarean deliveries would have been carried out with the fetal head above midpelvic station.[124] On the other hand, our estimates of the adverse effects of midpelvic operative vaginal delivery may have been underestimated as some cesarean deliveries in the second stage of labour would have been carried out with the fetal head below midpelvic station.[40,41,107] Further limitations of the 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 pre-pregnancy weight and position of the fetal head, which was addressed using multiple imputation. We were also unable to assess long-term effects of cesarean delivery and midpelvic operative vaginal delivery.

The increase in severe maternal morbidity following midpelvic forceps delivery was primarily due to the increased rate of severe postpartum hemorrhage. Higher rates of severe postpartum hemorrhage were also found in midpelvic vacuum deliveries among women with dystocia. Increased rates of postpartum hemorrhage following vacuum delivery at low and outlet station has been reported previously,[35] although such reports were restricted to babies ≥4000 g. Studies that have compared postpartum hemorrhage in midpelvic operative vaginal deliveries and cesarean deliveries have yielded conflicting results[25,27,28,34,53,125] at least partly due to differences in definitions of postpartum hemorrhage. We defined severe postpartum hemorrhage as postpartum hemorrhage requiring transfusion to ensure a clinically meaningful and standardized outcome. Although cases of postpartum hemorrhage observed in our study were due to atonic postpartum hemorrhage, the high rates of obstetric trauma following midpelvic operative vaginal delivery in our study suggest that some proportion of such hemorrhage was due to cervical, vaginal and perineal trauma.[126]

Third- and fourth-degree perineal laceration rates in our study were high following midpelvic operative vaginal delivery. Similar high rates have been reported in other recent studies of operative vaginal delivery.[32,35] Validation studies[94,112] show that the diagnosis of third- and fourth-degree perineal lacerations in the BCPDR is accurate (sensitivity and specificity of 90.1% and 99.8%, respectively for third-degree, and 100% and 100%, respectively for fourth-degree tears). With rates of anal sphincter injury as high as 23.0% following attempted midpelvic forceps deliveries, it is imperative that the risks and relevant long-term quality-of-life implications (to the pelvic floor health of attempted midpelvic 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 cesarean delivery).

Attempted midpelvic 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 midpelvic 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 strong 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 cesarean delivery rate could result in increases in severe perinatal and maternal morbidity, especially birth trauma, severe postpartum hemorrhage, and obstetric trauma.

Note: Given the strength of the associations in this study between the outcomes and operative vaginal delivery, I was interested in quantifying these associations among all operative vaginal deliveries compared with cesarean delivery (not only those restricted to midpelvic station). Furthermore, I wanted to examine whether these associations might differ by pelvic station and type of instrument. For example, would the association between low forceps (vs cesarean delivery) and severe perinatal morbidity/mortality be significantly different from the association between midpelvic forceps delivery (vs cesarean delivery) and severe perinatal morbidity/mortality? Therefore, the study in Chapter 5 compared these associations at outlet, low, and midpelvic station (vs. cesarean delivery).

Chapter 5: Outcomes following operative vaginal delivery at outlet, low-pelvic, and midpelvic station vs cesarean delivery[4]

5.1. Synopsis

Background: There is currently insufficient evidence regarding the perinatal and maternal safety of operative vaginal versus cesarean delivery given fetal distress or dystocia in the second stage of labour. Although many industrialized settings have tended to favor cesarean delivery in recent decades, increasing the rate of operative vaginal delivery is currently advocated as a strategy to curb the rising frequency of cesarean delivery, especially in the United States. The objective of this study was to quantify severe perinatal and maternal morbidity and mortality associated with operative vaginal delivery at outlet, low-pelvic, and midpelvic station, compared with cesarean delivery in the second stage of labour, and to determine whether these associations differ by pelvic station.

Methods: I conducted a population-based, retrospective cohort study of all term singleton deliveries by operative vaginal or cesarean delivery with prolonged second stage of labour in Canada from 2003-2013. The primary study outcomes were severe perinatal morbidity and mortality (including neonatal seizures, assisted ventilation, severe birth trauma, and perinatal death) and severe maternal morbidity and mortality (including severe postpartum hemorrhage, shock, sepsis, cardiac complication, acute renal failure, obstetric embolism and maternal death). Logistic regression was used to estimate adjusted odds ratios (AOR) and

[4] A version of this chapter has been submitted for review as Muraca GM, Sabr Y, Lisonkova S, Brant R, Cundiff GW, Joseph KS. Perinatal and maternal morbidity and mortality following operative vaginal versus cesarean delivery. (submitted for publication), Apr 2017.

95% confidence intervals (CI) after adjusting for potential confounders and stratifying by indication.

Results: There were 61,106 deliveries included in the study; 38,013 with dystocia and 23,093 with fetal distress. Among women with dystocia, forceps and vacuum delivery were associated with higher rates of composite severe perinatal morbidity and mortality compared with cesarean delivery, irrespective of pelvic station (forceps AOR 1.56, 95% CI 1.13-2.17; vacuum AOR 1.44, 95% CI 1.06-1.97). Vacuum delivery was associated with lower rates of severe maternal morbidity and mortality compared with cesarean delivery (dystocia AOR 0.64, 95% CI 0.51-0.81; fetal distress AOR 0.43, 95% CI 0.32-0.57). Severe birth trauma and obstetric trauma rates were substantially higher following operative vaginal delivery; rates of severe perineal laceration ranged from 11% to 25%.

Conclusion: Operative vaginal delivery increases the risk of severe perinatal morbidity and mortality compared with cesarean delivery among women with dystocia, while vacuum delivery decreases the risk of severe maternal morbidity and mortality among women with dystocia and fetal distress. Birth trauma and obstetric trauma are significantly increased following forceps and vacuum delivery compared with cesarean delivery.

5.2. Background and objectives

There is currently insufficient evidence regarding the perinatal and maternal safety of operative vaginal versus cesarean delivery given fetal distress or dystocia in the second stage of labour. This has resulted in wide variations in the use of operative vaginal delivery worldwide;[77,109,127,128] in 2014, operative vaginal delivery accounted for 3.2% of all deliveries in the United States,[129] 10.7% in Canada in 2012[109], and 16.4% in Ireland in 2010.[128] Although many industrialized settings have tended to favor cesarean delivery in recent decades,[22,99,109] increasing the rate of operative vaginal delivery is currently advocated as a strategy to curb the rising frequency of cesarean delivery, especially in the United States.[11]

The extant literature on perinatal and maternal morbidity following operative vaginal delivery compared with cesarean delivery is inconsistent,[24-30,32,35,130] at least partly because most previous studies were limited by the absence of information on pelvic station, a key determinant of perinatal and maternal outcomes.[37,38] We, therefore, carried out a study with two objectives, first, to estimate rates of severe perinatal and maternal morbidity and mortality following operative vaginal delivery compared with cesarean delivery, and second, to determine whether these associations differed by pelvic station.

5.3. Methods

Data were obtained from the Canadian Institute for Health Information's Discharge Abstract Database (DAD). The study population included all term (37 to 41 weeks gestation) singletons delivered in Canada (excluding Quebec) by operative vaginal or cesarean delivery between April 2003 and March 2013. The specific methods of abstraction used for compiling

DAD data, the coding practices used and the accuracy of the information in the DAD have been described in the Methods section of Chapter 2.

All operative vaginal deliveries are carried out in the second stage of labour, whereas cesarean deliveries can be carried out in either the first or second stage. Data source constraints precluded restricting cesarean deliveries to those that occurred in the second stage of labour. I therefore, restricted all operative vaginal and cesarean deliveries to those with a prolonged second stage of labour identified by diagnosis code (ICD-10-CA O631), as was done in the study presented in Chapter 3, to ensure an appropriate comparison.

Deliveries were excluded if the infant had any congenital anomaly or if the mother had a hypertensive disorder, diabetes mellitus or a placental abnormality. Deliveries were stratified by indication for operative delivery (dystocia or fetal distress).[114] Forceps deliveries were grouped into outlet, low, and midpelvic deliveries based on the Classification According to Station and Rotation (-5 to +5 cm)[38] as previously described above. Delivery by vacuum extraction was grouped into outlet, low, midpelvic, and not otherwise specified (NOS) categories based on the same classification system.[38]

The study included two primary outcomes, composite severe perinatal morbidity and mortality and composite severe maternal morbidity and mortality. Composite severe perinatal morbidity and mortality included neonatal seizures, assisted ventilation by endotracheal tube, severe birth trauma (intracranial laceration and hemorrhage, skull fracture, severe injury to the central or peripheral nervous systems, long bone injury, subaponeurotic hemorrhage, and injury to the liver or spleen), stillbirth and neonatal death. Composite severe maternal morbidity and mortality included severe postpartum hemorrhage (postpartum hemorrhage requiring transfusion), shock, sepsis, cardiac complications, acute renal failure, obstetric embolism, evacuation of incisional hematoma and death. Secondary outcomes included all birth trauma (intracranial hemorrhage and laceration, injury to the central or peripheral nervous systems, scalp, or skeleton, and other birth injury), severe birth trauma, obstetric trauma (third- and fourth-degree perineal tears, cervical and high vaginal lacerations, injury to pelvic organs, joints and ligaments, hematoma of the pelvis, extension of uterine incision, and other obstetric trauma) and severe perineal lacerations (third- and fourth-degree). 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 Appendix Table 5.1.

Adjusted odds ratios (AOR) and 95% confidence intervals (CI) were estimated using multivariable logistic regression to express the relationship between forceps and vacuum delivery (at outlet, low, midpelvic, and all stations combined) and the composite outcomes, with cesarean delivery as the reference group. The models were adjusted for maternal age, parity, birth weight, province of residence, and fiscal year. Modification of the effect of mode of delivery on the study outcomes by fiscal year, provider (obstetrician vs non-obstetrician), and institutional delivery volume (high, medium, low) was examined by introducing interaction terms into a logistic regression mixed-effects models with a logit link function to account for clustered observations within institutions. The magnitude of absolute effects was quantified by calculating adjusted rate differences and the adjusted number needed to treat

(NNT). The adjusted NNTs reflect the number of operative vaginal deliveries that would have had to be delivered by cesarean to avoid one case of the outcome of interest.

Modification of the relationship between operative vaginal delivery and the outcomes of interest by pelvic station was assessed using the Breslow-Day chi-square test[131] for heterogeneity of odds ratio. The significance of a linear trend in odds ratios across levels of pelvic station was determined using the Mantel-Haenszel chi-square test. The significance of trends in the rates of severe perineal lacerations by pelvic station was assessed using the Cochran-Armitage test for a linear trend in proportions.

Sensitivity analyses were carried out by estimating the association between attempted mode of delivery and composite perinatal and maternal morbidity and mortality by including failed forceps and vacuum attempts that resulted in cesarean delivery in the attempted operative vaginal delivery category. The database did not include information on the sequence of instruments applied in deliveries with sequential instrumentation. However, since it is uncommon for vacuum to be applied following failed forceps, a second sensitivity analysis was carried out assuming that all sequential instrument applications involved a failed vacuum delivery attempt. All statistical analyses were performed using SAS 9.4. The study was approved by the University of British Columbia’s Clinical Research Ethics Board.

5.4. Results

There were 887,857 singleton term deliveries by operative vaginal or cesarean deliveries during the study period. After exclusions (Figure 1), 61,106 singleton, term deliveries with a prolonged second stage were included in the study; 38,013 with dystocia and 23,093 with fetal distress (Figure 1). Older women (≥35 years), and those who delivered at later gestational ages (39-41 weeks) were more likely to have had a cesarean delivery. Mid-pelvic forceps was more commonly used in nulliparous women compared with vacuum, while vacuum delivery at all stations was more likely among parous women (Table 5.1). Macrosomic infants (>4000 g) were more likely to be delivered by cesarean and less likely to be delivered by vacuum extraction.

Overall, the rates of composite severe perinatal and maternal morbidity and mortality were 0.83% and 1.31%, respectively, in deliveries with dystocia. These rates were higher in deliveries with fetal distress (1.83% and 1.46, respectively). The rate of severe perinatal morbidity/mortality increased during the study period, especially in deliveries with fetal distress from 1.2% in 2003 to 2.6% in 2012, while severe maternal morbidity/mortality increased only in deliveries with dystocia, from 0.9% to 1.9% over the study period (Figure 5.2). During the same period, birth trauma rates decreased slightly and obstetric trauma rates increased in both the dystocia and fetal distress groups (Figure 5.2).

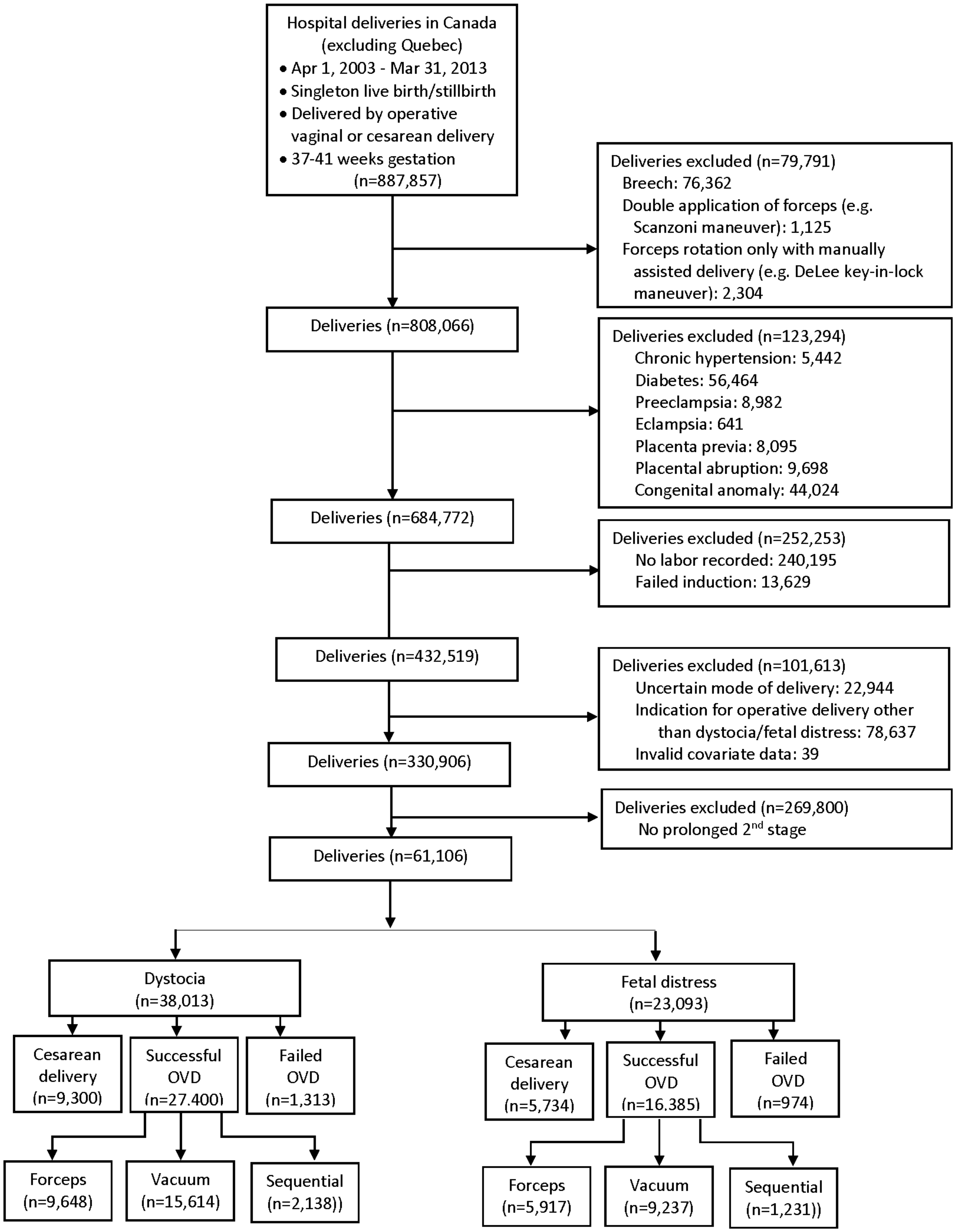

Figure 5.1. Derivation of study cohort.

Table 5.1. Maternal and infant characteristic and obstetric factors among women delivering term singletons by operative delivery with prolonged second stage of labour, Canada (excluding Quebec), 2003-2013 (N=55,450)

Characteristic	Cesarean delivery n=15034 No. (%)	Operative vaginal delivery: Forceps n=15565 No. (%)	Operative vaginal delivery: Vacuum n=24851 No. (%)	P-value
Maternal age (yr)				<0.0001
<20	444 (21.6)	484 (23.5)	1128 (54.9)	
20-24	1810 (23.9)	1974 (26.1)	3783 (50.0)	
25-29	4645 (26.2)	4956 (27.9)	8158 (45.9)	
30-34	5388 (28.4)	5490 (29.0)	8075 (42.6)	
35-39	2310 (29.7)	2294 (29.5)	3166 (40.7)	
≥40	437 (32.5)	367 (27.3)	541 (40.2)	
Parity				<0.0001
0	8475 (26.1)	9003 (27.8)	14963 (46.1)	
1	1078 (25.3)	953 (22.4)	2227 (52.3)	
≥2	236 (25.0)	160 (17.0)	547 (58.0)	
Missing	5245 (29.5)	5449 (30.6)	7114 (39.9)	
Gestational age (wks)				<0.0001
37-38	2297 (25.0)	2604 (28.3)	4290 (46.7)	
39-41	12737 (27.5)	12961 (28.0)	20561 (44.4)	
Birth weight (g)				<0.0001
<3000	936 (18.7)	1409 (28.1)	2666 (53.2)	
3000-3999	10603 (25.8)	11752 (28.5)	18822 (45.7)	
≥4000	3495 (37.7)	2404 (26.0)	3363 (36.3)	
Institutional delivery volume				<0.0001
Low	4486 (24.4)	4317 (23.5)	9581 (52.1)	
Medium	4762 (26.7)	4636 (25.9)	8469 (47.4)	
High	5786 (30.1)	6612 (34.4)	6801 (35.4)	
Provider				<0.0001
Obstetrician	14401 (30.2)	14990 (31.4)	18279 (38.3)	
Non-obstetrician	633 (8.1)	575 (7.4)	6572 (84.5)	
Indication				<0.0001
Dystocia	9300 (26.9)	9648 (27.9)	15614 (45.2)	
Fetal distress	5734 (27.5)	5917 (28.3)	9237 (44.2)	

5.4.1. Severe perinatal morbidity and mortality

The rate of severe perinatal morbidity and mortality in the cesarean delivery group was 0.66% in deliveries with dystocia and 1.80% in deliveries with fetal distress. Among women with dystocia, forceps and vacuum delivery were associated with higher rates of severe perinatal morbidity and mortality compared with cesarean delivery (forceps AOR 1.56, 95% CI 1.13-2.17; vacuum AOR 1.44, 95% CI 1.06-1.97; Table 5.2). Adjusted odds ratios for composite perinatal morbidity and mortality were not significantly different among outlet vs low vs midpelvic deliveries by forceps (AOR 1.77 vs 1.38 vs 1.74, p=0.34) or vacuum (1.35 vs 1.54 vs 1.62, p=0.43; Figure 5.3). Among deliveries with fetal distress, there was no significant difference in rates of severe perinatal morbidity and mortality with forceps or vacuum delivery at any pelvic station compared with cesarean delivery (Table 5.3; Figure 5.3).

5.4.2 Severe maternal morbidity and mortality

The rate of severe maternal morbidity and mortality in the cesarean delivery group was 1.65% in deliveries with dystocia and 2.18% in deliveries with fetal distress. Forceps delivery was not associated with severe maternal morbidity among women with dystocia or fetal distress. However, vacuum delivery was associated with lower rates of severe maternal morbidity and mortality compared with cesarean delivery; AOR 0.64, 95% CI 0.51-0.81 among women with dystocia and AOR 0.43, 95% CI 0.32-0.57 among women with fetal distress (Tables 5.2 and 5.3). The association between vacuum delivery and composite severe maternal morbidity and mortality was not modified by pelvic station (Figure 5.4).

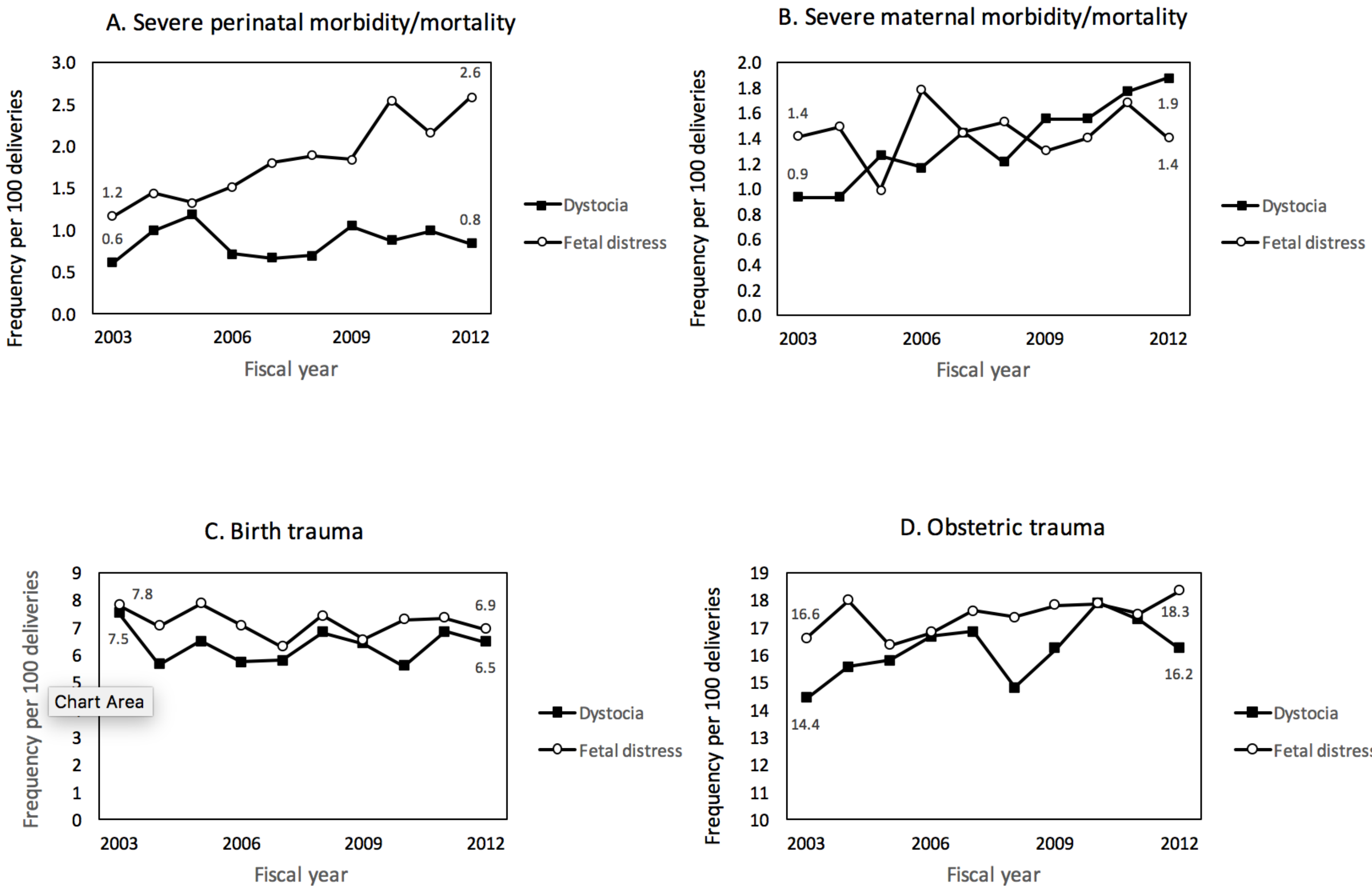

Figure 5.2. Temporal trends in A) severe perinatal morbidity/mortality, B) severe maternal morbidity/mortality, C) birth trauma, and D) obstetric trauma, stratified by indication, in term singleton deliveries in Canada (excluding Quebec), 2003-2013

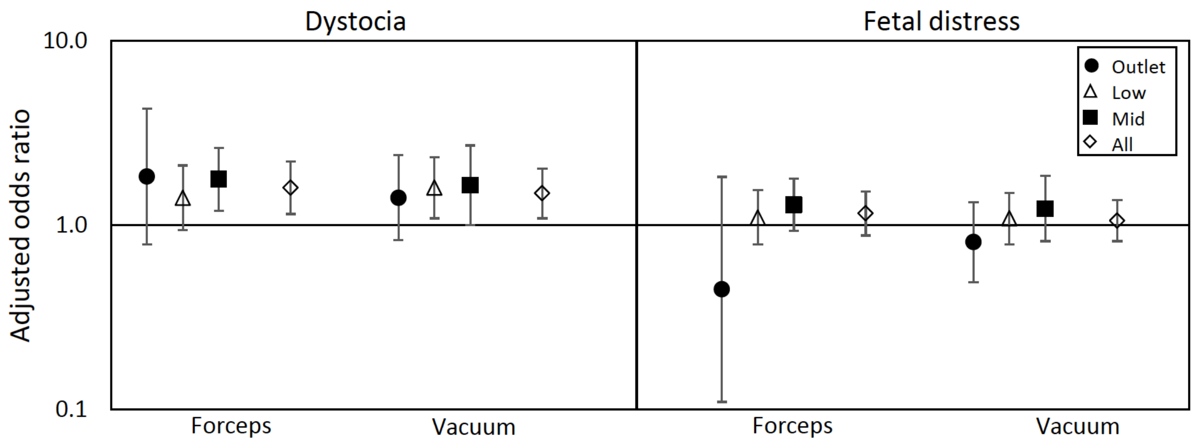

Figure 5.3. Adjusted odds ratios and 95% confidence intervals for severe perinatal morbidity/mortality in forceps and vacuum delivery compared with cesarean delivery, by pelvic station and indication in singleton term deliveries with prolonged second stage of labour, Canada (excluding Quebec), 2003-2013.

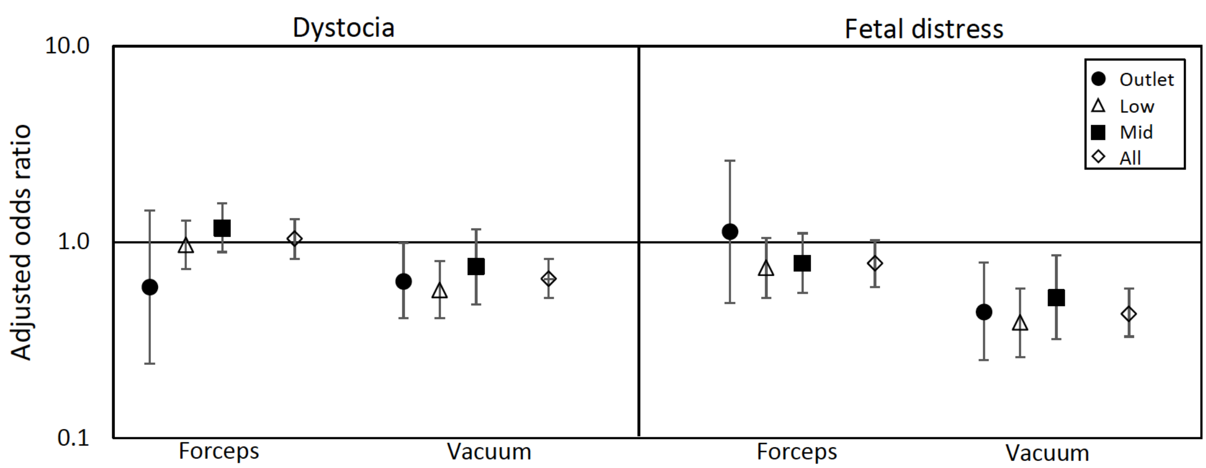

Figure 5.4. Adjusted odds ratios and 95% confidence intervals for severe maternal morbidity/mortality in forceps and vacuum delivery compared with cesarean delivery, by pelvic station and indication in singleton term deliveries with prolonged second stage of labour, Canada (excluding Quebec), 2003-2013.

Table 5.2. Rates, adjusted odds ratios (AOR), and 95% confidence intervals (CI) for perinatal and maternal outcomes by mode of delivery and pelvic station among term singleton deliveries with prolonged second stage and dystocia, Canada (excluding Quebec), 2003-2013

Outcome		Cesarean delivery n=9300	Forceps				Vacuum				
			All stations n=9648	**Outlet n=549**	**Low n=4901**	**Mid n=4198**	**All stations n=15614**	**Outlet n=2344**	**Low n=5191**	**Mid n=2158**	**NOS n=5921**
Severe perinatal morbidity and mortality	%	0.66	0.93	1.09	0.82	1.05	0.86	0.77	0.92	1.02	0.79
	AOR (95% CI)	Ref	**1.56 (1.13-2.17)**	1.77 (0.76-4.13)	1.38 (0.92-2.06)	**1.74 (1.18-2.58)**	**1.44 (1.06-1.97)**	1.35 (0.79-2.30)	**1.54 (1.05-2.26)**	1.62 (0.98-2.67)	1.32 (0.89-1.95)
Severe birth trauma	%	0.17	0.68	0.91	0.55	0.81	0.49	0.38	0.52	0.60	0.47
	AOR (95% CI)	Ref	**4.64 (2.68-8.03)**	**6.12 (2.22-16.9)**	**3.81 (2.04-7.10)**	**5.35 (2.94-9.74)**	**3.35 (1.94-5.77)**	**2.72 (1.19-6.20)**	**3.49 (1.87-6.51)**	**3.61 (1.71-7.61)**	**3.35 (1.80-6.25)**
Birth trauma	%	2.09	5.97	7.29	5.39	6.48	8.04	6.61	7.76	10.84	7.82
	AOR (95% CI)	Ref	**3.24 (2.74-3.82)**	**4.04 (2.83-5.77)**	**3.10 (2.56-3.75)**	**3.28 (2.71-3.96)**	**4.11 (3.52-4.80)**	**3.47 (2.79-4.32)**	**3.96 (3.32-4.72)**	**4.54 (3.71-5.55)**	**4.33 (3.63-5.15)**
Severe maternal morbidity and mortality	%	1.65	1.53	0.91	1.47	1.69	0.98	0.98	0.85	1.11	1.05
	AOR (95% CI)	Ref	1.03 (0.81-1.29)	0.58 (0.24-1.42)	0.96 (0.72-1.27)	1.17 (0.88-1.56)	**0.64 (0.51-0.81)**	**0.62 (0.40-0.97)**	**0.56 (0.40-0.79)**	0.74 (0.48-1.15)	**0.69 (0.51-0.93)**
Obstetric trauma	%	6.33	24.9	19.3	25.6	24.8	15.0	12.8	15.5	17.3	14.6
	AOR (95% CI)	Ref	**5.34 (4.85-5.88)**	**4.08 (3.24-5.14)**	**5.41 (4.86-6.02)**	**5.40 (4.84-6.04)**	**2.89 (2.63-3.18)**	**2.36 (2.04-2.74)**	**2.91 (2.60-3.26)**	**3.35 (2.90-3.86)**	**2.92 (2.61-3.27)**
Severe perineal laceration (3^{rd},4^{th} deg)	% (95% CI)	<0.05	**21.9 (21.1-22.8)**	**18.4 (15.4-21.9)**	**23.0 (21.9-24.2)**	**21.1 (19.9-22.4)**	**13.9 (13.3-14.4)**	**11.5 (10.3-12.8)**	**14.5 (13.5-15.5)**	**15.8 (14.3-17.4)**	**13.5 (12.7-14.4)**

NOS, not otherwise specified; OR, odds ratio.
All models are adjusted for maternal age, parity, birth weight, province, and fiscal year of birth.
Bold text denotes statistically significant associations.

Table 5.3. Rates, adjusted odds ratios (AOR), and 95% confidence intervals (CI) for perinatal and maternal outcomes by mode of delivery and pelvic station among term singleton deliveries with prolonged second stage and fetal distress, Canada (excluding Quebec), 2003-2013

Outcome		**Cesarean delivery n=5734**	**Forceps**				**Vacuum**				
			All stations n=5917	**Outlet n=257**	**Low n=2944**	**Mid n=2716**	**All stations n=9237**	**Outlet n=1350**	**Low n=3516**	**Mid n=1672**	**NOS n=2699**
Severe perinatal morbidity and mortality	%	1.80	1.94	0.78	1.83	2.17	1.78	1.41	1.82	1.97	1.78
	AOR (95% CI)	Ref	1.14 (0.87-1.49)	0.44 (0.11-1.79)	1.07 (0.77-1.50)	1.27 (0.92-1.77)	1.03 (0.80-1.32)	0.78 (0.48-1.29)	1.06 (0.77-1.45)	1.20 (0.80-1.81)	1.02 (0.72-1.45)
Severe birth trauma	%	0.16	0.88	0.39	0.58	1.25	0.70	0.44	0.68	1.14	0.59
	AOR (95% CI)	Ref	**6.68 (3.28-13.6)**	3.00 (0.38-23.9)	**4.51 (2.00-10.2)**	**9.29 (4.42-19.5)**	**5.25 (2.60-10.6)**	**3.31 (1.17-9.39)**	**5.29 (2.44-11.5)**	**8.11 (3.59-18.3)**	**4.50 (1.96-10.3)**
Birth trauma	%	2.69	7.15	5.84	6.11	8.39	8.51	5.48	8.02	13.3	7.67
	AOR (95% CI)	Ref	**2.97 (2.45-3.59)**	**2.75 (1.58-4.77)**	**2.77 (2.22-3.46)**	**3.15 (2.55-3.90)**	**3.35 (2.80-4.00)**	**2.24 (1.68-2.98)**	**3.08 (2.51-3.78)**	**4.34 (3.48-5.40)**	**3.55 (2.85-4.42)**
Severe maternal morbidity and mortality	%	2.18	1.59	2.33	1.46	1.66	0.93	0.96	0.82	1.14	0.93
	AOR (95% CI)	Ref	0.77 (0.59-1.01)	1.14 (0.49-2.62)	0.73 (0.51-1.04)	0.78 (0.55-1.10)	**0.43 (0.32-0.57)**	**0.43 (0.24-0.77)**	**0.38 (0.25-0.58)**	**0.52 (0.31-0.85)**	**0.43 (0.28-0.67)**
Obstetric trauma	%	8.09	26.3	27.2	27.6	24.7	16.0	15.8	16.0	17.8	15.0
	AOR (95% CI)	Ref	**4.23 (3.78-4.73)**	**4.70 (3.50-6.30)**	**4.50 (3.97-5.11)**	**3.90 (3.42-4.44)**	**2.28 (2.04-2.55)**	**2.22 (1.86-2.65)**	**2.22 (1.95-2.54)**	**2.50 (2.13-2.94)**	**2.23 (1.93-2.57)**
Severe perineal laceration (3rd,4th degree)	% (95% CI)	<0.09	**22.8 (21.8-23.9)**	**25.3 (20.4-30.9)**	**24.5 (23.0-26.1)**	**20.8 (19.3-22.4)**	**14.9 (14.2-15.7)**	**14.8 (13.0-16.8)**	**14.7 (13.6-15.9)**	**16.2 (14.5-18.0)**	**14.5 (13.2-15.9)**

NOS, not otherwise specified; OR, odds ratio.
All models are adjusted for maternal age, parity, birth weight, province, and fiscal year of birth.
Bold text denotes statistically significant associations.

5.4.3. Birth trauma

Birth trauma and severe birth trauma were higher in both the forceps and vacuum groups when compared with cesarean delivery, irrespective of indication. (Table 5.2, 5.3). The association between forceps delivery and birth trauma was not modified by pelvic station (in deliveries with dystocia, P for heterogeneity in OR 0.12, P for linear trend in OR 0.32; in deliveries with fetal distress, P for heterogeneity in OR 0.22, P for linear trend in OR 0.35; Figure 5.5), while the association between vacuum delivery and birth trauma varied by pelvic station. Among women with dystocia delivered by vacuum, the AOR for birth trauma was 3.47 at outlet station, 3.96 at low station and 4.54 at midpelvic station (P for heterogeneity in OR 0.0002, P for linear trend in OR <0.0001). Among women with fetal distress delivered by vacuum, the AOR for birth trauma was 2.24 at outlet station, 3.08 at low station and 4.34 at midpelvic station (P for heterogeneity in OR <0.0001, P for linear trend in OR <0.0001). The adjusted rate differences for birth trauma following forceps delivery were 4.67 and 5.29

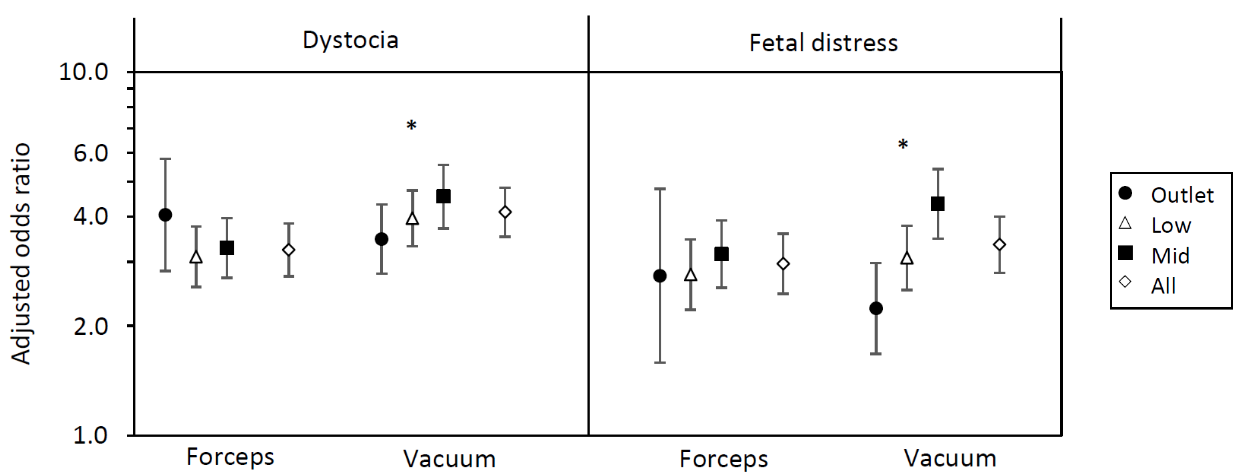

Figure 5.5. Adjusted odds ratios and 95% confidence intervals for birth trauma following forceps and vacuum delivery by pelvic station and indication, term singleton deliveries with a prolonged second stage of labour, Canada (excluding Quebec), 2003-2013.
Asterisks denote a P value of <0.05 (chi-square test for heterogeneity of the odds ratios, or a test for trend in the odds ratios).

per 100 deliveries compared with cesarean delivery for dystocia and fetal distress, respectively (NNTs of 21 and 19 respectively; Table 5.4). Adjusted rate differences and NNTs for birth trauma following vacuum delivery were similar; NNTs for women with fetal distress were 30, 18 and 11 for outlet, low and mid-pelvic vacuum, respectively (Table 5.4).

Table 5.4. Adjusted rate differences (per 100 deliveries) and number needed to treat (NNT) for perinatal and maternal outcomes following operative vaginal delivery (OVD) compared with cesarean delivery among term singleton deliveries with prolonged second stage, Canada (excluding Quebec), 2003-2013

Outcome	**Forceps**			**Vacuum**		
	RD	**(95% CI)**	**NNT***	**RD**	**(95% CI)**	**NNT***
Dystocia						
Severe perinatal morbidity and mortality	0.37	(0.09−0.77)	272	0.29	(0.04−0.64)	346
Severe birth trauma	0.63	(0.29−1.21)	160	0.40	(0.16−0.82)	247
Assisted ventilation by endotracheal tube	-0.20	(-0.28−-0.05)	-506	-0.10	(-0.20−0.06)	-1012
Birth trauma	4.67	(3.63−5.88)	21	6.49	(5.26−7.93)	15
Outlet	6.35	(3.82−9.97)	16	5.16	(3.74−6.94)	19
Low	4.39	(3.26−5.75)	23	6.19	(4.85−7.77)	16
Mid	4.77	(3.57−6.19)	21	7.40	(5.66−9.51)	14
Severe maternal morbidity and mortality	0.05	(-0.31−0.48)	2026	-0.59	(-0.81−-0.31)	-169
Obstetric trauma	27.5	(24.4−30.9)	4	12.0	(10.3−13.8)	8
Outlet	19.5	(14.2−26.2)	5	8.61	(6.58−11.0)	12
Low	27.9	(24.4−31.8)	4	12.1	(10.1−14.3)	8
Mid	27.9	(24.3−31.9)	4	14.9	(12.0−18.1)	7
Fetal distress						
Severe perinatal morbidity and mortality	0.25	(-0.23−0.88)	398	0.05	(-0.36−0.57)	1856
Severe birth trauma	0.89	(0.36−1.98)	112	0.67	(0.25−1.51)	150
Assisted ventilation by endotracheal tube	-0.49	(-0.76−-0.11)	-204	-0.55	(-0.78−-0.24)	-183
Birth trauma	5.29	(3.89−6.96)	19	6.31	(4.83−8.06)	16
Outlet	4.70	(1.56−10.1)	21	3.33	(1.83−5.32)	30
Low	4.75	(3.28−6.61)	21	5.59	(4.06−7.47)	18
Mid	5.77	(4.16−7.79)	17	8.97	(6.66−11.8)	11
Severe maternal morbidity and mortality	-0.50	(-0.89−0.02)	-199	-1.24	(-1.48−-0.94)	-80
Obstetric trauma	26.1	(22.5−30.2)	4	10.4	(8.42−12.5)	10
Outlet	29.9	(20.2−42.9)	3	9.87	(6.96−13.4)	10
Low	28.3	(24.0−33.3)	4	9.87	(7.69−12.5)	10
Mid	23.5	(19.6−27.8)	4	12.1	(9.14−15.7)	8

RD, rate difference; CI, confidence interval; NNT, number needed to treat.
Rate differences estimated using cesarean delivery as the reference group.
All models adjusted for maternal age, parity, birth weight, province, and fiscal year.
*The adjusted NNTs reflected the average number of women delivered by operative vaginal delivery that would have had to be delivered by cesarean to avoid one case of the outcome of interest

5.4.4. Obstetric trauma

As with birth trauma, rates of obstetric trauma were higher among women with operative vaginal delivery compared with cesarean delivery, especially with forceps (Figure 5.6). For deliveries with dystocia, the associations between forceps and vacuum delivery and obstetric trauma were modified by pelvic station. There was a linear increase in the effect of vacuum delivery on obstetric trauma (AOR at outlet station 2.36, AOR at low station 2.91 and AOR at mid-pelvic station 3.35, P for linear trend in OR<0.0001; Table 5.2). Among women with fetal distress, the effect of operative vaginal delivery on obstetric trauma was not significantly modified by pelvic station (AOR at outlet station 4.70, AOR at low station 4.50 and AOR at mid-pelvic station 3.90, P for heterogeneity in OR 0.10; Table 5.3). The adjusted rate differences for forceps and vacuum delivery compared with cesarean delivery are listed in Table 5.4; NNTs for obstetric trauma following forceps delivery ranged from 3 to 5, while those for vacuum delivery ranged from 7 to 12 depending on pelvic station and indication.

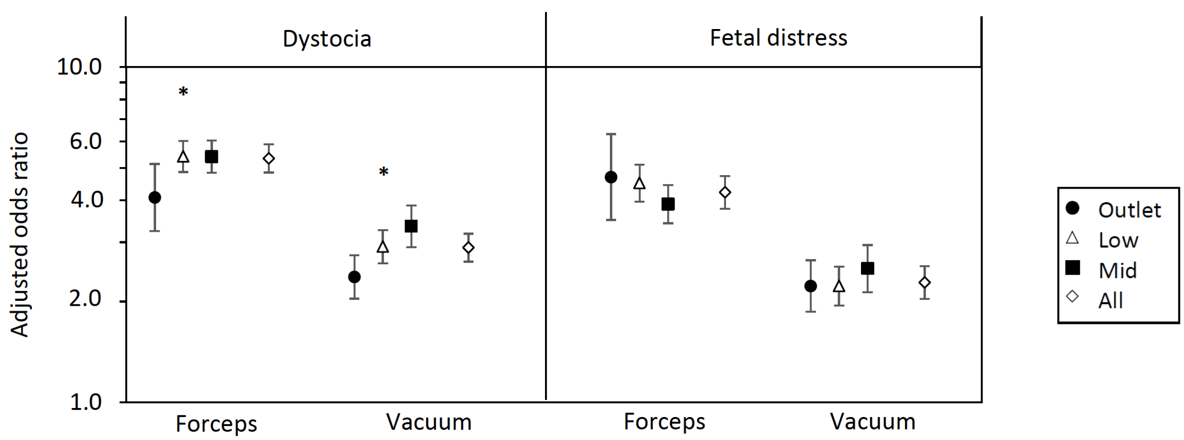

Figure 5.6. Adjusted odds ratios and 95% confidence intervals for obstetric trauma following forceps and vacuum delivery by pelvic station and indication, term singleton deliveries with a prolonged second stage of labour, Canada (excluding Quebec), 2003-2013.
Asterisks denote a P value of <0.05 (chi-square test for heterogeneity of the odds ratios, or trend in the odds ratios).

5.4.5. Severe perineal laceration

Rates of severe perineal lacerations were high (11% to 25%) among all operative vaginal deliveries, regardless of pelvic station (Figure 5.7). Among women with dystocia, the severe perineal laceration rate following forceps delivery was not affected by pelvic station. However, in the vacuum group, there was a positive linear trend in the rate of severe lacerations by station (Figure 5.6). Among deliveries with fetal distress, severe perineal laceration rates were lower following forceps at midpelvic station compared with low and outlet forceps (p for linear trend=0.0009). All P values for chi-square test for heterogeneity and linear trends in odds ratios and proportions are listed in Appendix Table 5.2. Rates of severe perineal laceration were higher in forceps deliveries without an episiotomy irrespective of indication. This pattern was not observed among vacuum deliveries (Appendix Figure 5.1).

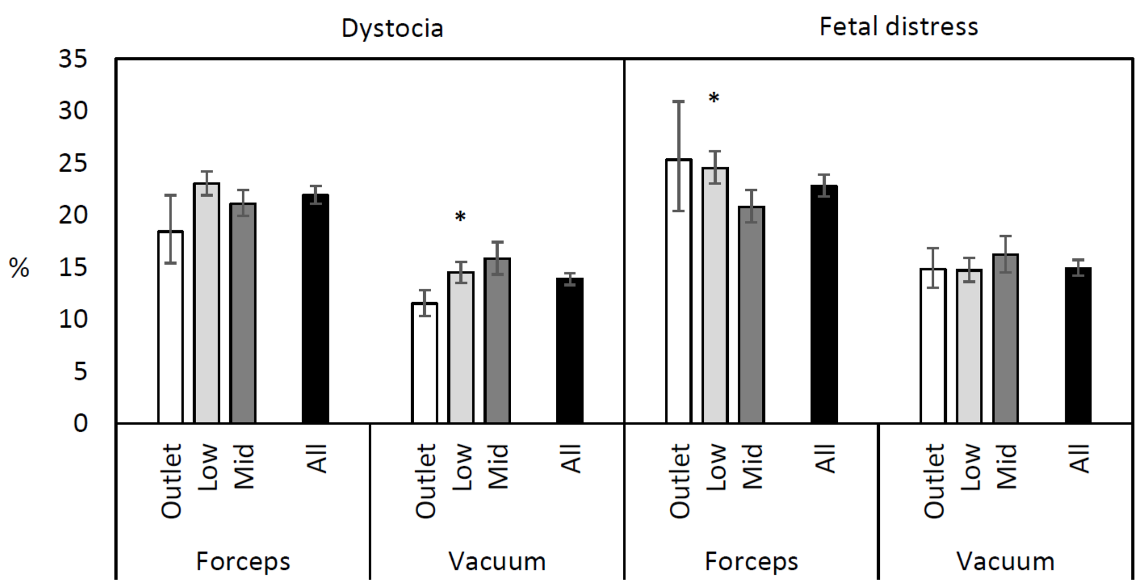

Figure 5.7. Rates of severe perineal lacerations and 95% confidence intervals for obstetric trauma following forceps and vacuum delivery by pelvic station and indication, term singleton deliveries with a prolonged second stage of labour, Canada (excluding Quebec), 2003-2013. Asterisks denote a P value of <0.05 for Cochran-Armitage test for a linear trend in proportions.

5.4.6. Subgroup and sensitivity analyses

Neither fiscal year nor type of practitioner (obstetrician vs non-obstetrician) modified the relationship between mode of delivery and any of the study outcomes. However, the association between operative vaginal delivery and outcome was modified by institutional delivery volume. Among women with dystocia, the AOR for severe maternal morbidity and mortality following forceps delivery was significantly lower in institutions with a high delivery volume (AOR 0.90) compared with institutions with a medium delivery volume (AOR 1.51, p for interaction=0.04; Appendix Table 5.3). Among deliveries with fetal distress, the same trend was observed for the AORs for birth trauma which were lower in high vs medium delivery volume institutions (P for interaction=0.03). The association between operative vaginal delivery and obstetric trauma was also dependent on institutional delivery volume, regardless of instrument or indication, with the lowest AORs in high volume institutions (P values for interaction< 0.001, Appendix Table 5.3).

Although adverse outcomes following failed operative vaginal delivery were substantially more frequent than adverse outcomes following successful operative vaginal delivery (data not shown), the inclusion of failed operative vaginal delivery attempts did not appreciably change the association between attempted (all) operative vaginal delivery and any of the study outcomes when compared with cesarean delivery (Appendix Table 5.4). Similarly, when sequential instrument application was included with vacuum delivery, there was no substantial change in the association between attempted vacuum delivery and adverse outcomes, although there was a consistent increase in the magnitude of the positive associations and a decrease in the magnitude of the negative associations. Lastly, among deliveries with fetal distress, failed trials of vacuum followed by an attempt at forceps delivery was associated with increased rates of severe perinatal morbidity and mortality, birth trauma, and obstetric trauma, compared with failed trials of vacuum followed by cesarean delivery (Appendix Table 5.5).

5.5. Discussion

Our study showed higher rates of severe perinatal morbidity and mortality following operative vaginal delivery compared with cesarean delivery among women with dystocia, although this association was not seen among women with fetal distress. Rates of birth trauma and severe birth trauma were significantly increased following operative vaginal delivery compared with cesarean delivery. Severe maternal morbidity and mortality rates were lower among women delivered by vacuum extraction compared with cesarean delivery for both dystocia and fetal distress. However, rates of obstetric trauma were significantly increased following forceps and vacuum delivery compared with cesarean delivery. Severe perineal laceration rates were high following operative vaginal delivery and constituted an important fraction of obstetric trauma. Some of the effects of operative vaginal delivery were modified by the pelvic station at which the procedure was carried out whereas other associations were not similarly affected.

Among deliveries with dystocia, the increased rates of severe perinatal morbidity and mortality in deliveries associated with forceps and vacuum were driven mainly by the increased rate of severe birth trauma, the commonest of which were subaponeurotic hemorrhage (among vacuum deliveries), and severe injury to the peripheral nervous system (brachial plexus injury; Appendix Table 5.6). Rates of severe birth trauma were also high following operative vaginal delivery among women with fetal distress, although this effect was matched by higher rates of assisted ventilation among women with fetal distress who delivered by cesarean.

Vacuum delivery was associated with a lower risk of severe maternal morbidity and mortality compared with cesarean delivery by approximately one third in deliveries with dystocia and by more than half in deliveries with fetal distress. The lower risks can be attributed to the higher rates of sepsis and cardiac complications among women delivered by cesarean (Appendix Table 5.6). Conversely, the rates of obstetric trauma were two to four-fold higher following vacuum deliveries compared with cesarean deliveries and more than one in 10 women delivered by vacuum extraction had a severe perineal laceration. Although rates of sepsis and cardiac complications following forceps delivery were also lower than rates following cesarean delivery, rates of severe postpartum hemorrhage were higher following forceps delivery (1.26% in forceps deliveries with dystocia, 1.23% in forceps deliveries with fetal distress; Appendix Table 5.6). Uterine atony was the major contributor to the higher rates of postpartum hemorrhage, however, increased rates of hemorrhage likely also reflect increased blood loss related to perineal and vaginal trauma.[126]

The rate of severe perineal laceration was 18.4% (95% CI 15.4%-21.9%) following outlet forceps among women with dystocia. This rate was 25.3% (95% CI 20.4%-30.9%) among women with fetal distress. The accuracy of these rates is supported by a validation study[91] which showed third- and fourth-degree laceration codes in the Discharge Abstract Database have a sensitivity and specificity of 97.1% and 99.9%, respectively. On the other hand, the relatively low rate of severe perineal laceration among women delivered by low and especially midpelvic forceps (compared with outlet forceps) was unexpected. One possible explanation involves misclassification of pelvic station, which can be challenging to ascertain. Also, litigation concerns surrounding midpelvic forceps delivery[22]may have led to a deliberate mislabeling of midpelvic forceps as low or outlet forceps. Alternatively, less experienced providers may avoid the use of forceps in higher stations, skewing the midpelvic results by more experienced providers.

High rates of severe perineal laceration following operative vaginal delivery, ranging from 14% to 45%, have been reported in previous studies[20,29,30,37,132-135] Operative vaginal delivery is an established risk factor for severe perineal laceration[136-138] and known to increase the risk of pelvic floor disorders in the five to 10 years after a first delivery.[139] Such high rates are concerning because severe perineal laceration can result in significant morbidity, including infection, incontinence, chronic pain, and loss of sexual function.[136,140,141] Issues related to the increased risk of anal sphincter trauma following operative vaginal delivery, and relevant long-term quality-of-life implications, should be carefully discussed with women considering operative vaginal delivery.

The strengths of our study include the use of a comprehensive database that included information on approximately 98% of births in Canada (excluding Quebec).[90] The restriction of the study population to women with a prolonged second stage ensured that the comparison between operative vaginal delivery and cesarean delivery was clinically meaningful. Also, the stratification of operative vaginal delivery by pelvic station was an additional strength. The limitations of our study include an inability to account for the skill of the operator. It is possible that birth and obstetric trauma associated with operative vaginal delivery is restricted to less experienced operators. This could potentially explain the modification of the effect of operative vaginal delivery by hospital volume. However, women delivering in hospital have little understanding of the relevant issues regarding expertise in operative vaginal delivery, and our data reflect the experience and skills of contemporary practitioners. I was limited by the inability to ascertain pelvic station in cesarean deliveries as the data source did not include such information. Since cesarean delivery is more likely carried out at midpelvic vs outlet station, our contrasts may have favoured the cesarean delivery group in the comparison with outlet procedures. On the other hand, at midpelvic station our estimates of the adverse effects of operative vaginal delivery likely represent underestimates of the true effect as some cesarean delivery would have been carried out with substantial descent of the fetal head.

Our study shows that operative vaginal delivery by forceps or vacuum among women with dystocia is associated with higher rates of severe perinatal morbidity, while vacuum delivery is associated with lower rates of severe maternal morbidity compared with cesarean delivery. The risks of severe birth trauma and obstetric trauma are substantially higher following operative vaginal delivery compared with cesarean delivery and such risks vary significantly by pelvic station. Encouraging operative vaginal delivery as an alternative to cesarean delivery without increasing skills in performing, and selecting candidates for such deliveries could result in increases in severe birth trauma and obstetric trauma. Consideration should be given to counselling women in the antepartum period about the risks of operative vaginal delivery and cesarean delivery.

Note: The results from the studies in Chapters 3 to 5 demonstrate consistently strong associations between operative vaginal delivery, at all pelvic stations, and obstetric and birth trauma. However, efforts to increase the use of operative vaginal delivery are already underway.[11,20] As a result, I estimated the population-level effects of increasing the rate of operative vaginal delivery on the rate of obstetric and birth trauma. Consequently, the last study in this dissertation, detailed in Chapter 6, used an ecological study design to quantify the population-level associations between these rates, and estimated the potential excess population burden of such trauma given increases in the rate of operative vaginal delivery.

Chapter 6: Ecological association between operative vaginal delivery and obstetric and birth trauma[5]

6.1. Synopsis

Background: The inverse relationship between population rates of operative vaginal delivery and cesarean delivery has led to recommendations for increasing operative vaginal delivery rates as a solution for addressing the high rates of cesarean delivery. However, recent studies evaluating the perinatal and maternal safety of operative vaginal delivery and cesarean delivery have shown higher rates of severe perinatal and maternal adverse outcomes following operative vaginal delivery, particularly obstetric trauma and severe birth trauma. Therefore, I carried out a study to determine the relationship between population rates of operative vaginal delivery and obstetric trauma and severe birth trauma.

Methods: Operative vaginal delivery, obstetric trauma and birth trauma frequencies among live born, term, singletons in four Canadian provinces were obtained using information from the Canadian Institute for Health Information between 2004 and 2014 (n=1,938,913). Stratification by parity and obstetric history yielded 132 province-years as units of analysis. The primary outcomes were obstetric trauma (e.g., severe perineal lacerations) and severe birth trauma (e.g., intracranial hemorrhage). Adjusted rate ratios (ARR) and 95% confidence intervals (CI) were estimated using ecological Poisson regression.

Results: The rate of obstetric trauma was 7.2% in nulliparous women, and 2.2% and 2.7% among parous women without and with a previous cesarean delivery, respectively, while

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[5] A version of this chapter is under review as Muraca GM, Lisonkova S, Skoll A, Brant R, Cundiff GW, Sabr Y, Joseph KS. (2018) Associations between rates of operative vaginal delivery, obstetric trauma, and birth trauma.

rates of severe birth trauma were 2.1%, 1.7% and 0.7%, respectively. Among nulliparous women, operative vaginal delivery rates were associated with obstetric trauma (ARR 1.06, 95% CI 1.05-1.06; i.e., a 1% absolute increase in operative vaginal delivery was associated with a 6% relative increase in obstetric trauma). This association was stronger in parous women, while ARRs were lower following vacuum compared with forceps delivery. The strongest associations were with sequential instrumentation (ARR 1.44, 95% CI 1.35–1.55 in nulliparous women). Operative vaginal delivery rates were also associated with severe birth trauma in nulliparous women (ARR 1.05, 95% CI 1.03-1.07).

Conclusion: Increases in population rates of operative vaginal delivery lead to significantly higher population rates of obstetric trauma, as well as severe birth trauma in nulliparous women.

6.2 Background and objectives

The increase in cesarean delivery over the past several decades has occurred concomitantly with a decline in operative vaginal deliveries. In the United States, operative vaginal delivery rates decreased from 9.4% in 1995 to 3.1% of all deliveries in 2015, whereas cesarean delivery rates increased from 20.8% to 32.0% over this period.[98,142] In Canada as well, rates of operative vaginal delivery followed the same downward trajectory from 16.8% of all vaginal deliveries in 1995 to 13.2% in 2014,[10,96] whereas cesarean delivery rates increased from 17.6% in 1995 to 27.3% in 2014. The inverse relationship between population rates of operative vaginal delivery and cesarean delivery has led to recommendations for increasing operative vaginal delivery rates as a solution for addressing the high rates of cesarean delivery.[11]

The recommendation to increase the operative vaginal delivery rate as a method of preventing increases in cesarean delivery is premised on the assumption that operative vaginal delivery has a similar or greater relative safety compared with cesarean delivery. However, recent studies[32,35,143,144] evaluating the perinatal and maternal safety of operative vaginal delivery and cesarean delivery have shown higher rates of severe perinatal and maternal adverse outcomes following operative vaginal delivery, particularly obstetric trauma and severe birth trauma. Further, these associations vary by operative instrument (forceps/vacuum/sequential instrumentation) and pelvic station (outlet/low-pelvic/midpelvic).

I carried out a study attempting to quantify the relationship between population rates of operative vaginal delivery and obstetric trauma and severe birth trauma.

6.3. Methods

The study was carried out on all hospital deliveries in four Canadian provinces, namely, Alberta, Manitoba, Ontario, and Saskatchewan, with data obtained from the Canadian Institute for Health Information's Discharge Abstract Database. Deliveries that occurred in the other provinces and territories in Canada were excluded because of a lack of detailed information on parity. Details on data abstraction, validity, and information contained in the Discharge Abstract Database has been described previously in the Methods section of Chapter 2.

All full term hospital deliveries between 37 and 41 weeks' gestation that resulted in a singleton live birth between April, 2004, and March, 2015 were included in the study (hereafter referred to as fiscal years 2004 to 2014). Operative vaginal deliveries were grouped into three categories based on pelvic station: outlet, low-pelvic, and midpelvic deliveries, defined based on the Classification According to Station and Rotation described in previous chapters.[38]

The two primary outcomes were obstetric trauma and severe birth trauma. Obstetric trauma included severe perineal lacerations (third- and fourth-degree), cervical and high vaginal lacerations, pelvic hematoma (perineum, vagina, or vulva), obstetric injury to the pelvic organs, pelvic joints or ligaments, injury to the bladder/urethra, laceration to the broad ligament of the uterus, extension of the uterine incision, wound dehiscence and other obstetric trauma. Severe birth trauma included intracranial hemorrhage and laceration, skull fracture, severe injury to the central or peripheral nervous system (i.e. brain damage or brachial plexus injury), fracture of the long bones, and injury to the liver or spleen. The inclusion and exclusion criteria, confounders, outcomes and other details are listed in Appendix Table 6.1.

Women were categorized by parity and obstetric history into three strata: nulliparous women, parous women without a previous cesarean delivery, and women with a previous cesarean delivery. Within each of these strata, temporal trends (by year) in obstetric and severe birth trauma by mode of delivery, operative instrument, and pelvic station were assessed using the Cochran-Armitage test for linear trend in proportions and by comparing rates in 2014 with those in 2004. Adjusted rate ratios (ARR) and 95% confidence intervals (CI) were estimated using ecological random-intercept Poisson regression models to quantify associations between operative vaginal delivery rates and the frequency of obstetric trauma and severe birth trauma. Stratified analyses were used to quantify the effects of instruments (forceps, vacuum, sequential instrumentation) and the pelvic station at which the operative vaginal delivery was attempted, while adjusting for confounders, namely, maternal age, hypertensive disorders, diabetes, labour induction and macrosomia. Each province-year represented one unit of analysis resulting in 44 units in each of the three strata (n=132). The number of cases of obstetric trauma (or severe birth trauma) in each province-year served as the outcome and these were offset by the number of live births in that province-year. All analyses were conducted using SAS version 9.4 for Windows (SAS Institute Inc., Cary, NC). Ethics approval for the study was obtained from the Clinical Research Ethics Board at the University of British Columbia.

6.4. Results

The study population included 1,938,913 singleton, term deliveries within 132 province-year units stratified based on parity and obstetric history. The rate of obstetric trauma was 7.2% among nulliparous women, 2.2% among parous women without a previous cesarean delivery, and 2.7% among women with a previous cesarean delivery, while the rate of severe birth trauma was 2.1, 1.7, and 0.7 per 1000 deliveries in the three groups, respectively (Table 6.1). Most cases of obstetric trauma were due to severe perineal laceration (71.0%; Appendix Table 6.2), while severe birth trauma was mostly due to brachial plexus injury (69.9%; Appendix Table 6.3). Details of the associations between maternal and other characteristics and obstetric and severe birth trauma are shown in Table 6.1. The rates of operative vaginal delivery and cesarean delivery were 18.2% and 26.6%, respectively, in nulliparous women, 5.5% and 6.7%, respectively, in parous women with no previous cesarean delivery, and 3.4% and 81.9% in women with a previous cesarean delivery (Appendix Table 6.4).

6.4.1. Temporal trends in obstetric trauma

Among nulliparous women, the overall rate of obstetric trauma increased significantly from 6.6% deliveries in 2004 to 7.2% in 2014 (P <0.01; Figure 6.1A). Among operative vaginal deliveries to nulliparous women, the obstetric trauma rate increased significantly from 16.6% to 19.4% (P<0.001; Figure 6.1B). Obstetric trauma rates stratified by operative instrument (Figure 6.1C) and by pelvic station (Figure 6.1D) showed that the greatest increases occurred among forceps deliveries (19.4% in 2004 and 26.5% in 2014; P<0.001) and at low-pelvic station (15.6% to 20.9%; P<0.001).

The rate of obstetric trauma decreased non-significantly in parous women with no previous cesarean delivery (P value= 0.09; Figure 6.2A), while the same rate increased among parous women with no cesarean delivery who had an operative vaginal delivery (from 6.8% in 2004 to 7.4% in 2014; Figure 6.2B). The largest increase was observed among such parous women with forceps delivery (Figure 6.2C).

The overall rate of obstetric trauma among parous women with a previous cesarean delivery increased non-significantly (P value 0.06; Figure 6.3A); a significant increase occurred among such women who had an operative vaginal delivery (13.8% in 2004 to 18.7% in 2014; $P<0.001$; Figure 6.3B). The largest increase in obstetric trauma occurred among women with a forceps delivery: from 16.6% in 2004 to 25.6% in 2014 ($P<0.001$; Figure 6.3C).

6.4.2. Temporal trends in severe birth trauma

Overall rates of severe birth trauma did not change appreciably over the study period in nulliparous or parous women (Figures 6.4, 6.5A, 6.6A). However, among nulliparous women who had an operative vaginal delivery, the rate of severe birth trauma increased significantly (from 4.5 in 2004 to 6.8 per 1000 deliveries in 2014; $P=0.03$; Figure 6.4B). Such trauma also increased among parous women without a previous cesarean delivery (from 6.5 to 10.6 per 1000 deliveries; $P<0.01$; Figure 6.5B). In nulliparous women, the increase in severe birth trauma was most pronounced among forceps deliveries (7.4 in 2004 and 14.3 per 1000 deliveries in 2014; Figure 6.4C) and operative vaginal deliveries at outlet station (2.1 to 9.2 per 1000 deliveries; Figure 6.4D). Temporal increases in severe birth trauma by operative instrument and pelvic station were not significant among parous women (Figure 6.5C, 6.5D, 6.6C and 6.6D).

Table 6.1. Distribution of obstetric trauma and severe birth trauma by maternal, obstetric and infant characteristics, term singletons, Canada*, 2004-2014 (n=1 938 913)

Maternal/obstetric/infant characteristic	Number of women /infants	Women with obstetric trauma		P-value	Infants with severe birth trauma		P-value
		No.	Rate (%)		No.	Rate (‰)	
Nulliparous	839 772	60 472	7.2		1 728	2.1	
Advanced maternal age (≥35 yrs)				<0.001			0.22
Yes	95 769	6 615	6.9		181	1.9	
No	744 003	53 857	7.2		1 547	2.1	
Hypertensive disorders				<0.001			<0.001
Yes	59 808	4 017	6.7		214	3.6	
No	779 964	56 455	7.2		1 514	1.9	
Diabetes				0.80			<0.001
Yes	37 697	2 727	7.2		170	4.5	
No	802 075	57 745	7.2		1 558	1.9	
Labour induction				0.01			<0.001
Yes	237 192	17 353	7.3		693	2.9	
No	602 580	43 119	7.2		1 035	1.7	
Macrosomia (>4 000 g)				<0.001			<0.001
Yes	88 068	8 584	9.8		636	7.2	
No	751 704	51 888	6.9		1 092	1.5	
Parous (no previous CD)	834 616	18 116	2.2		1 459	1.7	
Advanced maternal age (≥35 yrs)				<0.001			<0.001
Yes	187 413	4 694	2.5		387	2.1	
No	647 203	13 422	2.1		1 072	1.7	
Hypertensive disorders				0.41			<0.001
Yes	30 839	690	2.2		107	3.5	
No	803 777	17 426	2.2		1 352	1.7	
Diabetes				<0.001			<0.001
Yes	42 471	1 062	2.5		264	6.2	
No	792 145	17 054	2.2		1 195	1.5	
Labour induction				<0.001			<0.001
Yes	197 202	4 632	2.4		524	2.7	
No	637 414	13 484	2.1		935	1.5	
Macrosomia (>4 000 g)				<0.001			<0.001
Yes	118 908	4 344	3.7		914	7.7	
No	715 708	13 772	1.9		545	0.8	
Parous (previous CD)	264 525	7 254	2.7		179	0.7	
Advanced maternal age (≥35 yrs)				<0.001			0.67
Yes	80 305	1 963	2.4		57	0.7	
No	184 20	5 291	2.9		122	0.7	
Hypertensive disorders				0.02			0.30
Yes	9 469	223	2.4		9	1.0	
No	255 056	7 031	2.8		170	0.7	
Diabetes				<0.001			<0.001
Yes	245 130	442	2.3		26	1.3	
No	19 395	6 812	2.8		153	0.6	
Labour induction				<0.001			<0.001
Yes	11 703	788	6.7		21	1.8	
No	252 822	6 466	2.6		158	0.6	
Macrosomia (>4 000 g)				<0.001			<0.001
Yes	31 969	1 099	3.4		70	2.2	
No	232 556	6 155	2.7		109	0.5	

* Includes data from Alberta, Manitoba, Ontario, and Saskatchewan. CD, cesarean delivery.

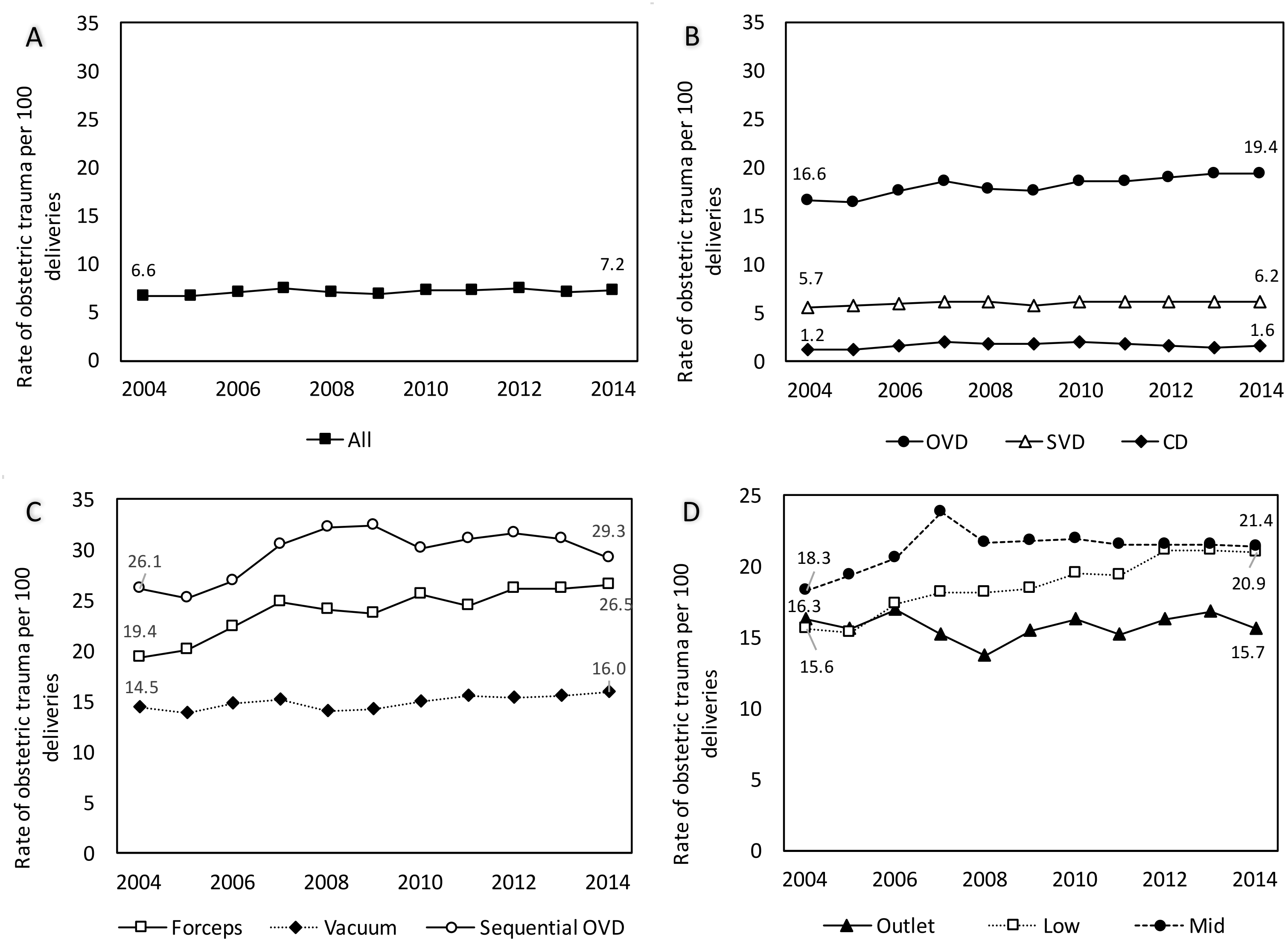


Figure 6.1. Temporal trends in obstetric trauma overall (A), stratified by mode of delivery (B), stratified by operative instrument (C), and stratified by pelvic station (D) among singleton term deliveries to nulliparous women, Canada, 2004-2014. OVD, operative vaginal delivery; SVD, spontaneous vaginal delivery; CD, cesarean delivery.

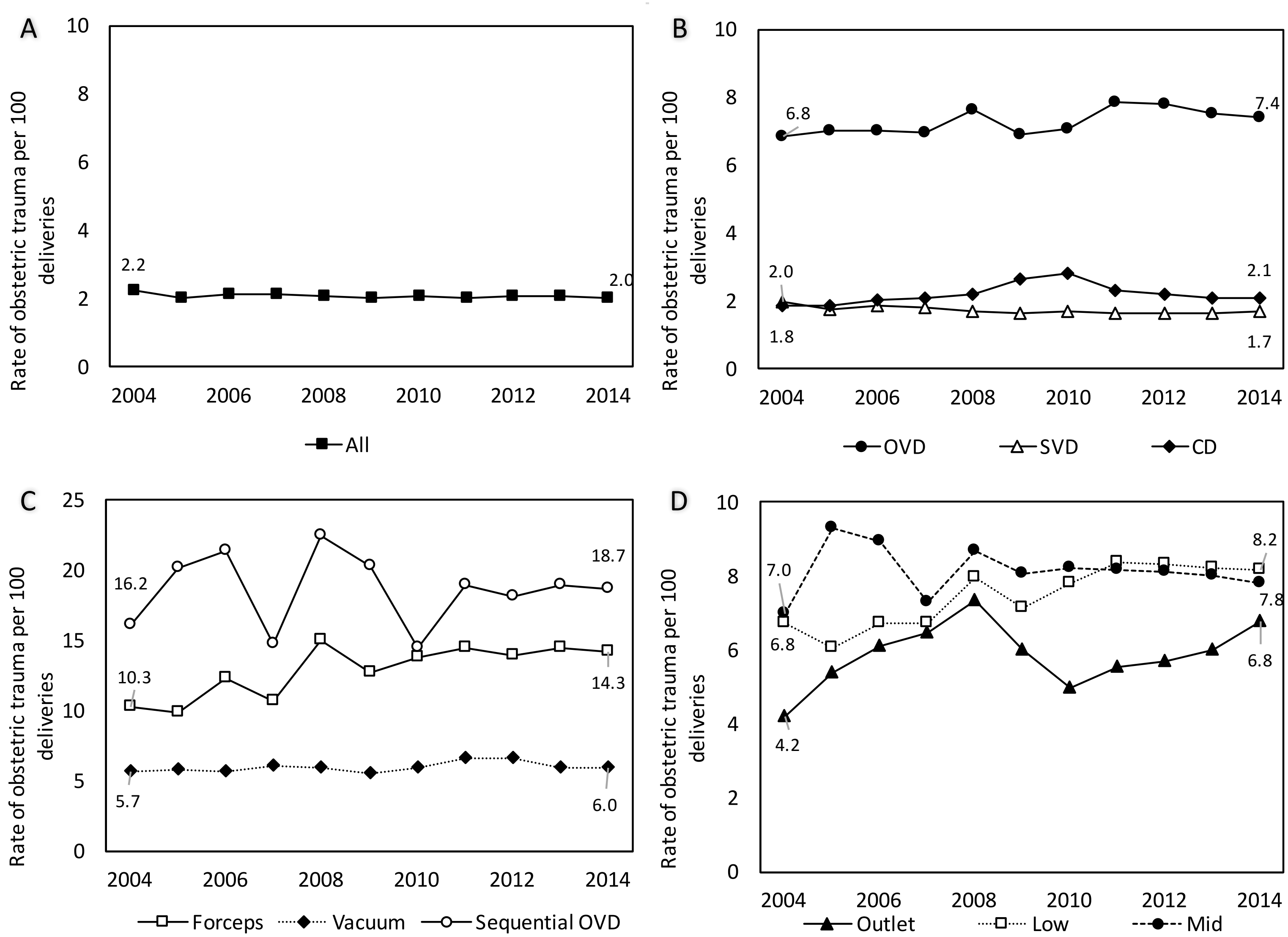


Figure 6.2. Temporal trends in obstetric trauma overall (A), stratified by mode of delivery (B), stratified by operative instrument (C), and stratified by pelvic station (D) among singleton term deliveries to parous women without a previous cesarean delivery, Canada, 2004-2014. OVD, operative vaginal delivery; SVD, spontaneous vaginal delivery; CD, cesarean delivery.

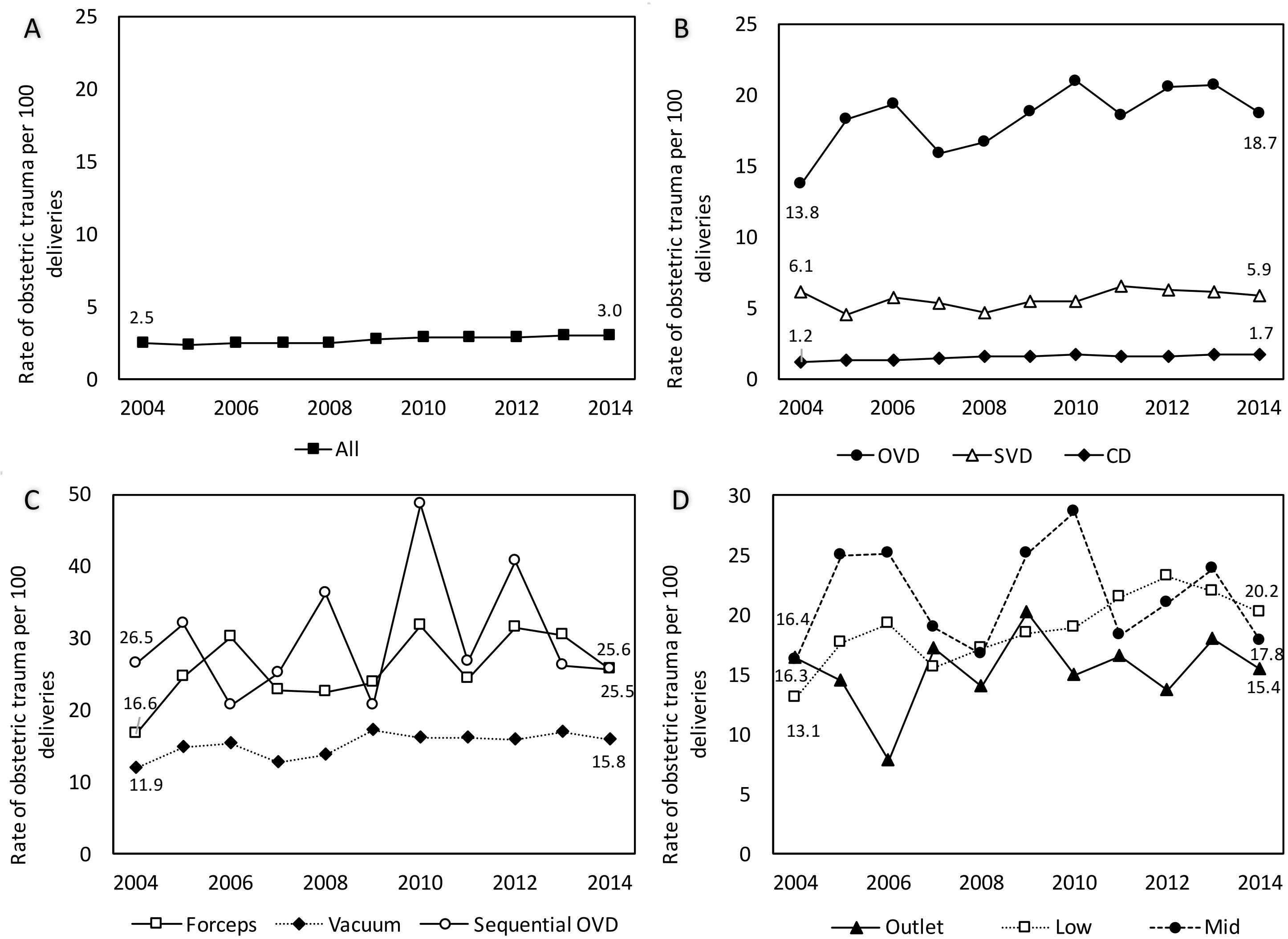


Figure 6.3. Temporal trends in obstetric trauma overall (A), stratified by mode of delivery (B), stratified by operative instrument (C), and stratified by pelvic station (D) among singleton term deliveries to women with a previous cesarean delivery, Canada, 2004-2014. OVD, operative vaginal delivery; SVD, spontaneous vaginal delivery; CD, cesarean delivery.

6.4.3. Association between operative vaginal delivery and obstetric trauma

In nulliparous women, the rate of operative vaginal delivery was positively associated with obstetric trauma (ARR 1.06, 95% CI 1.05-1.06; Table 6.2). This association was significantly stronger in parous women with or without a previous cesarean delivery (ARRs 1.10, 95% CI 1.08-1.13 and 1.11, 95% CI 1.07-1.16, respectively), as compared with nulliparous women.

The ARR expressing the association between the rate of forceps and obstetric trauma in nulliparous women was 1.09 (95% CI 1.08-1.10), while the ARR for vacuum delivery was 1.06 (95% CI 1.05-1.07). The greatest relative increase in obstetric trauma was associated with sequential instrumentation in nulliparous women (ARR 1.44, 95% CI 1.35–1.55).

Among parous women, the ARRs for the association between forceps/vacuum and obstetric trauma were similar to those in nulliparous women. However, the associations were relatively stronger for forceps deliveries in parous women without a previous cesarean delivery (ARR 1.26, 95% CI 1.10-1.43) and vacuum deliveries in women with a previous cesarean delivery (ARR 1.16, 95% CI 1.11-1.22). Deliveries following the use of sequential instruments were not significantly associated with the obstetric trauma rate in either group of parous women.

Operative vaginal deliveries at outlet, low-pelvic, and midpelvic station were positively associated with obstetric trauma in nulliparous women (Table 6.2). A similar pattern was seen in the associations between the outlet, low and midpelvic operative vaginal delivery rates and obstetric trauma among parous women (Table 6.2).

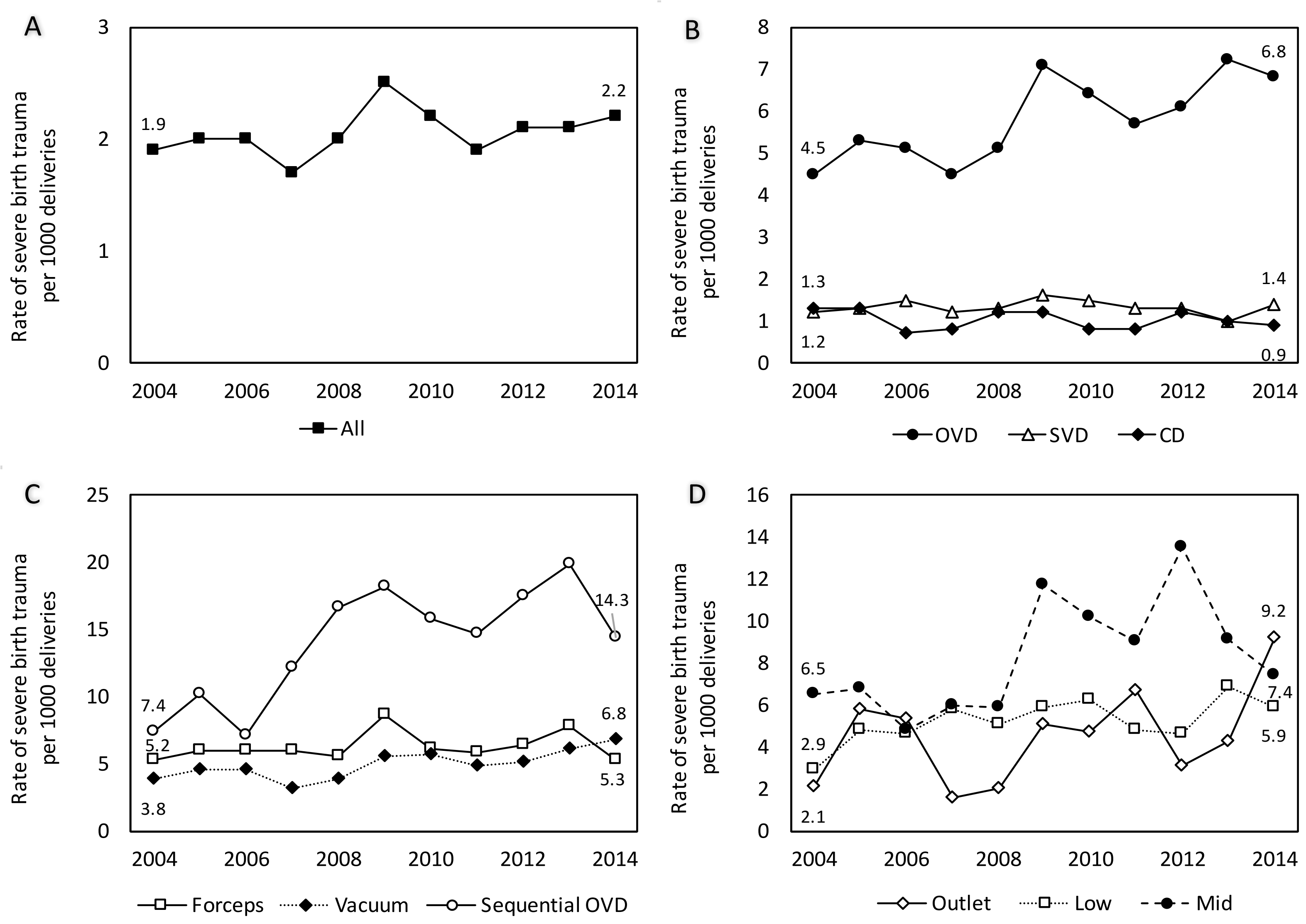


Figure 6.4. Temporal trends in severe birth trauma overall (A), stratified by mode of delivery (B), stratified by operative instrument (C), and stratified by pelvic station (D) among singleton term deliveries to nulliparous women, Canada, 2004-2014. OVD, operative vaginal delivery; SVD, spontaneous vaginal delivery; CD, cesarean delivery.

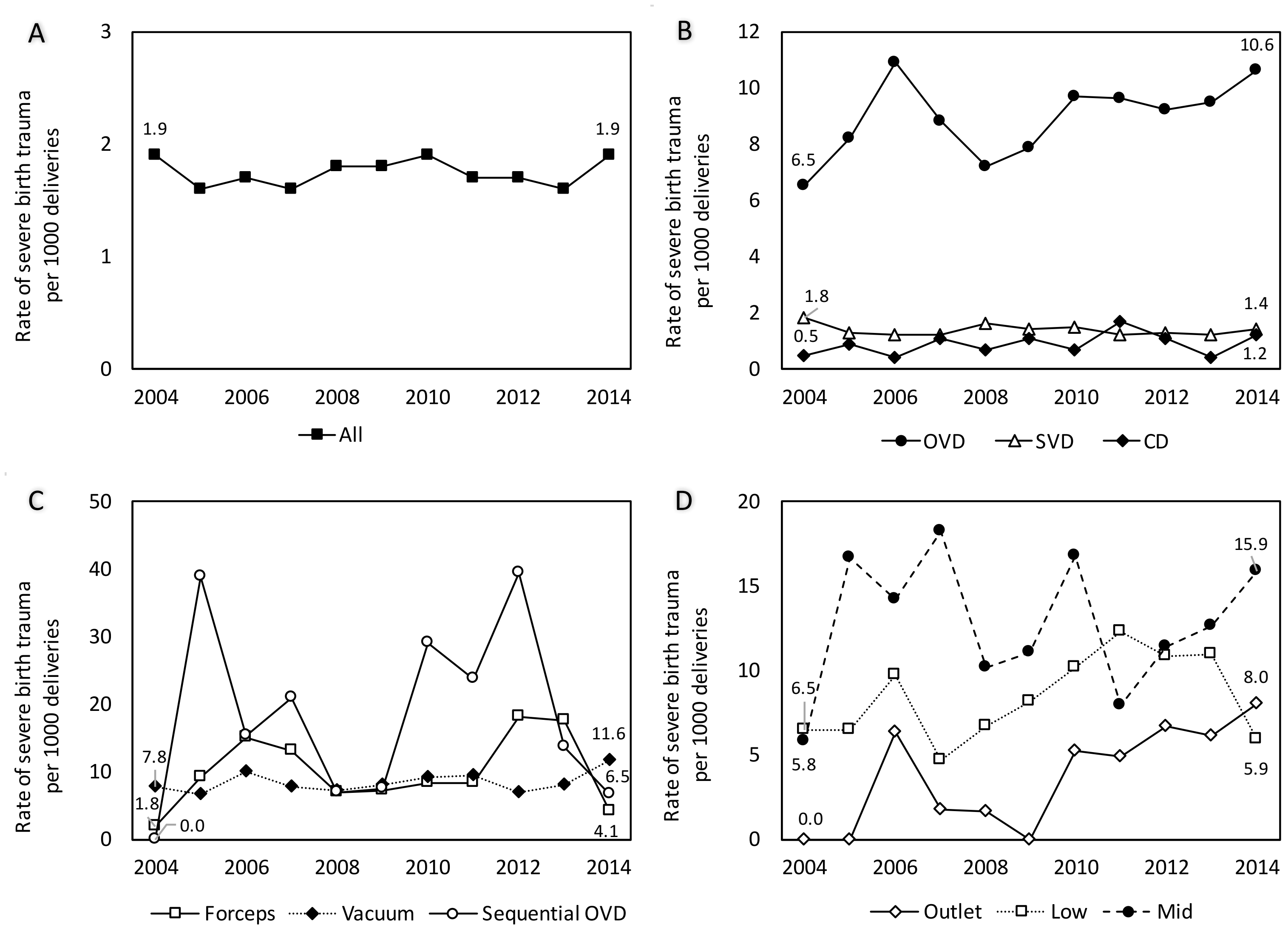


Figure 6.5. Temporal trends in obstetric trauma overall (A), stratified by mode of delivery (B), stratified by operative instrument (C), and stratified by pelvic station (D) among singleton term deliveries to women with a previous cesarean delivery, Canada, 2004-2014. OVD, operative vaginal delivery; SVD, spontaneous vaginal delivery; CD, cesarean delivery.

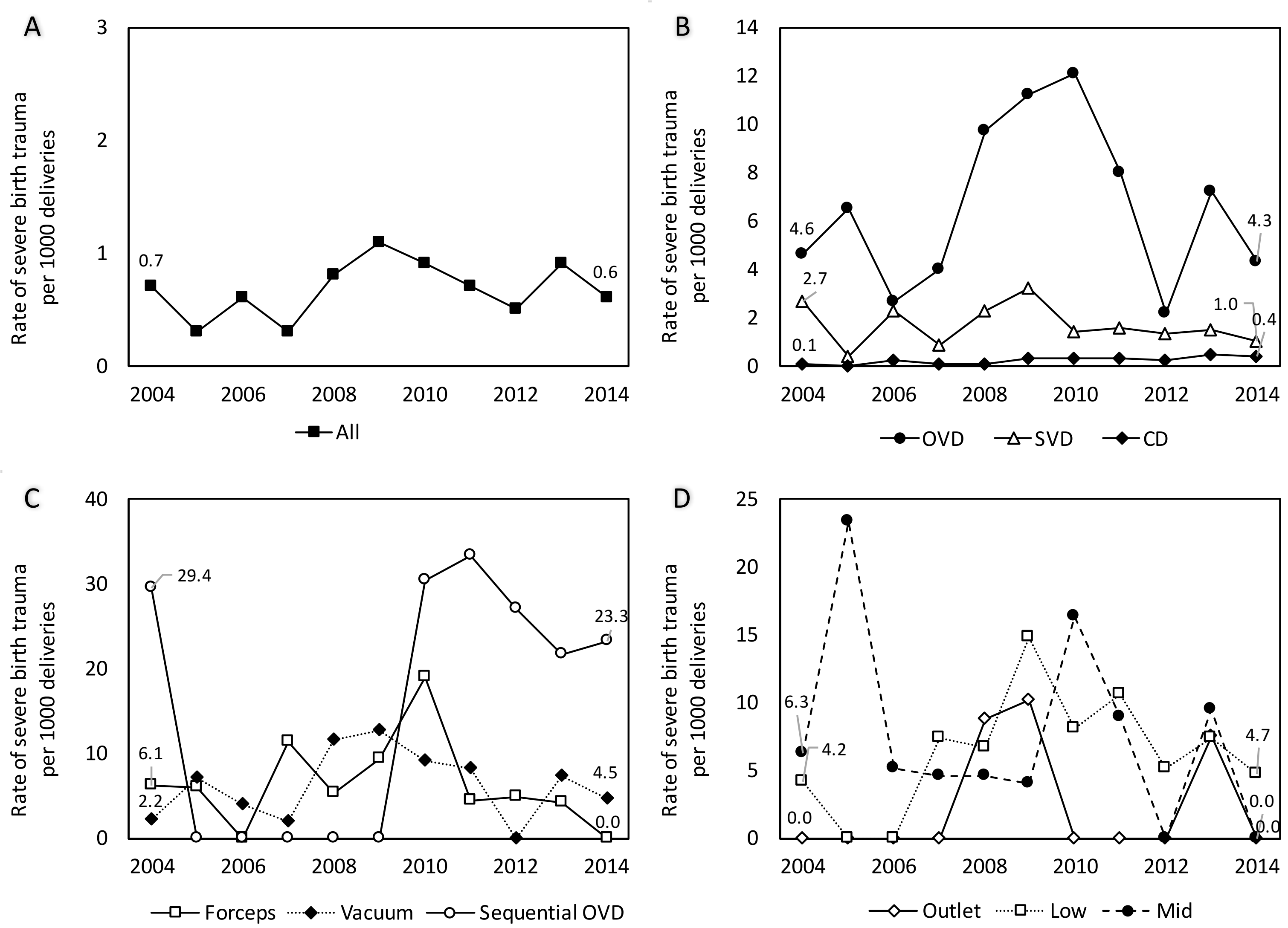


Figure 6.6. Temporal trends in severe birth trauma overall (A), stratified by mode of delivery (B), stratified by operative instrument (C), and stratified by pelvic station (D) among singleton term deliveries to parous women without a previous cesarean delivery, Canada, 2004-2014. OVD, operative vaginal delivery; SVD, spontaneous vaginal delivery; CD, cesarean delivery.

Table 6.2. Crude and adjusted rate ratios (ARR) and 95% confidence intervals (CI) expressing the change in obstetric trauma rates per 1% absolute increase in operative vaginal delivery rates, term singleton deliveries, Canada*, 2004-2014

	Nulliparous		Parous			
			No previous cesarean		With a previous cesarean	
	ARR	95% CI	ARR	95% CI	ARR	95% CI
All OVD	1.06	1.05-1.06	1.10	1.08-1.13	1.11	1.07-1.16
Forceps	1.09	1.08-1.10	1.26	1.10-1.43	1.11	1.00-1.25
Vacuum	1.06	1.05-1.07	1.05	1.03-1.08	1.16	1.11-1.22
Sequential	1.44	1.35-1.55	1.19	0.84-1.67	0.95	0.83-1.09
Outlet station	1.07	1.06-1.09	1.22	1.14-1.30	1.17	1.04-1.31
Low-pelvic station	1.04	1.03-1.05	0.98	0.93-1.03	1.02	0.94-1.11
Midpelvic station	1.07	1.07-1.08	1.14	1.12-1.17	1.25	1.20-1.30

*Includes data from Alberta, Manitoba, Ontario, and Saskatchewan.
OVD, operative vaginal delivery. Crude and adjusted rate ratios were obtained from ecological random-intercept Poisson regression models.
Adjusted for older maternal age (≥35 years of age), hypertension, diabetes, labour induction and macrosomia.

For the study period 2004-2014, the relative increase in the obstetric trauma rate per 1% increase in the operative vaginal delivery rate was equivalent to a 0.43% absolute increase in obstetric trauma rates among nulliparous women, a 0.22% absolute increase among parous women without a previous cesarean delivery and a 0.30% absolute increase among women with a previous cesarean delivery (Table 6.3). Calculations based on the number of full term, singleton live births in Canada in 2015-2016[13] showed that a 1% increase in the rate of operative vaginal delivery would result in approximately 708 excess cases of obstetric trauma per year in nulliparous women, 360 excess cases of obstetric trauma among parous women without a previous cesarean delivery and 158 excess cases of obstetric trauma among women with a previous cesarean delivery (Table 6.3).

Table 6.3. Absolute percent increase in the obstetric trauma rate and number of excess cases of obstetric trauma per year per 1% absolute increase in operative vaginal delivery rates, term singletons deliveries, Canada*, 2004-2014

	Obstetric trauma increase – Nulliparous women		Obstetric trauma increase – Parous women			
			No previous cesarean		With a previous cesarean	
	Absolute % increase	No. of excess cases/year	Absolute % increase	No. of excess cases/year	Absolute % increase	No. of excess cases/year
All OVD rate	0.43	708	0.22	360	0.30	158
Forceps rate	0.65	1 061	0.57	937	0.30	158
Vacuum rate	0.43	708	0.11	180	0.43	230
Sequential rate	3.17	5 189	-	-	-	-
Outlet OVD rate	0.50	825	0.48	793	0.46	245
Low-pelvic OVD rate	0.29	472	-	-	-	-
Midpelvic OVD rate	0.50	825	0.31	504	0.68	360

*Includes data from Alberta, Manitoba, Ontario, and Saskatchewan.
OVD, operative vaginal delivery.

6.4.4. Association between operative vaginal delivery and severe birth trauma

Operative vaginal delivery rates were positively associated with severe birth trauma only in nulliparous women (ARR 1.05, 95% CI 1.03-1.07; Table 6.4). Pelvic station-specific operative vaginal delivery rates were positively associated with severe birth trauma at low-pelvic station (ARR 1.06, 95% CI 1.01-1.12) and midpelvic station (ARR 1.04, 95% CI 1.01-1.07). However, these associations were significant only in nulliparous women (Table 6.4).

During the study period, the absolute increase in the rate of severe birth trauma per 1% increase in the operative vaginal delivery rate was 0.11 per 1000 deliveries to nulliparous women. Calculations based on the number of full term, singleton live births in Canada in 2015-2016[13] showed that this would result in approximately 18 excess cases of severe birth trauma annually[145] (Table 6.5).

Table 6.4. Crude and adjusted rate ratios (ARR) and 95% confidence intervals (CI) expressing the change in severe birth trauma rates per 1% absolute increase in operative vaginal delivery rates, term singleton deliveries, Canada*, 2004-2014

	Nulliparous		Parous without a previous cesarean		Parous with a previous cesarean	
	ARR	95% CI	ARR	95% CI	ARR	95% CI
All OVD rate	1.05	1.03-1.07	0.98	0.94-1.04	1.02	0.85-1.22
Forceps rate	1.01	0.95-1.08	1.09	0.68-1.76	0.86	0.37-2.00
Vacuum rate	0.97	0.90-1.04	0.96	0.89-1.04	1.25	0.91-1.72
Sequential rate	1.53	1.03-2.27	2.00	0.58-6.86	0.47	0.17-1.27
Outlet OVD rate	1.03	0.96-1.10	0.91	0.71-1.15	1.27	0.58-2.80
Low-pelvic OVD rate	1.06	1.01-1.12	1.18	0.98-1.43	0.87	0.49-1.55
Midpelvic OVD rate	1.04	1.01-1.07	0.94	0.87-1.02	1.12	0.82-1.53

*Includes data from Alberta, Manitoba, Ontario, and Saskatchewan.
OVD, operative vaginal delivery. Crude and adjusted rate ratios were obtained from ecological random-intercept Poisson regression models. Adjusted for rates of older maternal age (≥35 years of age), hypertension, macrosomia, and labour induction.

Table 6.5. Absolute per mille increase in the severe birth trauma rate and number of excess cases of severe birth trauma per year per 1% absolute increase in operative vaginal delivery rates, term singletons deliveries, Canada*, 2004-2014

	Nulliparous	
	Absolute ‰ increase	No. of excess cases/year
All OVD rate	0.11	18
Forceps rate	-	-
Vacuum rate	-	-
Sequential rate	1.11	191
Outlet OVD rate	-	-
Low-pelvic OVD rate	0.13	22
Midpelvic OVD rate	0.08	14

*Includes data from Alberta, Manitoba, Ontario, and Saskatchewan.
OVD, operative vaginal delivery.
Calculations based on the number of full term, singleton live births in Canada in 2015-2016.[13]

6.5. Discussion

Our study showed positive associations between the rate of operative vaginal delivery and obstetric trauma after adjustment for known confounders, with effects ranging from a 6% to 11% increase in obstetric trauma per 1% absolute increase in population rates of operative vaginal deliveries. The associations between operative vaginal delivery and obstetric trauma were significantly stronger among parous women with no previous cesarean delivery (ARR of 1.10, 95% CI 1.08-1.13) and among parous women with a previous cesarean delivery (ARR 1.11, 95% CI 1.07-1.16) compared with associations among nulliparous women (ARR 1.06, 95% CI 1.05-1.06). The rate of operative vaginal delivery was positively associated with severe birth trauma in nulliparous women but not in parous women.

The rates of obstetric trauma in our study are consistent with rates reported from other provinces of Canada[146] as well as the United Kingdom[147] where operative vaginal delivery rates are similar to those in Canada. The temporal increase in obstetric trauma observed in this study did not parallel obstetric trauma trends in the United States; for instance, the obstetric trauma rate in Washington State decreased from 6.7% in 1987 to 2.5% in 2009, while the operative vaginal delivery rate declined from 6.3% to 3.9% over the same period.[148] The increase in obstetric trauma among operative vaginal deliveries in our population occurred despite an 11% decline in the rate of operative vaginal delivery in Canada over the study period.[109] The increase in adverse maternal outcomes in our study suggests that the safety of operative vaginal procedures is declining in Canada, especially following forceps use, likely due to a decline in expertise or due to poor selection of candidates for operative vaginal delivery.[22]

Third- and fourth-degree perineal lacerations represented 86.3% of the obstetric trauma cases among women with operative vaginal delivery (Appendix Table 6.2). Quality-of-life impairments following these severe lacerations include perineal pain, dyspareunia and sexual dysfunction, abscess formation, wound breakdown, and rectovaginal fistulae.[149] Perhaps the most disabling complication following a severe perineal laceration is anal incontinence. Third- or fourth-degree perineal laceration is the most common cause of anorectal symptoms in women.[150] The reported rates of anal incontinence following the primary repair of a severe perineal laceration range between 15% and 61%, with a mean of 39%[150] and these rates increase with time up to 54% at 3-8 years following delivery.[151] However, various hygienic, social, and psychological issues associated with anal incontinence make it difficult for women to be forthcoming about such issues. This has resulted in an under-recognition of the true burden of anal incontinence related to severe perineal laceration and a neglect of the serious psychosocial consequences of this condition. Moreover, there is accumulating evidence of a positive association between the rate of operative vaginal delivery and subsequent rates of surgery for pelvic organ prolapse.[148] Although, the relationship between operative vaginal delivery and obstetric anal sphincter injury is well established,[150] the benefit versus risk profile of operative vaginal delivery may require reevaluation in the light of evidence regarding the long-term effects of severe perineal laceration.

The limitations of our study include those that are typical of large database studies. Although the Discharge Abstract Database has standardized processes and data quality monitoring procedures, has been validated[92,94] and no significant coding changes occurred during the study period, data transcription errors may have occurred. Also, our analyses were based on an ecological design and the quantified relationships are susceptible to the ecological fallacy. However, an ecological design is appropriate for assessing associations at the population level,[152,153] and clinical observation and individual-level studies show that operative vaginal deliveries are in fact more likely to cause obstetric and birth trauma.[32,35,143,144] Finally, I was not able to adjust for differences in maternal characteristics, such as pre-pregnancy obesity, on which our data source lacked information.

In conclusion, there is a positive association between the population rate of operative vaginal delivery and population rates of obstetric trauma, and severe birth trauma in nulliparous women. Recommendations to reduce cesarean delivery rates by increasing rates of operative vaginal delivery should be tempered by the understanding that such actions will result in higher rates of obstetric trauma.

Chapter 7: Discussion

7.1. Summary of findings

Current recommendations to expand the use of operative vaginal delivery in an effort to reduce the rate of cesarean delivery assume that operative vaginal delivery is a safe alternative to cesarean delivery. However, the lack of relevant, rigorous studies comparing perinatal and maternal outcomes in operative vaginal and cesarean deliveries has made it difficult to draw robust conclusions about the relative safety of these interventions. (Chapter 1)

In Canada, as in most industrialized countries, the operative vaginal delivery rate has declined in recent decades. However, the study of mode of delivery trends in Chapter 2 demonstrated that the temporal changes in operative vaginal delivery rates between 2003 and 2012 were dependent on pelvic station, with rates of operative vaginal delivery at the outlet and low stations increasing significantly and rates of midpelvic operative vaginal delivery declining significantly. The decrease in operative vaginal delivery rate was driven chiefly by decreases in the rate of midpelvic forceps deliveries. The vacuum delivery rate increased at outlet and low stations but not at midpelvic station. There are wide variations in operative vaginal delivery rates among Canadian provinces and territories at all pelvic stations, suggesting large variations in instrument preference and/or an evolution in standards of practice. The variation in the rates of operative vaginal delivery across Canada is indicative of a lack of healthcare quality and highlights the need for outcome-based evidence to inform practice guidelines on optimal delivery options for women requiring these interventions. (Chapter 2)

The studies presented in Chapters 3 and 4 provided estimates of severe perinatal and maternal morbidity/mortality among full term, singleton deliveries in the second stage of labour based on mode of delivery. Among deliveries with dystocia, attempted midpelvic operative vaginal delivery was associated with an increased risk of severe perinatal morbidity/mortality compared with cesarean delivery, while severe maternal morbidity/mortality was similar following either mode of delivery. In deliveries with fetal distress, the results were less consistent. The pan-Canadian study reported in Chapter 3 showed that attempted sequential midpelvic instrument use was associated with higher rates of severe perinatal morbidity/mortality and attempted midpelvic vacuum delivery was associated with lower rates of severe maternal morbidity/mortality. On the other hand, the study based on data from British Columbia (presented in Chapter 4) showed that attempted midpelvic vacuum was associated with higher rates of severe perinatal morbidity/mortality compared with cesarean delivery and severe maternal morbidity/mortality rates were higher after attempted midpelvic forceps than after cesarean delivery. (Chapters 3 and 4)

Attempted midpelvic operative vaginal delivery, regardless of instrument(s) used or indication, was consistently associated with substantially higher rates of severe birth trauma and obstetric trauma compared with cesarean delivery. Delivery with attempted sequential midpelvic instruments was associated with the highest rates of severe birth trauma, particularly when the indication for operative delivery was fetal distress. Severe perineal lacerations were high following all operative vaginal delivery, irrespective of indication or instrument(s) used (Chapters 3 and 4).

The study reported in Chapter 5 showed that operative vaginal delivery at all pelvic stations (outlet, low, and midpelvic) was associated with higher rates of severe perinatal morbidity/mortality compared with cesarean delivery among women with dystocia, but not among women with fetal distress. Severe maternal morbidity/mortality rates were lower among women delivered by vacuum compared with cesarean delivery for both dystocia and fetal distress. The rate of severe maternal morbidity/mortality was similar after forceps and cesarean delivery. Rates of birth trauma, severe birth trauma, and obstetric trauma were significantly increased after operative vaginal delivery compared with cesarean delivery. Again, severe perineal laceration rates were notably high after operative vaginal delivery, even at outlet pelvic station. The effect of operative vaginal delivery on birth and obstetric trauma was modified by the pelvic station at which the procedure was carried out, whereas other associations were not similarly affected. (Chapter 5)

The ecological modeling in Chapter 6 demonstrated that the rate of operative vaginal delivery was positively associated with the rate of obstetric trauma after adjustment for known confounders. Specifically, a 1% increase in the operative vaginal delivery rate in Canada may result in over 700 additional cases of obstetric trauma per year among nulliparous women. The associations between operative vaginal delivery and obstetric trauma were significantly stronger among parous women, with or without a previous cesarean delivery when compared with associations among nulliparous women. The same modeling showed that the rate of operative vaginal delivery was positively associated with severe birth trauma in nulliparous women but not in parous women. Severe perineal lacerations accounted for 87% of the cases of obstetric trauma among operative vaginal deliveries in this study. The increased frequency of severe perineal lacerations is likely to cause substantial future morbidity for women as such injury is the primary modifiable risk factor for anal incontinence and are strongly associated with pelvic organ prolapse, one of the most common indications for gynaecologic surgery. (Chapter 6)

Table 7.1 summarizes the results from the comparative analyses of perinatal and maternal morbidity/mortality among operative vaginal and cesarean deliveries. (Chapters 3-6)

Table 7.1. Summary of results from analyses comparing perinatal and maternal morbidity and mortality among operative vaginal deliveries and cesarean deliveries

Population	Setting	No. of deliveries	Perinatal morbidity/mortality	Maternal morbidity/mortality	Severe birth trauma	Obstetric trauma
Midpelvic OVD or CD with prolonged 2nd stage of labour	Canada (excluding Quebec) 2003-2013	28 923	Dystocia			
			2 to 3-fold ↑ rates with OVD	No association	5 to 9-fold ↑ rates with OVD	3 to 5-fold ↑ rates with OVD
			Fetal distress			
			2.6-fold ↑ rates with sequential only	↓ rates among vacuum (AOR 0.52)	9 to 24-fold ↑ rates with OVD	2 to 3-fold ↑ rates with OVD
Midpelvic OVD or CD in 2nd stage of labour	British Columbia 2004-2014	10 901	Dystocia			
			2 to 4-fold ↑ rates with OVD	1.5-fold ↑ rates with OVD	3 to 8-fold ↑ rates with OVD)	3 to 8-fold ↑ rates with OVD
			Fetal distress			
			1.3-fold ↑ rates following vacuum	2 to 3-fold ↑ rates following forceps and sequential	2 to 5-fold ↑ rates with OVD	3 to 7-fold ↑ rates with OVD
All OVD or CD with prolonged 2nd stage of labour	Canada (excluding Quebec) 2003-2013	55 450	Dystocia			
			1.5-fold ↑ rates with OVD	↓ rates among vacuum	3 to 5-fold ↑ rates with OVD	3 to 5-fold ↑ rates with OVD
			Fetal distress			
			No association	↓ rates among vacuum	5 to 6-fold ↑ rates with OVD	2 to 4-fold ↑ rates with OVD
All deliveries	Alberta, Manitoba, Ontario, Saskatchewan 2004-2014	1 938 913	NA	NA	5% relative increase with a 1% absolute increase in OVD among nulliparas; 18 excess cases/yr	6-11% relative increase with a 1% absolute increase in OVD; 708 excess cases/yr among nulliparas

OVD, operative vaginal delivery; CD, cesarean delivery; NA, not applicable.

7.2. Strengths and limitations

My studies represent an important advance over previous studies in several ways. Firstly, they examine attempted mode of delivery rather than actual mode of delivery. By assessing attempted mode of delivery, I could evaluate associations with adverse outcomes regardless of whether the attempt was successful, a design that is analogous to an intention-to-treat analysis in a clinical trial. Secondly, the large, population-based study carried out enabled the estimation of specific perinatal and maternal outcome rates in clinically meaningful groups, stratified by indication, operative instrument, and pelvic station. Previous research on this topic has been compromised by the inability to account for the effects of these important determinants of perinatal and maternal outcomes. Thirdly, women in the cesarean delivery groups were restricted to those that occurred in the second stage of labour, which ensured that the reference groups for our analyses represented the appropriate clinical alternative, a critical feature of my study design that was not a part of previous studies which attempted to compare these interventions. Fourthly, the associations between midpelvic operative vaginal delivery and severe perinatal and maternal morbidity/mortality were confirmed by similar results in two distinct analyses using different data sources and different analytical models. Lastly, the use of multinomial propensity score analysis provided more precise estimates of the study outcomes than those obtained using regression techniques, due to a more parsimonious model, particularly in the smaller strata (i.e. midpelvic delivery with sequential instruments). A recent commentary on the effects of unmeasured confounding in observational studies applauded the methodological rigour of this analysis stating: "The analysis of Muraca and colleagues' work exemplifies how researchers may address the issue of unmeasured confounders with observational studies" and concluded that despite the observational nature of the study, the reported associations of increased risk are strong enough to be considered causal.[154]

This body of work is not without limitations. Some degree of misclassification and miscoding is inevitable in large health databases. However, several studies have validated the use of such databases as suitable sources for research. The DAD and the BCPDR have been shown to have good validity and reliability when evaluated against population surveys, detailed clinical registries, and chart reviews. Another limitation was the lack of information on pelvic station in women who had a cesarean delivery. Although our study restricted cesarean deliveries to those that occurred in the second stage of labour, it is possible that some of these deliveries occurred before the fetal head reached zero station. However, the frequency of such deliveries is likely to have been low; fewer than 10% of women have an unengaged fetal head at the onset of the second stage of labour.[124] In fact, I may have underestimated the adverse effects of midpelvic operative vaginal delivery because some cesarean deliveries in the second stage of labour would have been carried out with the fetal head below midpelvic station.[40,41,107] In addition, our data sources precluded the study of medium- or long-term outcomes, such as incontinence and placental morbidity.

I was also limited by our inability to account for operator skill with different modes of delivery as this factor could serve as both a potential confounder and an effect modifier in our study. However, skill is a challenging construct to measure and some studies[76,80,133] show that neither attending physician’s forceps volume, nor physician years-in-practice, are associated with neonatal trauma and severe perineal laceration rates. The high rates of severe perinatal and maternal morbidity reported in our analyses may or may not be reflective of adverse outcome rates following midpelvic operative vaginal deliveries carried out by highly experienced obstetricians. It should be noted, however, that our study did not attempt to characterize the best possible outcome following such procedures. The rates observed in my studies reflect current rates of severe perinatal and maternal morbidity following all midpelvic operative vaginal deliveries in Canada. I did investigate potential modification of the effect of operative vaginal delivery by institutional volume: there was no significant difference in severe perinatal and maternal morbidity following such intervention in high- versus medium- versus low-volume centres.[143] Equally important, pregnant women have little understanding of the issues relating to expertise in midpelvic operative vaginal delivery, and our study findings reflect the experience and skills of contemporary practitioners.

Composite outcomes

My focus in this dissertation was on perinatal and maternal safety following different delivery options and this was assessed based on rates of severe perinatal and maternal morbidity and mortality. Since the components of perinatal and maternal morbidity/mortality are rare in industrialized countries, combining outcomes of similar severity into composite outcomes allowed for the study of such endpoints in a clinically meaningful and efficient manner. Although I acquired data on large populations, the many stratifications (forceps/ vacuum/sequential, outlet/low/midpelvic, dystocia/fetal distress, perinatal/maternal) translated into smaller groups. These smaller groups, combined with a low outcome rate, made the analysis of individual severe adverse outcomes challenging. In addition, my interest in controlling for potential confounders further limited my ability to quantify associations when few cases of the outcome had occurred.

The severe perinatal and maternal morbidity/mortality composite outcomes were created to capture component outcomes of similar severity and to measure similar underlying pathophysiological processes. If a severe morbidity represented a pathophysiological process unique to one intervention group (such as OASI) it was not included in the primary composite outcome.

I created the secondary composite obstetric and birth trauma outcomes to provide women and their care providers with estimates of the frequency of any such trauma associated with the various modes of delivery. I intentionally defined these outcomes to include subtypes of trauma similar in severity, but not necessarily common to all modes of delivery. The rationale for combining subtypes of trauma with such different distributions between the intervention arms was 1) to be able to inform women about their risk of experiencing any severe obstetric or birth trauma and 2) to try to balance the component outcomes to those that occur following each intervention.

There were, however, limitations to this approach that should be discussed. The lack of overlap in the distribution of trauma subtypes between intervention groups may have biased our estimates towards the null. For example, the obstetric trauma composite outcome included both OASI and extensions of the uterine incision. The higher rate of OASI following operative vaginal deliveries and the higher rates of uterine incision extension following cesarean deliveries would mask or attenuate the effect of the other when combined into one composite outcome. Nevertheless, my aim was to provide women with an estimate of any obstetric trauma associated with each operative delivery option, in an attempt to simultaneously focus on all severe manifestations of obstetric trauma. Although the component outcomes of the obstetric trauma composite outcome did not measure the same underlying pathophysiologic process, the frequency of each component outcome was consistently reported and, when estimable, separate adjusted regression analysis was conducted for each component outcome.

Confounding by indication

Confounding by indication is defined as a bias in the relationship between an intervention and the intended outcome of the intervention due to the clinical reasons for intervening, with the indication for intervention based on a care provider's assessments of the presumed beneficial effect of the intervention.[121] Confounding occurs because the intervention and the indication are closely correlated, and a greater need for intervention is associated with a higher rate of the adverse outcome.

For example, women who deliver by cesarean delivery often have increased rates of adverse perinatal and maternal outcomes when compared with women who have spontaneous vaginal deliveries. However, women with pre-existing co-morbidity or high-risk pregnancies are much more likely to deliver by cesarean delivery due to these high-risk indications, thereby confounding the association between mode of delivery and adverse outcomes. Thus, an intervention may appear to be causing an adverse outcome simply because it is disproportionately carried out in a population that has an inherently higher risk of experiencing the adverse outcome.

The potential for the results of my studies on operative vaginal delivery to be biased due to confounding by indication depends on whether the indication for operative vaginal delivery is correlated with a higher risk of maternal and perinatal morbidity. In deliveries with fetal distress, the need for an expeditious delivery might have resulted in the most severe cases being delivered by operative vaginal delivery, thus biasing our results in favour of cesarean delivery. On the other hand, as we were not able to exclude all women with pre-existing co-morbidity, our estimates may have favoured the operative vaginal delivery groups due to confounding by indication for cesarean delivery.

Specific concerns regarding confounding by indication in these analyses have been based on the premise that operative vaginal deliveries would have occurred at lower stations in the pelvis than in women delivered by cesarean section.[155] Since cesarean delivery is more likely carried out at midpelvic vs outlet station, our contrasts may have favoured the cesarean delivery group in the comparisons with outlet procedures. At midpelvic station our estimates of the adverse effects of operative vaginal delivery likely represent underestimates of the true effect as some cesarean deliveries would have been carried out with substantial descent of the fetal head.

With respect to our estimates of obstetric and birth trauma, nonexperimental evaluation of the adverse effects of 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.[156]

Finally, the suggestion that the choice between operative vaginal delivery and cesarean delivery is clearly dictated by clinical indication contradicts the proposition that an increase in the use of operative vaginal delivery could have any effect on the rate of cesarean delivery. There must be overlap in the indication for all operative delivery options or else a reduction in the cesarean delivery rate by increasing forceps and/or vacuum use is impossible.

7.3. Future research directions

Future research directions suggested by these studies include identifying target populations for the safe reduction of the cesarean delivery rate. One way to do this would be to stratify women into subpopulations based on demographic factors and obstetric history, and then identify any subpopulations in whom lower rates of cesarean delivery do not result in higher rates of perinatal or maternal morbidity/mortality. If higher rates of cesarean delivery are associated with lower rates of adverse outcomes, that group of women would not be the ideal target in which to reduce cesarean delivery. Further, ecological analyses relating cesarean delivery rates with morbidity rates would provide insight into the optimal rate of cesarean delivery.

It would be ideal if clinicians could better identify deliveries at high risk for dystocia. Some deliveries by forceps or vacuum would have had better outcomes had they been delivered by cesarean earlier in labour. And there are likely women who were delivered by cesarean who may have had fewer complications had they laboured longer and had an operative vaginal delivery. Research focusing on selecting candidates and minimizing harm given difficult labour are important next steps to improve maternity care and safety.

One variable that was not included in the estimation of the associations between operative vaginal delivery and obstetric trauma was the availability and use of epidural anesthesia. Epidural anesthesia has been shown to be associated with an increased rate of operative vaginal delivery and is more often used in deliveries with a larger fetus.[157,158] Previous investigations of the relationship between epidural anesthesia and obstetric trauma have found positive associations between epidural use and obstetric anal sphincter injuries; however, the inclusion of operative vaginal delivery and birthweight in these analyses have consistently been found to mediate this relationship, suggesting that epidural is not an independent risk factor for anal sphincter injury.[159-163] Interestingly, a population-based cohort study of 214,256 vaginal deliveries among primiparous women in Denmark found that epidural anesthesia was protective against obstetric anal sphincter injury (AOR 0.84, 95% CI 0.81-0.88). However the relationship between the use of epidural, operative vaginal delivery, and birthweight were highly correlated and difficult to disentangle.[164] Nevertheless, regarding the analyses in this dissertation, the potential confounding of the relationship between operative vaginal delivery and obstetric trauma by epidural use is not a concern due to the temporal precedence of epidural administration in this process.

Studies comparing long-term morbidity associated with each mode of delivery would significantly add to our understanding of the risks and benefits of these interventions. Also, studying maternal and perinatal outcomes in subsequent pregnancies, by mode of delivery, in women who have had an operative vaginal delivery would assist women and their care providers in planning. Another important related avenue of research is to evaluate the feasibility of, and framework for, increasing training in operative vaginal delivery. Lastly, qualitative research into women experiences following operative vaginal delivery is warranted. We are missing women's voices and perspectives on these issues. Qualitative work exploring women's experiences during and after this situation would be an important extension of this research that will help understand how this knowledge can be used to improve maternity care overall.

7.4. Significance and implications of dissertation research

<u>Is there a place for operative vaginal delivery in obstetrics?</u>

In short, yes. I am not advocating for the abandonment of operative vaginal delivery. There are many women who would choose to have an operative vaginal delivery rather than a cesarean delivery and providing this option for such women is an incredibly valuable service. However, the results of these studies justify concerns about the recommendation to increase the use of operative vaginal delivery as an alternative to cesarean delivery. These concerns stem from the gratuitous use of the cesarean delivery rate as a metric of obstetric practice quality and by extension, from the pressure to reduce cesarean delivery rates irrespective of associated effects on perinatal and maternal morbidity and mortality.

Currently, more than one in ten full-term, singleton deliveries in Canada occur with the assistance of forceps, vacuum, or both instruments sequentially. Among these deliveries, approximately 21% are carried out at midpelvic station. This translates to approximately

10,000 births by midpelvic operative vaginal delivery in Canada annually. The most significant implication of this dissertation is that each of the 10,000 women who face the decision between a midpelvic operative vaginal delivery and a cesarean delivery should now be informed of the risks and benefits of these procedures so that they can make an evidence-informed decision about their birthing experience. Furthermore, although the comparative results of these studies are significant, perhaps the most compelling findings are the crude rates of obstetric trauma among women who had a forceps or vacuum delivery.

Exposing the epidemic of obstetric trauma in Canada

The high rates of severe perineal tears following operative vaginal delivery should give us pause – from 18-25% with forceps, and 12-15% with vacuum delivery. Even among deliveries at outlet station, when operative vaginal delivery is the most intuitive choice and considered the least invasive, the crude rates of severe birth trauma (intracranial hemorrhage or laceration, skull fracture, severe injury to the central or peripheral nervous system, subaponeurotic hemorrhage, long bone injury, and injury to liver or spleen), all birth trauma (intracranial hemorrhage or laceration, all injury to central or peripheral nervous system, and all injury to scalp or skeleton), and obstetric trauma (3^{rd} and 4^{th}-degree perineal laceration, cervical or high vaginal laceration, injury to pelvic organ/joint/ligament, pelvic hematoma and extension of uterine incision) are considerable (0.91%, 7.29%, 19.3%, respectively in deliveries with dystocia and 0.39%, 5.84%, and 27.2%, respectively, in deliveries with fetal distress). The benefit versus risk profile of operative vaginal delivery needs to be carefully communicated to women given our evolving understanding of the long-term effects of severe perineal lacerations. Women need to be informed about the substantially increased risk of severe obstetric injury following all forceps and vacuum deliveries along with the relevant long-term quality-of-life implications.

One may argue that a cesarean delivery is, due to the uterine incision and resulting scar, a form of obstetric trauma. However, every woman who has a cesarean delivery knows that she will have a uterine incision. Maternity care providers offering midpelvic operative vaginal delivery have a responsibility to ensure that women are informed of all the relevant risks of these procedures, particularly the likelihood of severe obstetric trauma and the long-term implications. If a woman perceives a uterine incision to be more traumatic than a 20% risk of a severe perineal laceration, then her autonomy must be respected and she should feel supported in her choice to attempt an operative vaginal delivery. On the other hand, if a woman perceives a 20% risk of a severe perineal laceration as unacceptable and feels more comfortable with having a uterine incision, along with all the attendant risks, that choice should be equally supported and respected.

The significant positive association between the operative vaginal delivery rate and the rate of obstetric trauma should make policy-makers cautious about recommending increased operative vaginal delivery without making provisions for increased services to repair and rehabilitate the pelvic floor. A recent report from CIHI[165] aiming to compare Canada's healthcare system with the countries included in the Organisation for Economic Co-operation and Development (OECD) found that in 2015 the rate of third- and fourth-degree perineal lacerations in Canada greatly exceeded that of any of the other OECD countries (Figure 7.1). Furthermore, the rate of obstetric trauma in Canada shows staggering interprovincial variation, with third- and fourth-degree perineal laceration rates ranging from 5.9% of all operative vaginal deliveries in Newfoundland and Labrador to 25.7% in Quebec[165] (Figure 7.2). It is important to note that these are the rates of severe perineal lacerations among all operative vaginal deliveries not only those at midpelvic station. These remarkably high rates of severe obstetric trauma as well as the variability in national and provincial rates, warrant further investigation and highlight the need for initiatives to increase awareness and prevention of this often-dismissed maternal morbidity.[166]

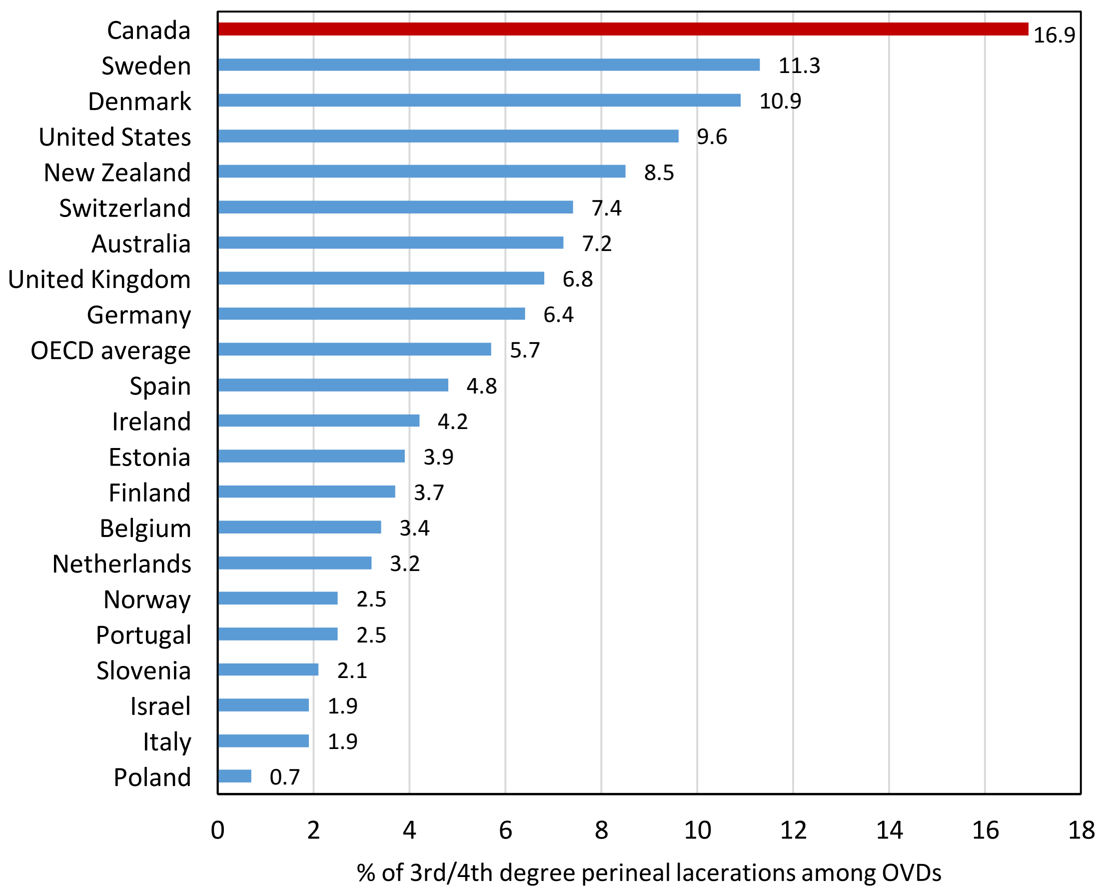


Figure 7.1. Rate of third- or fourth-degree perineal lacerations among operative vaginal deliveries, OECD countries, 2014-2015[165]

A recent study[166] from the United States evaluating the use of third- and fourth-degree perineal laceration rates as obstetric quality measures concluded that they would be of limited utility as a quality metric. This conclusion was based on the finding that 1) there was minimal variation in laceration rates by institution in the US and 2) since operative vaginal delivery was the strongest modifiable risk factor for these lacerations, "diminishing the use of operative vaginal delivery, in an effort to decrease severe perineal lacerations, likely would result in an increased rate of cesarean delivery."[166] The rates and risk ratios of severe perineal lacerations among operative vaginal deliveries in this study is listed in Table 7.2. In response to this study, ACOG issued a Committee Opinion[167] that dismissed obstetric trauma as a performance indicator of obstetric services. The lack of variability in rates of severe perineal lacerations seems to not be the case for Canada given the recent data on inter-provincial and international variations (Figures 7.1 and 7.2). Furthermore, I disagree that the potential effects on the rate of cesarean delivery invalidate the use of third- and fourth-degree perineal lacerations as a measure of obstetric care quality. Further research is required to shed light on the reasons for the high rates of obstetric trauma in Canada among women with an operative vaginal delivery, the implications for affected women and the healthcare system, and the burden attributable to operative vaginal delivery.

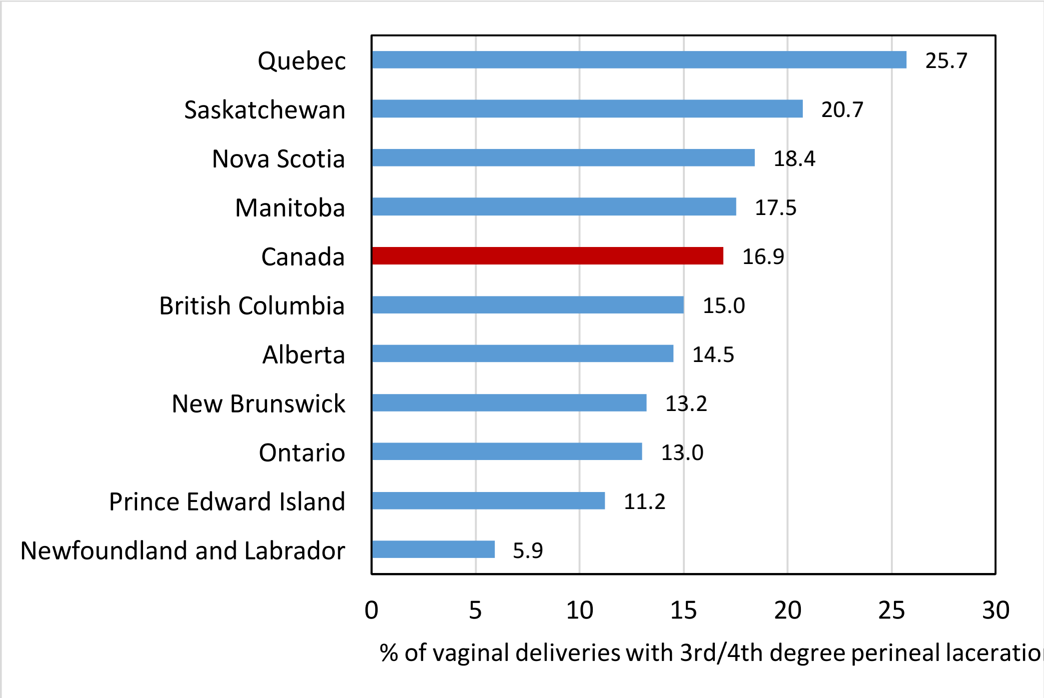


Figure 7.2. Rate of third- or fourth-degree perineal lacerations among operative vaginal deliveries, Canada (excluding Territories), 2014-2015.[165]

Table 7.2. Crude rates, adjusted rate ratios and 95% confidence intervals (CI) of third- and fourth-degree perineal lacerations among operative vaginal delivery, USA, 1998-2010[166]

Mode of delivery	Third-degree		Fourth-degree	
	%	Risk ratio (95% CI)	%	Risk ratio (95% CI)
Forceps with episiotomy	18.3	5.65 (5.55-5.75)	10.0	10.6 (10.3-10.8)
Forceps without episiotomy	19.3	6.54 (6.40-6.68)	6.4	8.81 (8.49-9.15)
Vacuum with episiotomy	12.5	4.53 (4.47-4.59)	6.1	7.45 (7.30-7.60)
Vacuum without episiotomy	8.1	3.14 (3.10-3.19)	2.3	3.30 (3.21-3.40)

Operative vaginal delivery with sequential instruments

The rate of operative vaginal delivery with sequential instruments declined by 36% in Canada since 2004 from 7.3 per 1000 deliveries to 4.7 per 1000 deliveries in 2012. However, in some provinces, such as Saskatchewan, the rate of sequential instrument use remains high with as many as 1% of all term singleton deliveries carried out with sequential instrumentation. The rates of adverse perinatal and maternal outcomes following sequential instrument use echo what has previously been shown in several studies. As the SOGC guidelines clearly state, there is no place for the use of sequential instruments in routine obstetric practice. I acknowledge that these cases likely represent very challenging deliveries and the rates of adverse outcomes following this mode of delivery in this thesis support this. Nonetheless, the geographic variations in the use of sequential obstetric instruments in Canada suggest that such delivery rates can and should be well below 1%.

Professional pressures to reduce cesarean delivery

Concerns relating to the increasing rate of cesarean delivery are reasonable. The morbidity associated with cesarean delivery, such as infection or hemorrhage in the index delivery, and uterine rupture or placentation problems in subsequent pregnancies, have been well characterized.[168-173] However, it is not reasonable to advocate for a reduction in the cesarean delivery rate without evaluating the maternal and perinatal morbidity and mortality associated with this reduction. Neglecting to do so would mean that the rate of cesarean delivery is the performance indicator of obstetric service quality rather than maternal and perinatal morbidity and mortality. When cesarean delivery rates are risk-adjusted, lower than expected rates have been shown to be associated with higher than expected adverse maternal or neonatal outcomes[174] highlighting the fact that in some scenarios, the dangers of not performing a cesarean delivery outweigh the risks of doing so. Ignoring such immediate and long-term dangers is likely to have measurable unintended negative consequences and will pressure clinicians to avoid cesarean delivery with potentially serious outcomes.

As stated in the conceptual framework guiding these studies (Figure 1.4), the purpose of this work was to support maternity care providers in discussing the risks and benefits of all mode of delivery options with women in their care to encourage and facilitate an evidence-informed collaborative decision regarding mode of delivery, preferably in the antenatal period. Nevertheless, the final decision on the choice of pregnancy and childbirth related interventions must always be the woman's. A recent Supreme Court ruling in the United Kingdom, Montgomery v Lanarkshire Health Board (Supreme Court of the United Kingdom)[175] formalized this assertion. The Appellant was a woman with a high risk of experiencing shoulder dystocia during labour (i.e., of small stature and with insulin-dependent diabetes). She was not informed by her maternity care provider about the well-known and substantial decreased risk of neonatal morbidity associated with a cesarean delivery for a woman in her circumstance. Consequently, she attempted a vaginal delivery, experienced shoulder dystocia during labour, and her child suffered from cerebral palsy due to fetal asphyxia. The Supreme Court ruled in favour of Montgomery and stated: "It is impossible to consider a particular procedure in isolation from its alternatives. Pregnancy is a powerful illustration. Where either mother or child is at heightened risk from vaginal delivery, doctors should volunteer the pros and cons of that option compared to a cesarean." The language used in this judgement is meaningful since the court defines planned vaginal birth as a "procedure" or "treatment," which confers a greater liability to obtain informed consent than previously. Women have a right to unbiased information on the risks of vaginal birth. It is no longer acceptable for obstetric trauma to be considered a necessary side effect of childbirth.

<u>Societal pressures to reduce cesarean delivery</u>

There is an ideological divide in contemporary society about what constitutes a successful delivery. There are those who believe that “achieving” a “normal” vaginal birth constitutes a successful delivery. Others believe that the delivery of a healthy baby by a healthy mother, regardless of mode of delivery, is the measure of success. It is for this reason that the results of this dissertation may be seen to be polarizing. Such divisive points of view often lead to an unpleasant societal phenomenon faced by childbearing women, namely, birth shaming. Campaigns that promote vaginal birth as “normal birth,” by extension imply that births by cesarean delivery are unnatural or abnormal. Of course, having an uncomplicated vaginal delivery resulting in a healthy baby and mother is ideal. However, these campaigns become problematic when we consider that a vaginal birth is impractical, very difficult or not possible to achieve for many women. These campaigns are especially harmful when targeting women for whom there is little evidence to recommend vaginal delivery over cesarean delivery.

Reproductive rights researchers suggest that the fixation with natural birth has very little to do with birth, babies or parenting and everything to do with the way society views women, motherhood and women's reproductive function as something to be controlled and dominated.[176,177] Women's access to quality medical services, rather than assumptions about the proper form of labour and delivery, should be our chief concern. It is not acceptable to assume that severe obstetric trauma is a necessary side-effect of “achieving” a vaginal birth. Nor is it acceptable to choose not to share information about pertinent risks with women in the interest of not frightening them. The findings of this dissertation highlight the importance of never underestimating the power of politics on a woman's body and on her reproductive outcomes.

Labelling birth as "natural" and "unnatural" has the potential to pressure women into seeking a vaginal birth at all costs, and to leave women who do not "achieve" a vaginal birth to feel guilty and bereft over failing to give birth in the socially sanctioned way, even if cesarean delivery is the safer option. In the context of the comparison of operative vaginal and cesarean delivery, the assumption is that since deliveries by forceps and vacuum are carried out vaginally, they qualify as more "natural" than cesarean deliveries. It is important to understand that, similar to cesarean deliveries, forceps and vacuum deliveries are invasive procedures with their own risks – risks that have now been quantified and that should be communicated to women who may encounter them. Women who consent to cesarean delivery are informed of the associated risks. Women who consent to forceps or vacuum delivery should be afforded the same standard of informed consent.

7.5. Conclusion

Currently, there is little evidence to suggest that midpelvic operative vaginal delivery is a safer option than cesarean delivery for mothers or babies in Canada. The results of my studies suggest that encouraging higher rates of operative vaginal delivery as a strategy to reduce the cesarean delivery rate could result in increases in severe perinatal and maternal morbidity, especially severe birth trauma, severe postpartum hemorrhage, and obstetric trauma.

Midpelvic operative vaginal deliveries carried out by experienced obstetricians have saved the lives of countless babies over the last several decades. However, improvements in surgery and anesthesia, and changes in fecundity in countries such as Canada appear to have altered the relative safety profile of cesarean delivery versus operative vaginal delivery at midpelvic station. Given the lack of significant benefit and the high rates of obstetric trauma, it is questionable whether ramping up training programs in operative vaginal delivery is warranted. However, if the campaign to increase rates of operative vaginal delivery carries on, specialized training courses are critically needed if we expect these deliveries to be carried out safely. The onus is on those that believe these programs are justified to ensure that the results of such training on perinatal and maternal outcomes are carefully evaluated before continuing to assert the safety of midpelvic operative vaginal delivery.

This thesis should encourage health policy-makers to question the use of cesarean delivery rates as the metric for assessing obstetric performance as it may be justifiable to have increased cesarean delivery rates if this leads to reduced maternal and perinatal morbidity and mortality. It would be far more rational to focus on indices of perinatal and maternal severe morbidity and mortality that quantify safety and well-being of mothers and babies. Quantification of the relative risks and benefits of different modes of delivery at midpelvic station, through studies such as these, will help women make informed choices that optimize their health and the health of their babies.

References

1. American College of Obstetricians and Gynecologists (ACOG). Approaches to limit intervention during labor and birth. Committee Opinion No. 687. *Obstet Gynecol* 2017;129:e20-8.

2. Canadian Institute for Health Information (CIHI). *Health indicators 2012.* Ottawa, ON, 2012.

3. CIHI. Childbirth indicators by place of residence. 2017; Available from: https://apps.cihi.ca/mstrapp/asp/Main.aspx?Server=apmstrextprd_i&project=Quick%20Stats&uid=pce_pub_en&pwd=&evt=2048001&visualizationMode=0&documentID=029DB170438205AEBCC75B8673CCE822. Accessed 22 November, 2017.

4. Millar WJ, Nair C, Wadhera S. Declining cesarean section rates: a continuing trend? *Health Reports-Statistics Canada* 1996;8:17-24.

5. Liu S, Rusen ID, Joseph KS, et al. Recent trends in caesarean delivery rates and indications for caesarean delivery in Canada. *J Obstet Gynaecol Can* 2004;26:735-42.

6. Bayrampour H, Heaman M. Advanced maternal age and the risk of cesarean birth: a systematic review. *Birth* 2010;37:219-26.

7. Vahratian A, Siega-Riz AM, Savitz DA, Zhang J. Maternal pre-pregnancy overweight and obesity and the risk of cesarean delivery in nulliparous women. *Ann Epidemiol* 2005;15:467-74.

8. Boyle A, Reddy UM. Epidemiology of cesarean delivery: the scope of the problem. *Semin Perinatol* 2012;36:308-14.

9. Public Health Agency of Canada (PHAC). *Perinatal health indicators for Canada 2011.* Ottawa, ON, 2012.

10. PHAC. *Canadian perinatal health report, 2008 Edition.* Ottawa, ON, 2008.

11. Caughey AB, Cahill AG, Guise J-M, Rouse DJ. Safe prevention of the primary cesarean delivery. *Am J Obstet Gynecol* 2014;210:179-93.

12. ACOG Task Force on Cesarean Delivery Rates. *Evaluation of cesarean delivery.* Washington, DC: ACOG, 2000.

13. Spong CY, Berghella V, Wenstrom KD, Mercer BM, Saade GR. Preventing the first cesarean delivery: summary of a joint Eunice Kennedy Shriver National Institute of Child Health and Human Development, Society for Maternal-Fetal Medicine, and American College of Obstetricians and Gynecologists workshop. *Obstet Gynecol* 2012;120:1181-93.

14. U. S. Department of Health Human Services. *Healthy people 2020.* Washington, DC, 2012.

15. Villar J, Valladares E, Wojdyla D, et al. Caesarean delivery rates and pregnancy outcomes: the 2005 WHO global survey on maternal and perinatal health in Latin America. *Lancet* 2006;367:1819-29.

16. Bauer C, Voutsos LJ. Preventing the first cesarean delivery: summary of a joint Eunice Kennedy Shriver National Institute of Child Health and Human Development, Society for Maternal-Fetal Medicine, and American College of Obstetricians and Gynecologists workshop. *Obstet Gynecol* 2013;121:686-7.

17. Betrán AP, Gulmezoglu AM, Robson M, et al. WHO global survey on maternal and perinatal health in Latin America: classifying caesarean sections. *Reprod Health* 2009;6:18.

18. Rossignol M, Moutquin J-M, Boughrassa F, et al. Preventable obstetrical interventions: how many caesarean sections can be prevented in Canada? *J Obstet Gynaecol Can* 2013;35:434-43.

19. Cargill YM, MacKinnon CJ, Arsenault M-Y, et al. Guidelines for operative vaginal birth. *J Obstet Gynaecol Can* 2004;26:747-61.

20. Gossett DR, Gilchrist-Scott D, Wayne DB, Gerber SE. Simulation training for forceps-assisted vaginal delivery and rates of maternal perineal trauma. *Obstet Gynecol* 2016;128:429-35.

21. Deering S. Forceps, simulation, and social media. *Obstet Gynecol* 2016;128:425-6.

22. Dildy GA, Belfort MA, Clark SL. Obstetric forceps: a species on the brink of extinction. *Obstet Gynecol* 2016;128:436-9.

23. Merriam AA, Ananth CV, Wright JD, Siddiq Z, D'Alton ME, Friedman AM. Trends in operative vaginal delivery, 2005–2013: a population-based study. *BJOG* 2017;124:1365–72.

24. Towner D, Castro MA, Eby-Wilkens E, Gilbert WM. Effect of mode of delivery in nulliparous women on neonatal intracranial injury. *N Engl J Med* 1999;341:1709-14.

25. Walsh CA, Robson M, McAuliffe FM. Mode of delivery at term and adverse neonatal outcomes. *Obstet Gynecol* 2013;121:122-8.

26. Werner EF, Janevic TM, Illuzzi J, Funai EF, Savitz DA, Lipkind HS. Mode of delivery in nulliparous women and neonatal intracranial injury. *Obstet Gynecol* 2011;118:1239.

27. Murphy DJ, Liebling RE, Verity L, Swingler R, Patel R. Early maternal and neonatal morbidity associated with operative delivery in second stage of labour: a cohort study. *Lancet* 2001;358:1203-7.

28. Robertson PA, Laros Jr RK, Zhao R-L. Neonatal and maternal outcome in low-pelvic and midpelvic operative deliveries. *Am J Obstet Gynecol* 1990;162:1436-44.

29. Bashore RA, Phillips WH, Jr., Brinkman CR, 3rd. A comparison of the morbidity of midforceps and cesarean delivery. *Am J Obstet Gynecol* 1990;162:1428-34.

30. Dierker LJ, Rosen MG, Thompson K, Debanne S, Linn P. The midforceps: maternal and neonatal outcomes. *Am J Obstet Gynecol* 1985;152:176-183.

31. Friedman EA. Midforceps delivery: no? *Clin Obstet Gynecol* 1987;30:93-105.

32. Halscott TL, Reddy UM, Landy HJ, et al. Maternal and neonatal outcomes by attempted mode of operative delivery from a low station in the second stage of labor. *Obstet Gynecol* 2015;126:1265-72.

33. Contag SA, Clifton RG, Bloom SL, et al. Neonatal outcomes and operative vaginal delivery versus cesarean delivery. *Amer J Perinatol* 2010;27:493-9.

34. Lowe B. Fear of failure: a place for the trial of instrumental delivery. *BJOG* 1987;94:60-6.

35. Bailit JL, Grobman WA, Rice MM, et al. Evaluation of delivery options for second-stage events. *Am J Obstet Gynecol* 2016;214:e1-10.

36. Burrows LJ, Meyn LA, Weber AM. Maternal morbidity associated with vaginal versus cesarean delivery. *Obstet Gynecol* 2004;103:907-12.

37. Hagadorn-Freathy AS, Yeomans ER, Hankins GD. Validation of the 1988 ACOG forceps classification system. *Obstet Gynecol* 1991;77:356-60.

38. Cunningham F. *Williams Obstetrics. 24th edition.* New York: McGraw-Hill Medical; 2014.

39. Cunningham FG, Leveno KJ, Bloom SL, Hauth JC, Rouse DJ, Spong CY. *Williams Obstetrics.* 23rd ed. New York: McGraw-Hill Medical; 2010.

40. Tan EK. Difficult caesarean delivery of an impacted head and neonatal skull fracture: can the morbidity be avoided? *J Obstet Gynaecol* 2007;27:427-8.

41. Steer PJ. Is a fractured skull discovered in the neonate after caesarean section delivery always evidence of negligence? *BJOG* 2016;123:336.

42. Menticoglou S. Delivering the impacted head at caesarean section. *J Obstet Gynaecol Can* 2016;38:234.

43. Majoko F, Gardener G. Trial of instrumental delivery in theatre versus immediate caesarean section for anticipated difficult assisted births. *Cochrane Database Syst Rev* 2008.

44. Majoko F, Gardener G. Trial of instrumental delivery in theatre versus immediate caesarean section for anticipated difficult assisted births. *Cochrane Database Syst Rev* 2012.

45. Sanderson S, Tatt ID, Higgins J. Tools for assessing quality and susceptibility to bias in observational studies in epidemiology: a systematic review and annotated bibliography. *Int J Epidemiol* 2007;36:666-76.

46. Mallen C, Peat G, Croft P. Quality assessment of observational studies is not commonplace in systematic reviews. *J Clin Epidemiol* 2006;59:765-9.

47. Stroup DF, Berlin JA, Morton SC, et al. Meta-analysis of observational studies in epidemiology: a proposal for reporting. *JAMA* 2000;283:2008-12.

48. Von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. *International Journal of Surgery* 2014;12:1495-9.

49. Wells G, Shea B, O'connell D, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. Ottawa Hospital Research Institute, 2014.

50. Martin A, Srihari V. Geometrically evident: framing studies using the Graphic Appraisal Tool for Epidemiology (GATE). *J Am Acad Child Adolesc Psychiatry* 2006;45:1521-6.

51. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ* 2003;327:557-60.

52. Al-Kadri H, Sabr Y, Al-Saif S, Abulaimoun B, Ba'Aqeel H, Saleh A. Failed individual and sequential instrumental vaginal delivery: contributing risk factors and maternal-neonatal complications. *Acta Obstet Gynecol Scand* 2003;82:642-8.

53. Murphy D. Cohort study of operative delivery in the second stage of labour and standard of obstetric care. *BJOG* 2003;110:610-5.

54. ACOG. *Committee on obstetrics, maternal and fetal medicine: Obstetrics forceps.* Washington, DC, 1989.

55. Traub A, Morrow R, Ritchie J, Dornan K. A continuing use for Kielland's forceps? *BJOG* 1984;91:894-8.

56. Cibils LA, Ringler GE. Evaluation of midforceps delivery as an alternative. *J Perinat Med* 1990;18:5-11.

57. Liebling RE, Swingler R, Patel RR, Verity L, Soothill PW, Murphy DJ. Pelvic floor morbidity up to one year after difficult instrumental delivery and cesarean section in the second stage of labor: a cohort study. *Am J Obstet Gynecol* 2004;191:4-10.

58. Rodriguez AI, Porter KB, O'Brien WF. Blunt versus sharp expansion of the uterine incision in low-segment transverse cesarean section. *Am J Obstet Gynecol* 1994;171:1022-5.

59. Clark SL, Yeh SY, Phelan JP, Bruce S, Paul RH. Emergency hysterectomy for obstetric hemorrhage. *Obstet Gynecol* 1984;64:376-80.

60. Repke JT, Spence MR, Calhoun S. Risk factors in the development of cesarean section infection. *Surg Gynecol Obstet* 1984;158:112-6.

61. Cooke W. Evaluation of the midforceps operation. *Am J Obstet Gynecol* 1967;99:327-32.

62. O'Driscoll K, Meagher D, MacDonald D, Geoghegan F. Traumatic intracranial haemorrhage in firstborn infants and delivery with obstetric forceps. *BJOG* 1981;88:577-81.

63. Fenichel GM, Webster DL, Wong WK. Intracranial hemorrhage in the term newborn. *Arch Neurol* 1984;41:30-4.

64. Chiswick ML, James DK. Kielland's forceps: association with neonatal morbidity and mortality. *BMJ* 1979;1:7-9.

65. Nichols PL, Chen T-C. *Minimal brain dysfunction: A prospective study.* Psychology Press, Hillsdale, NJ; 1981.

66. Friedman EA. Patterns of labor as indicators of risk. *Clin Obstet Gynecol* 1973;16:172-83.

67. Friedman EA, Sachtleben MR, Bresky PA. Dysfunctional labor: XII. Long-term effects on infant. *Am J Obstet Gynecol* 1977;127:779-83.

68. Friedman EA, Sachtleben-Murray MR, Dahrouge D, Neff RK. Long-term effects of labor and delivery on offspring: a matched-pair analysis. *Am J Obstet Gynecol* 1984;150:941-5.

69. Friedman EA, Neff RK. *Labor and delivery: impact on offspring.* PSG Publishing Company; 1987.

70. Hughey M, McElin T, Lussky R. Forceps operations in perspective. I. Midforceps rotation operations. *J Reprod Med* 1978;20:253-9.

71. Cyr RM, Usher RH, McLean FH. Changing patterns of birth asphyxia and trauma over 20 years. *Am J Obstet Gynecol* 1984;148:490-8.

72. Nelson KB, Broman SH. Perinatal risk factors in children with serious motor and mental handicaps. *Ann Neurol* 1977;2:371-7.

73. Bowes WA, Jr., Bowes C. Current role of the midforceps operation. *Clin Obstet Gynecol* 1980;23:549-57.

74. Dierker LJ, Rosen MG, Thompson K, Lynn P. Midforceps deliveries: long-term outcome of infants. *Am J Obstet Gynecol* 1986;154:764-8.

75. Hankins GD, Uckan E, Rowe TF, Collier S. Forceps and vacuum delivery: expectations of residency and fellowship training program directors. *Am J Perinatol* 1999;16:23-8.

76. Crosby D, Sarangapani A, Simpson A, Windrim R, Satkunaratnam A, Higgins M. An international assessment of trainee experience, confidence, and comfort in operative vaginal delivery. *Ir J Med Sci* 2017;186:715-21.

77. Daly N, Bonham S, O'Dwyer V, O'Connor C, Kent E, Turner MJ. National variations in operative vaginal deliveries in Ireland. *Int J Gynaecol Obstet* 2014;125:210-3.

78. Fong A, Wu E, Pan D, Chung JH, Ogunyemi DA. Temporal trends and morbidities of vacuum, forceps, and combined use of both. *J Matern-Fetal Neonatal Med* 2014;27:1886-91.

79. Hankins GD, Uckan E, Rowe TF, Collier S. Forceps and vacuum delivery: expectations of residency and fellowship training program directors. *Am J Perinatol* 1999;16:23-8.

80. Powell J, Gilo N, Foote M, Gil K, Lavin J. Vacuum and forceps training in residency: experience and self-reported competency. *J Perinatol* 2007;27:343-6.

81. Satterfield JM, Spring B, Brownson RC, et al. Toward a transdisciplinary model of evidence-based practice. *Milbank Q* 2009;87:368-90.

82. Towle A, Godolphin W. Framework for teaching and learning informed shared decision making. *BMJ* 1999;319:766-71.

83. ACOG Practice bulletin No. 115: Vaginal birth after previous cesarean delivery. *Obstet Gynecol* 2010;116:450-63.

84. Roberts RG, Deutchman M, King VJ, Fryer GE, Miyoshi TJ. Changing policies on vaginal birth after cesarean: impact on access. *Birth* 2007;34:316-22.

85. Kennedy HP, Cheyney M, Lawlor M, Myers S, Schuiling K, Tanner T. The development of a consensus statement on normal physiologic birth: a modified delphi study. *J Midwifery Womens Health* 2015;60:140-45.

86. Minkoff H, Chervenak FA. Elective primary cesarean delivery. *N Engl J Med* 2003;348:946-50.

87. Minkoff H, Powderly KR, Chervenak F, McCullough LB. Ethical dimensions of elective primary cesarean delivery. *Obstet Gynecol* 2004;103:387-92.

88. Dietz HP, Campbell S. Toward normal birth–but at what cost? *Am J Obstet Gynecol* 2016;215:439-44.

89. Farrell SA. Cesarean section versus forceps-assisted vaginal birth: It's time to include pelvic injury in the risk-benefit equation. *CMAJ* 2002;166:337-8.

90. Wen SW, Liu S, Marcoux S, Fowler D. Uses and limitations of routine hospital admission/separation records for perinatal surveillance. *Chronic Dis Inj Can* 1997;18:113-9.

91. Joseph KS, Fahey J. Validation of perinatal data in the Discharge Abstract Database of the Canadian Institute for Health Information. *Chronic Dis Can* 2009;29:96-100.

92. CIHI. *Data quality study of the 2015-2016 Discharge Abstract Database: a focus on hospital harm.* Ottawa, ON; 2016.

93. Perinatal Services British Columbia. Special reports: data and surveillance. 2016; Available from: www.perinatalservicesbc.ca/health-professionals/data-surveillance. Accessed November 22, 2017.

94. Frosst G, Hutcheon J, Joseph KS, Kinniburgh B, Johnson C, Lee L. Validating the British Columbia Perinatal Data Registry: a chart re-abstraction study. *BMC Pregnancy Childbirth* 2015;15:123.

95. Martin JA, Hamilton BE, Ventura SJ, Osterman MJ, Wilson EC, Mathews T. Births: final data for 2010. *Natl Vital Stat Rep* 2012;61:1-72.

96. Health Canada. *Canadian perinatal health report, 2003 Edition.* Ottawa, ON; 2003.

97. Clark SL, Belfort MA, Hankins GD, Meyers JA, Houser FM. Variation in the rates of operative delivery in the United States. *Am J Obstet Gynecol* 2007;196:526.e521-5.

98. Martin JA, Hamilton BE, Osterman MJK, Curtin SC, TJ. M. Births: final data for 2012. *Natl Vital Stat Rep* 2013;62:1-68.

99. Loudon J, Groom K, Hinkson L, Harrington D, Paterson-Brown S. Changing trends in operative delivery performed at full dilatation over a 10-year period. *J Obstet Gynaecol* 2010;30:370-5.

100. ACOG. *Practice Bulletin No. 17: Operative vaginal delivery.* Washington, DC; 2000.

101. Yeomans ER. Operative vaginal delivery. *Obstet Gynecol* 2010;115:645-53.

102. Goetzinger KR, Macones GA. Operative vaginal delivery: current trends in obstetrics. *Women's Health* 2008;4:281-90.

103. Joseph KS, Young DC, Dodds L, et al. Changes in maternal characteristics and obstetric practice and recent increases in primary cesarean delivery. *Obstet Gynecol* 2003;102:791-800.

104. Hauth JC, Gilstrap LC, Hankins GD. Examination of data base in midforceps delivery study. *Am J Obstet Gynecol* 1985;153:814.

105. Baerthlein WC, Moodley S, Stinson SK. Comparison of maternal and neonatal morbidity in midforceps delivery and midpelvis vacuum extraction. *Obstet Gynecol* 1986;67:594-7.

106. ACOG. Operative Vaginal Delivery. Practice Bulletin No. 154. *Obstet Gynecol* 2015:e56–65.

107. Alexander JM, Leveno KJ, Hauth J, et al. Fetal injury associated with cesarean delivery. *Obstet Gynecol* 2006;108:885-90.

108. Alexander JM, Leveno KJ, Rouse DJ, et al. Comparison of maternal and infant outcomes from primary cesarean delivery during the second compared with first stage of labor. *Obstet Gynecol* 2007;109:917-21.

109. Muraca GM SY, Brant R, Cundiff GW, Joseph KS. Temporal and regional variations in operative vaginal delivery in Canada by pelvic station, 2004-2012. *J Obstet Gynaecol Can* 2016;38:627-35.

110. Ducarme G, Hamel JF, Bouet PE, Legendre G, Vandenbroucke L, Sentilhes L. Maternal and neonatal morbidity after attempted operative vaginal delivery according to fetal head station. *Obstet Gynecol* 2015;126:521-9.

111. Bailit J, Garrett J. Comparison of risk-adjustment methodologies for cesarean delivery rates. *Obstet Gynecol* 2003;102:45-51.

112. Frosst G. Validity of pre-pregnancy body mass index (BMI) information derived from a population-based perinatal database. Proceedings of the Healthy Mothers and Healthy Babies: New Research and Best Practice Conference; Vancouver, British Columbia, 2014.

113. Perinatal Services British Columbia. *British Columbia perinatal surveillance, 2000/2001 to 2010/2011.*.

114. Henry OA, Gregory KD, Hobel CJ, Platt LD. Using ICD-9 codes to identify indications for primary and repeat cesarean sections: agreement with clinical records. *Am J Public Health* 1995;85:1143-6.

115. McCaffrey DF, Griffin BA, Almirall D, Slaughter ME, Ramchand R, Burgette LF. A tutorial on propensity score estimation for multiple treatments using generalized boosted models. *Stat Med* 2013;32:3388-414.

116. Lee KJ, Carlin JB. Multiple imputation for missing data: fully conditional specification versus multivariate normal imputation. *Am J Epidemiol* 2010;171:624-32.

117. Harder VS, Stuart EA, Anthony JC. Propensity score techniques and the assessment of measured covariate balance to test causal associations in psychological research. *Psychol Methods* 2010;15:234-49.

118. Lee BK, Lessler J, Stuart EA. Improving propensity score weighting using machine learning. *Stat Med* 2010;29:337-46.

119. Lee BK, Lessler J, Stuart EA. Weight trimming and propensity score weighting. *PLoS One* 2011;6:e18174.

120. Austin PC. An introduction to propensity score methods for reducing the effects of confounding in observational studies. *Multivariate Behav Res* 2011;46:399-424.

121. Joseph KS, Mehrabadi A, Lisonkova S. Confounding by indication and related concepts. *Curr Epidemiol Rep* 2014;1:1-8.

122. Knight D, Newnham JP, McKenna M, Evans S. Comparison of abdominal and vaginal examinations for the diagnosis of engagement of the fetal head. *Aust N Z J Obstet Gynaecol* 1993;33:154-8.

123. Dupuis O, Silveira R, Zentner A, et al. Birth simulator: reliability of transvaginal assessment of fetal head station as defined by the American College of Obstetricians and Gynecologists classification. *Am J Obstet Gynecol* 2005;192:868-74.

124. Dupuis O, Ruimark S, Corinne D, Simone T, André D, René-Charles R. Fetal head position during the second stage of labor: comparison of digital vaginal examination and transabdominal ultrasonographic examination. *Eur J Obstet Gynecol Reprod Biol* 2005;123:193-7.

125. Abdel-Aleem H, Shaaban OM, Hassanin AI, Ibraheem AA. Analysis of cesarean delivery at Assiut University Hospital using the Ten Group Classification System. *Int J Gynaecol Obstet* 2013;123:119-23.

126. Knight M, Callaghan WM, Berg C, et al. Trends in postpartum hemorrhage in high resource countries: a review and recommendations from the International Postpartum Hemorrhage Collaborative Group. *BMC Pregnancy Childbirth* 2009;9:1.

127. Wildman K, Blondel B, Nijhuis J, Defoort P, Bakoula C. European indicators of health care during pregnancy, delivery and the postpartum period. *Eur J Obstet Gynecol Reprod Biol* 2003;111:S53-S65.

128. Macfarlane A, Blondel B, Mohangoo A, et al. Wide differences in mode of delivery within Europe: risk-stratified analyses of aggregated routine data from the Euro-Peristat study. *BJOG* 2015;123:559-68.

129. Hamilton B, Martin J, Osterman M, Curtin S, Matthews T. Births: final data for 2014. *Natl Vital Stat Rep* 2015;64:1-64.

130. Ducarme G, Hamel J-F, Bouet P-E, Legendre G, Vandenbroucke L, Sentilhes L. Maternal and neonatal morbidity after attempted operative vaginal delivery according to fetal head station. *Obstet Gynecol* 2015;126:521-9.

131. Breslow NE, Day NE. *Statistical methods in cancer research: Vol. I - The analysis of case-control studies.* Lyon: IARC;1980.

132. Friedman T, Eslick G, Dietz H. Instrumental delivery and OASI. *Int Urogynecol J* 2016;27:S30-1.

133. Miller ES, Barber EL, McDonald KD, Gossett DR. Association between obstetrician forceps volume and maternal and neonatal outcomes. *Obstet Gynecol* 2014;123:248-54.

134. Gurol-Urganci I, Cromwell D, Edozien L, et al. Third-and fourth-degree perineal tears among primiparous women in England between 2000 and 2012: time trends and risk factors. *BJOG* 2013;120:1516-25.

135. Johnson JH, Figueroa R, Garry D, Elimian A, Maulik D. Immediate maternal and neonatal effects of forceps and vacuum-assisted deliveries. *Obstet Gynecol* 2004;103:513-8.

136. Lowder JL, Burrows LJ, Krohn MA, Weber AM. Risk factors for primary and subsequent anal sphincter lacerations: a comparison of cohorts by parity and prior mode of delivery. *Am J Obstet Gynecol* 2007;196:344.e341-5.

137. Mikolajczyk RT, Zhang J, Troendle J, Chan L. Risk factors for birth canal lacerations in primiparous women. *Am J Perinatol* 2008;25:259-64.

138. Richter HE, Brumfield CG, Cliver SP, Burgio KL, Neely CL, Varner RE. Risk factors associated with anal sphincter tear: a comparison of primiparous patients, vaginal births after cesarean deliveries, and patients with previous vaginal delivery. *Am J Obstet Gynecol* 2002;187:1194-8.

139. Handa VL, Blomquist JL, McDermott KC, Friedman S, Muñoz A. Pelvic floor disorders after childbirth: effect of episiotomy, perineal laceration, and operative birth. *Obstet Gynecol* 2012;119:233-9.

140. Dudding TC, Vaizey CJ, Kamm MA. Obstetric anal sphincter injury: incidence, risk factors, and management. *Ann Surg* 2008;247:224-37.

141. Kammerer-Doak D, Rogers RG. Female sexual function and dysfunction. *Obstet Gynecol Clin North Am* 2008;35:169-83.

142. Martin JA, Hamilton BE, Osterman M, Driscoll AK, Mathews T. Births: Final Data for 2015. *Natl Vital Stat Rep* 2017;66:1.

143. Muraca GM, Sabr Y, Lisonkova S, et al. Perinatal and maternal morbidity and mortality after attempted operative vaginal delivery at midpelvic station. *CMAJ* 2017;189:E764-E72.

144. Muraca GM, Skoll A, Lisonkova S, et al. Perinatal and maternal morbidity and mortality among term singletons following midcavity operative vaginal delivery versus caesarean delivery. *BJOG* 2017; doi: 10.1111/1471-0528.14820.

145. Statistics Canada. Births, estimates, by province and territory. 2017; Available from: http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/demo04a-eng.htm, Accessed August 3, 2017.

146. Wen SW, Liu S, Kramer MS, et al. Comparison of maternal and infant outcomes between vacuum extraction and forceps deliveries. *Am J Epidemiol* 2001;153:103-7.

147. Smith LA, Price N, Simonite V, Burns EE. Incidence of and risk factors for perineal trauma: a prospective observational study. *BMC Pregnancy Childbirth* 2013;13:59.

148. Lisonkova S, Lavery JA, Ananth CV, et al. Temporal trends in obstetric trauma and inpatient surgery for pelvic organ prolapse: an age-period-cohort analysis. *Am J Obstet Gynecol* 2016; 215:208.e1-12.

149. Harvey M-A, Pierce M, Walter J-E, et al. Obstetrical anal sphincter injuries (OASIS): prevention, recognition, and repair. *J Obstet and Gynaecol Can* 2015;37:1131-48.

150. Sultan AH, Kettle C. Diagnosis of perineal trauma. *Perineal and anal sphincter trauma*: Springer; 2009:13-9.

151. Wegnelius G, Hammarström M. Complete rupture of anal sphincter in primiparas: long-term effects and subsequent delivery. *Acta Obstet Gynecol Scand* 2011;90:258-63.

152. Susser M. The logic in ecological: I. The logic of analysis. *Am J Public Health* 1994;84:825-9.

153. Wen SW, Kramer MS. Uses of ecologic studies in the assessment of intended treatment effects. *J Clin Epidemiol* 1999;52:7-12.

154. Ananth CV, Schisterman EF. Hidden biases in observational epidemiology: the case of unmeasured confounding. *BJOG* 2017;doi: 10.1111/1471-0528.14960.

155. Barrett JF, Zaltz A, Geary M, Sermer M. Beware selection bias. *CMAJ* 2017;28;189:E1096.

156. Miettinen OS. The need for randomization in the study of intended effects. *Stat Med* 1983;2:267-71.

157. Anim-Somuah M, Smyth RM, Jones L. Epidural versus non-epidural or no analgesia in labour. *Cochrane Database Syst Rev* 2011:CD000331.

158. Ekéus C, Hjern A, Hjelmstedt A. The need for epidural analgesia is related to birthweight-a population-based register study. *Acta Obstet Gynecol Scand* 2009:397-401.

159. Robinson JN, Norwitz ER, Cohen AP, McElrath TF, Lieberman ES. Epidural analgesia and third- or fourth-degree lacerations in nulliparas. *Obstet Gynecol* 1999;94:259-62.

160. Loewenberg-Weisband Y, Grisaru-Granovsky S, Ioscovich A, Samueloff A, Calderon-Margalit R. Epidural analgesia and severe perineal tears: a literature review and large cohort study. *J Matern Fetal Neonatal Med* 2014;27:1864-9.

161. Walker MP, Farine D, Rolbin SH, Ritchie JW. Epidural anesthesia, episiotomy, and obstetric laceration. *Obstet Gynecol* 1991;77:668-71.

162. Christianson LM, Bovbjerg VE, McDavitt EC, Hullfish KL. Risk factors for perineal injury during delivery. *Am J Obstet Gynecol* 2003;189:255-60.

163. Carroll TG; Engelken M; Mosier MC; Nazir N. Epidural analgesia and severe perineal laceration in a community-based obstetric practice. *J Am Board Fam Pract* 2003;16:1-6.

164. Jangö H, Langhoff-Roos J, Rosthøj S, Sakse A. Modifiable risk factors of obstetric anal sphincter injury in primiparous women: a population-based cohort study. *Am J Obstet Gynecol* 2014;210:59.e1-6.

165. Benchmarking Canada's health care systems: International comparisons, 2017. Available from : https://www.cihi.ca/sites/default/files/document/oecd-benchmarking-canadas-health-systems-2017-en-web.xlsx. Accessed November 29, 2017.

166. Friedman AM, Ananth CV, Prendergast E, D'Alton ME, Wright JD. Evaluation of third-degree and fourth-degree laceration rates as quality indicators. *Obstet Gynecol* 2015;125:927-37.

167. ACOG. Committee Opinion No. 647: Limitations of perineal lacerations as an obstetric quality measure. *Obstet Gynecol* 2015;126:e108-11.

168. Silver RM. Implications of the first cesarean: perinatal and future reproductive health and subsequent cesareans, placentation issues, uterine rupture risk, morbidity, and mortality. *Semin Perinatol* 2012;36:315-23.

169. Paré E, Quinones JN, Macones GA. Vaginal birth after caesarean section versus elective repeat caesarean section: assessment of maternal downstream health outcomes. *BJOG* 2006;113:75-85.

170. Lumbiganon P, Laopaiboon M, Gülmezoglu AM, et al. Method of delivery and pregnancy outcomes in Asia: the WHO global survey on maternal and perinatal health 2007-2008. *Lancet* 2010;375:490-9.

171. Souza J, Gülmezoglu A, Lumbiganon P, et al. WHO Global Survey on Maternal and Perinatal Health Research Group. Caesarean section without medical indications is associated with an increased risk of adverse short-term maternal outcomes: the 2004–2008 WHO Global Survey on Maternal and Perinatal Health. *BMC Med* 2010;8:71.

172. Timor-Tritsch IE, Monteagudo A. Unforeseen consequences of the increasing rate of cesarean deliveries: early placenta accreta and cesarean scar pregnancy. A review. *Am J Obstet Gynecol* 2012;207:14-29.

173. Marshall NE, Fu R, Guise J-M. Impact of multiple cesarean deliveries on maternal morbidity: a systematic review. *Am J Obstet Gynecol* 2011;205:262.e1-8.

174. Srinivas SK, Fager C, Lorch SA. Evaluating risk-adjusted cesarean delivery rate as a measure of obstetric quality. *Obstet Gynecol* 2010;115:1007-13.

175. Supreme Court of the United Kingdom. Montgomery v Lanarkshire Health Board. UKSC 11. 2015; Available from : https://www.supremecourt.uk/cases/docs/uksc-2013-0136-judgment.pdf Accessed December 1, 2017.

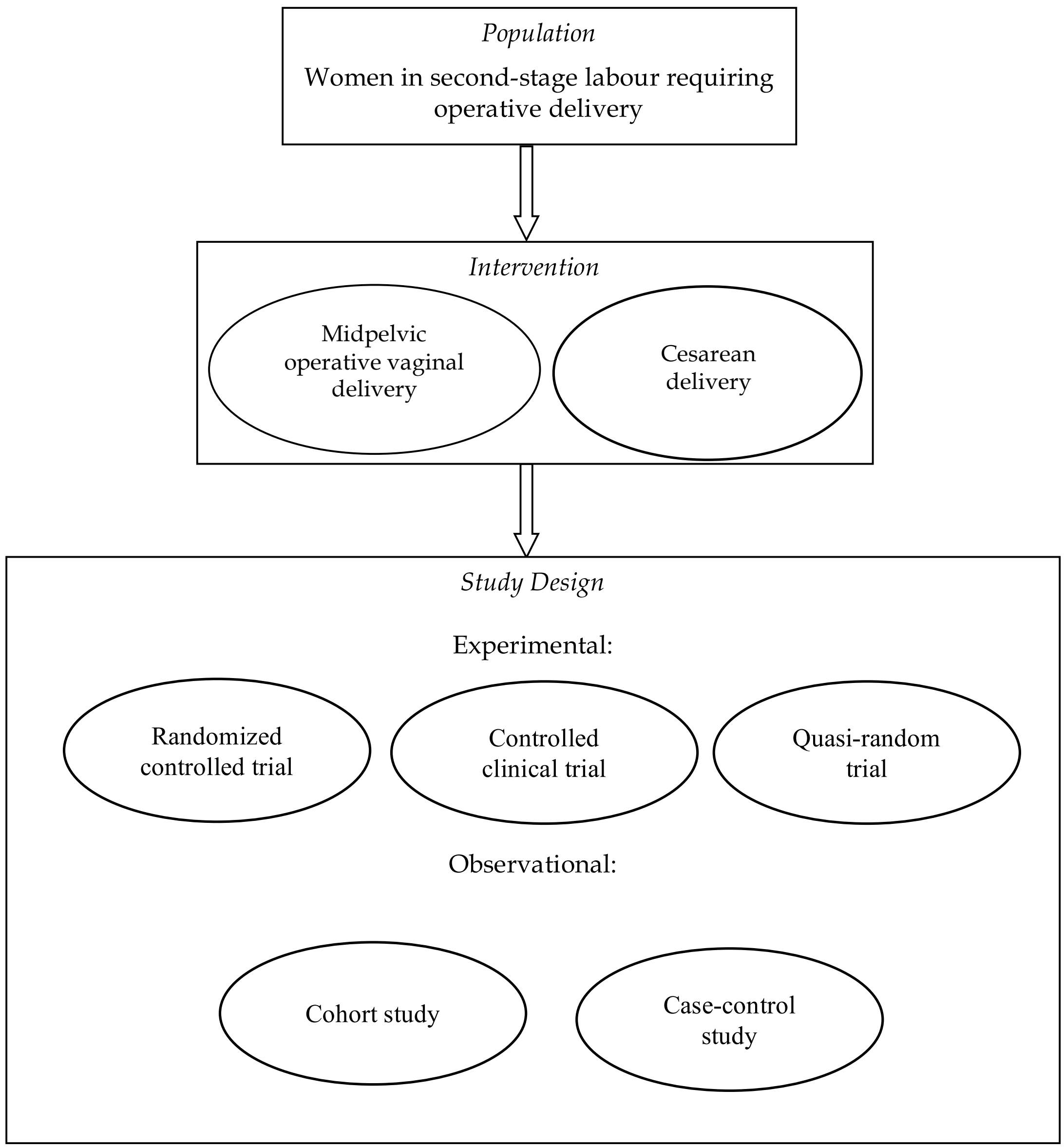
176. de Costa C. A sort of progress. *Lancet* 1998;351:1202-03.

177. Tuteur A. *Push Back: Guilt in the Age of Natural Parenting.* HarperCollins, Toronto, ON; 2016.

Appendices

Appendix to Chapter 1

Appendix Figure 1.1. Conceptual model for systematic review search strategy



Appendix Table 1.2 Systematic review search strategies

MEDLINE (Ovid) Search Results – Conducted 11-16-16
Database: Ovid MEDLINE® In-Process & Other Non-Indexed Citations and Ovid MEDLINE® <1946 to Present>
Search Strategy:

1 Labor Stage, Second/ (989)
2 second?stage.mp. (3)
3 Obstetric Labor Complications/ (14036)
4 labo?r complication?.tw. (208)
5 Fetal Distress/ (2856)
6 fetal distress.tw. (3493)
7 1 or 2 or 3 or 4 or 5 or 6 (19486)
8 Cesarean Section/ or Delivery, Obstetric/ (48373)
9 c?esarean.tw. (38107)
10 8 or 9 (63271)
11 Extraction, Obstetrical/ or Obstetrical Forceps/ or Vacuum Extraction, Obstetrical/ (3591)
12 (instrumental delivery or operative delivery).tw. (1372)
13 11 or 12 (4709)
14 exp Clinical Trial/ or double-blind method/ or (clinical trial* or randomized controlled trial or multicenter study).pt. or exp Clinical Trials as Topic/ or ((randomi?ed adj7 trial*) or (controlled adj3 trial*) or (clinical adj2 trial*) or ((single or doubl* or tripl* or treb*) and (blind* or mask*))).ti,ab. (1044592)
15 exp Case-Control Studies/ or Control Groups/ or Matched-Pair Analysis/ or ((case* adj5 control*) or (case adj3 comparison*) or control group*).ti,ab. (855698)
16 cohort.ti,ab. Or exp Cohort Studies/ or longitudinal.ti,ab. Or prospective.ti,ab. Or retrospective.ti,ab. (1508942)
17 exp Cross-Sectional Studies/ or cross-sectional.ti,ab. Or “prevalence study”.ti,ab. (210171)
18 exp Epidemiologic Studies/ or “epidemiologic study”.ti,ab. (1490535)
19 14 or 15 or 16 or 17 or 18 (2740354)
20 7 and 10 and 13 (705)
21 7 and 10 and 13 and 19 (336)

Embase (Ovid) Search Results – Conducted 11-16-16
Database: Embase <1974 to Present>
Search Strategy:

1 labor stage 2/ (842)
2 second?stage.mp. (9)
3 labor complication/ (9264)
4 labo?r complication?.tw. (222)
5 fetus distress/ (5343)
6 fetal distress.tw. (4482)
7 1 or 2 or 3 or 4 or 5 or 6 (17133)
8 cesarean section/ (55507)

Appendix Table 1.2 (cont'd) Systematic review search strategies

9 c?esarean.tw. (48849)
10 8 or 9 (67062)
11 instrumental delivery/ or forceps delivery/ or vacuum extraction/ (5749)
12 (instrumental delivery or operative delivery).tw. (1932)
13 11 or 12 (6691)
14 7 and 10 and 13 (571)
15 Clinical trial/ or Randomized controlled trial/ or Randomization/ or Single blind procedure/ or Double blind procedure/ or Crossover procedure/ or Placebo/ or Randomi?ed controlled trial$.tw. or Rct.tw. or Random allocation.tw. or Randomly allocated.tw. or Allocated randomly.tw. or (allocated adj2 random).tw. or Single blind$.tw. or Double blind$.tw. or Placebo$.tw. or Prospective study/ (1309423)
16 Clinical study/ or Case control study.mp. or Family study/ or Longitudinal study/ or Retrospective study/ or Prospective study/ or Cohort analysis/ or (Cohort adj (study or studies)).mp. or (Case control adj (study or studies)).tw. or (follow up adj (study or studies)).tw. or (observational adj (study or studies)).tw. or (epidemiologic$ adj (study or studies)).tw. or (cross sectional adj (study or studies)).tw. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword] (1043706)
17 15 or 16 (2073664)
18 7 and 10 and 13 and 17 (206)

EBM Reviews – Cochrane Central Register of Controlled Trials (Ovid) Search Results – Conducted 11-16-16
Database: EBM Reviews – Cochrane Central Register of Controlled Trials <November 2016>
Search Strategy:

1 labor stage, second/ (116)
2 second?stage.mp. (0)
3 Obstetric Labor Complications/ (334)
4 labo?r complication?.tw. (7)
5 Fetal Distress/ (103)
6 fetal distress.tw. (254)
7 1 or 2 or 3 or 4 or 5 or 6 (693)
8 Cesarean Section/ (1893)
9 c?esarean.tw. (4088)
10 8 or 9 (4250)
11 extraction, obstetrical/ or obstetrical forceps/ or vacuum extraction, obstetrical/ (116)
12 (instrumental delivery or operative delivery).tw. (186)
13 11 or 12 (281)
14 7 and 10 and 13 (37)

CINAHL (EBSCO) Search Results – Conducted 11-16-16
(MH "Labor Stage, Second") or (TI "second stage of labo?r") or (AB "second stage of labo?r") or (MH "Labor Complications") or (TI "labo?ur complication?") or (AB "labo?ur

Appendix Table 1.2 (cont'd) Systematic review search strategies

complication?”) or (MH “Obstetric Emergencies”) or (MH “Fetal Distress”) or (TI “fetal distress”) or (AB “fetal distress”) AND
(MH “Cesarean Section”) or (TI c?esarean) or (AB c?esarean) AND
(MH “Vacuum Extraction, Obstetrical”) or (MH “Obstetrical Forceps”) or (TI “instrumental delivery”) or (AB “instrumental delivery”) or (TI “operative delivery”) or (AB “operative delivery”)

Science Citation Index (Web of Science) Search Results – Conducted 11-16-16
“second stage of labo?r” or “labo?ur complication?” or “fetal distress” in Topic AND
c?esarean in Topic AND
“vacuum extraction” or “forceps delivery” or “instrumental delivery” or “operative delivery” in Topic

Appendix Table 1.3. Systematic review data extraction form

Review Title: A comparison of perinatal and maternal outcomes following midpelvic operative vaginal delivery and cesarean delivery

Reviewer: __________ Date Reviewed: __________

Notes:

Study ID: __________

Study Information Author & Year: Citation:

Type of Study ☐ RCT ☐ Controlled Clinical Trial ☐ Quasi RCT ☐ Cohort ☐ Case-Control ☐ Case Series ☐ Other

Study Eligibility	Inclusion	Exclusion
Participants:		
Interventions:		
Comparisons:		
Outcomes:		

Participants: Maternal age Gestational Age Study Setting Geographical region Socioeconomic status Comorbid conditions Population at common point in course of condition?	

Interventions: How was intervention measured/determined? Were case definitions well described and valid? Were exposure and comparison measures well described and valid? Were exposure and comparison factors measured prior to outcomes? Did exposure/comparison status change during follow-up? Were other interventions/exposures similar in both groups during follow-up? Were all participants accounted for at study conclusion? Who delivered intervention?	

Comparisons: Selected study participants representative of all eligible? Eligible population well described? Were relevant demographics of participants reported?	
Outcomes: How were outcomes measured? Were exposure and comparison measures equally well described among all participants? Were outcome assessors blinded to status? Were selected outcomes measurable and meaningful? Was follow-up time meaningful?	

Analysis: What type of analysis was performed? Was the analysis appropriate? Were covariates/ confounders measured and adjusted for? Were effect estimates given or calculable? Was the precision of effect estimates given or calculated? Intention-to-treat analysis employed?	
Results: Was the study internally valid? Are results of sufficient magnitude and precision? Can the generalizability of the results be determined?	

Appendix Table 1.4. List of excluded studies at full-text review stage for systematic review

First Author	Year	Title	Justification for Exclusion
Abenhaim HA	2007	Effect of instrument preference for operative deliveries on obstetrical and neonatal outcomes.	Incorrect pelvic station (no midpelvic OVD reported)
Bailit JL	2016	Evaluation of delivery option for second-stage events	Incorrect pelvic station (no midpelvic OVD reported, only low-pelvic and outlet OVD)
Barton DPJ	1992	Prolonged spontaneous labour in primigravidae whose labour was actively managed: Results of an audit.	Incorrect pelvic station (no midpelvic OVD reported)
Bashore RA	1990	A comparison of the morbidity of midforceps and cesarean delivery.	Outdated definition of midpelvic station
Benedetti TJ	1978	Shoulder dystocia. A complication of fetal macrosomia and prolonged second stage of labor with midpelvic delivery.	Incorrect pelvic station (no differentiation)
Bowes WA Jr.	1980	Current role of the midforceps operation.	Outdated definition of midpelvic station
Brown SJ	2012	Fecal incontinence during the first 12 months postpartum: Complex causal pathways and implications for clinical practice.	Lack of appropriate outcome (no results for midpelvic OVD)
Chang X	2007	Vacuum assisted delivery in Ecuador for prolonged second stage of labor: Maternal-neonatal outcome.	No comparison to cesarean delivery
Cheng YW	2007	Duration of the second stage of labor in multiparous women: maternal and neonatal outcomes.	Incorrect pelvic station (no differentiation)
Cheng YW	2007	How long is too long: Does a prolonged second stage of labor in nulliparous women affect maternal and neonatal outcomes?	Incorrect pelvic station (no differentiation)
Chow SL	1987	Rotational delivery with Kielland's forceps.	No comparison to cesarean delivery
Contag SA	2010	Neonatal outcomes and operative vaginal delivery versus cesarean delivery.	Incorrect pelvic station (low-pelvic OVD)
Cope I	1971	Operative delivery in obstetrics.	Improper study type (review)
Corrado F	1994	[Surgical delivery: comparison of two 5-year periods]	Foreign-language publication (Italian)
Dierker LJ Jr.	1985	The midforceps: maternal and neonatal outcomes.	Outdated definition of midpelvic station

First Author	Year	Title	Justification for Exclusion
Dierker LJ Jr.	1986	Midforceps deliveries: long-term outcome of infants.	Outdated definition of midpelvic station
Dundar O	2007	[Maternal and neonatal results of vacuum extraction.]	Foreign-language publication (Turkish)
Dupuis O	2005	[Decision-to-deliver interval for forceps delivery and cesarean section: 137 extractions for abnormal fetal heart rhythm during labor]	Foreign-language publication (French)
Ducarme G	2015	Maternal and neonatal morbidity after attempted operative vaginal delivery according to fetal head station	Did not compare midpelvic OVD with cesarean. Compared midpelvic OVD with low OVD. Spatula used in >80% of OVD at midpelvic station
Ebulue V	2008	Fear of failure: are we doing too many trials of instrumental delivery in theatre?	Lack of appropriate outcome (success rates only)
Farrell SA	2002	Cesarean section versus forceps-assisted vaginal birth: It's time to include pelvic injury in the risk-benefit equation.	Improper study type (review with no relevant references)
Fong A	2014	Temporal trends and morbidities of vacuum, forceps, and combined use of both.	No comparison with cesarean, no differentiation by pelvic station.
Gilstrap LC 3rd	1984	Neonatal acidosis and method of delivery.	Outdated definition of midpelvic station
Gopalani S	2004	Factors predictive of failed operative vaginal delivery.	Incorrect pelvic station (no differentiation)
Hagadorn-Freathy	1991	Validation of the 1988 ACOG forceps classification system	No comparison with cesarean
Halscott TL	2015	Maternal and neonatal outcomes by attempted mode of operative delivery from a low station in the second stage of labour	No midpelvic OVD (only low-pelvic OVD included)
Hofmeyr GJ	2012	Operative versus conservative management for 'fetal distress' in labour.	Incorrect pelvic station (no midpelvic OVD reported)
Jain V	1993	Mode of delivery in deep transverse arrest.	Incorrect pelvic presentation (transverse fetal position)
Klintorp S	1993	[Course of pregnancies and labors in a department of general surgery. A prospective study of pregnancies during a 1-year period at Horsholms hospital]	Foreign-language publication (Danish)

First Author	Year	Title	Justification for Exclusion
Krause W	1985	[Significance of trial vacuum extraction in the framework of obstetric surgery in vertex presentation]	Foreign-language publication (German)
Liebling RE	2004	Pelvic floor morbidity up to one year after difficult instrumental delivery and cesarean section in the second stage of labor: a cohort study.	Incorrect pelvic station (no differentiation)
McKelvey A	2010	Cesarean section in the second stage of labour: a retrospective review of obstetric setting and morbidity.	No comparison to cesarean delivery
Murphy DJ	2001	Failure to progress in the second stage of labour.	Improper study type (review)
Murphy DJ	2001	Cohort study of the decision to delivery interval and neonatal outcome for emergency operative vaginal delivery.	Incorrect pelvic station (no differentiation)
Murphy DJ	2001	Early maternal and neonatal morbidity associated with operative delivery in second stage of labour: a cohort study.	Observations included in a subsequent study selected for analysis
Okunwobi-Smith Y	2000	Decision to delivery intervals for assisted vaginal vertex delivery.	Incorrect pelvic station (no differentiation)
Olagundoye V	2007	The impact of a trial of instrumental delivery in theatre on neonatal outcome.	Incorrect pelvic station (no differentiation)
Olah KS	2005	Reversal of the decision for Cesarean section in the second stage of labour on the basis of consultant vaginal assessment.	Lack of appropriate outcome (physician decision-making process, not perinatal/maternal outcomes)
Patel RR	2003	Effect of operative delivery in the second stage of labor on breastfeeding success.	Incorrect pelvic station (no differentiation)
Patel RR	2004	Forceps delivery in modern obstetric practice.	Improper study type (review)
Rajasekar D	1997	Urinary tract injuries during obstetric intervention	Incorrect pelvic station (no differentiation)
Revah A	1997	Failed trial of vacuum or forceps--maternal and fetal outcome.	Incorrect pelvic station (no differentiation)
Ryan D	2006	Cesarean delivery in the second stage of labour: Revisit the past.	Improper study type (editorial letter)
Sadan O	2003	What to do after a failed attempt of vacuum delivery?	No comparison to cesarean delivery
Smith LJ	2007	Impact of birthing practices on the breastfeeding dyad.	Improper study type (textbook entry)
Spencer C	2006	Cesarean delivery in the second stage of labour: better training in instrumental delivery may reduce rates.	Improper study type (editorial)

First Author	Year	Title	Justification for Exclusion
Tan KH	1992	Kielland's forceps delivery: is it a dying art?	No comparison to cesarean delivery
Thompson JF	2002	Prevalence and persistence of health problems after childbirth: associations with parity and method of birth.	Incorrect stage of labour
Traub AI	1984	A continuing use for Kielland's forceps?	Incorrect pelvic station (no differentiation)
Vacca A	1983	Portsmouth operative delivery trial: a comparison vacuum extraction and forceps delivery.	Incorrect pelvic station (no differentiation)
Walsh	2013	Mode of delivery at term and adverse neonatal outcomes	Not restricted to midpelvic station.
Werner	2011	Mode of delivery in nulliparous women and neonatal intracranial injury	Not restricted to midpelvic station. Cesarean deliveries were not restricted to those in second stage of labour
Whitby EH	2004	Frequency and natural history of subdural haemorrhages in babies and relation to obstetric factors.	Incorrect pelvic station (no differentiation)

Appendix Table 1.5. Characteristics of included studies

Study component	Study characteristics
Bashore 1990	
Methods	Retrospective cohort study
Participants	358 midforceps and 486 cesarean deliveries
Interventions	Midpelvic forceps and cesarean deliveries during the second stage of labour
Outcomes	*Neonatal:* Apgar score <= 4 at 1 min, Apgar score <7 at 5 min, arterial and venous umbilical cord blood gas pH and base excess, shoulder dystocia, cephalohematoma, facial palsy, admission to NICU. *Maternal*: cervical/vaginal lacerations, third- and fourth-degree perineal lacerations, uterine extension, inadvertent cystotomy, febrile morbidity, pulmonary embolism, deep vein thrombosis, blood transfusion.
Lowe 1987	
Methods	Retrospective cohort study
Participants	Two-hundred and twenty-five women delivering singleton pregnancies of 37-43 weeks in duration at St. Mary's Maternity Hospital in Portsmouth, United Kingdom. All deliveries were expedited due to a lack of significant progress after at least an hour of pushing in the second stage of labour; performed when the fetal station was no lower than +2 cm below the ischial spines; and driven by indications other than suspected fetal distress alone.
Interventions	Trial of operative vaginal delivery (OVD) versus primary Cesarean delivery and unexpected failure of instrumentation during vaginal delivery.
Outcomes	*Neonatal*: "resuscitation score" (originally introduced by Healey et al in 1982, and designed to identify neonates with appreciable hypoxia and in need of resuscitation); admission to special care; need for phototherapy; trauma (cephalohematoma, bruising and laceration, facial palsy, or Erb's palsy), abnormal neurological behaviour, and mortality. *Maternal*: puerperal pyrexia, postpartum transfusion, and injury (including anal, rectal, and bladder tears and extension of surgical incision).
Murphy 2003	
Methods	Prospective cohort study
Participants	Three hundred and ninety-three women with term, singleton, cephalic pregnancies, >37 weeks' gestation who required operative delivery in theatre at full dilation between February 1999 and February 2000 from maternity units in two teaching hospitals in Bristol, United Kingdom.
Interventions	Midpelvic operative vaginal delivery versus cesarean delivery.
Outcomes	*Neonatal*: Admission to the Special Care Baby Unit (NICU), low Apgar score, low pH on cord blood assays, trauma (bruising, scalp and facial lacerations, cephalohematoma, cerebral hemorrhage, or brachial plexus injury), sepsis (which required microbiological confirmation), and neurological complications (meningitis, seizures and neonatal encephalopathy). *Maternal*: hemorrhage, genital tract trauma, and length of hospital stay.
Robertson 1990	
Methods	Retrospective cohort study
Participants	Singleton pregnancies, cephalic presentation, gestational age ≥ 37 weeks, experiencing a second stage of labour longer than 30 minutes.
Interventions	Four categories (midforceps, midpelvic vacuum, low-forceps, low-vacuum) of vaginal delivery versus cesarean delivery.
Outcomes	*Neonatal*: Admission to the NICU, days of ventilator use, time to achieve sustained, spontaneous respirations, necessity for active resuscitation at birth, Apgar scores at 1 and 5 minutes, presence of birth injury, birth weight, and umbilical arterial and venous cord gas values (pH, Base excess, PO2 and PCO2). *Maternal*: duration of intrapartum/postpartum hospital stay, blood transfusions, and estimated blood loss at delivery.

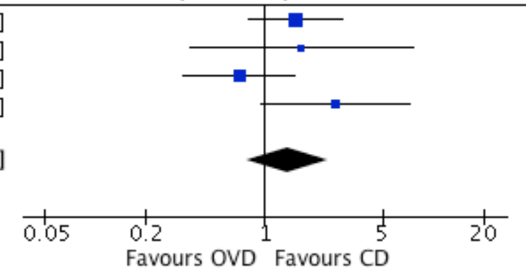
Appendix Figure 1.2. Forest plots for outcome comparisons

A. Admission to NICU

Study or Subgroup	Operative vaginal (OVD) Events	Operative vaginal (OVD) Total	Cesarean delivery Events	Cesarean delivery Total	Weight	Odds Ratio IV, Random, 95% CI
Bashore_1990	21	358	19	486	36.7%	1.53 [0.81, 2.89]
Lowe_1987	14	183	2	42	11.3%	1.66 [0.36, 7.58]
Murphy_2003	23	291	11	102	30.7%	0.71 [0.33, 1.51]
Robertson_1990	9	147	7	290	21.3%	2.64 [0.96, 7.23]
Total (95% CI)		**979**		**920**	**100.0%**	**1.37 [0.78, 2.39]**
Total events	67		39			

Heterogeneity: $Tau^2 = 0.12$; $Chi^2 = 4.68$, df = 3 (P = 0.20); $I^2 = 36\%$
Test for overall effect: Z = 1.11 (P = 0.27)

Odds Ratio
IV, Random, 95% CI

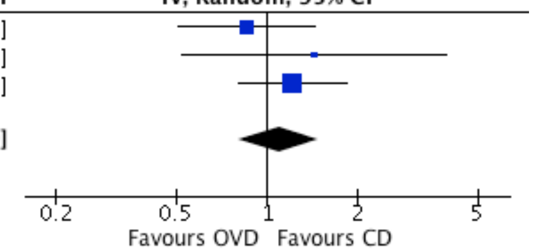


B. pH of umbilical cord arterial blood <7.10

Study or Subgroup	Operative vaginal (OVD) Events	Operative vaginal (OVD) Total	Cesarean delivery Events	Cesarean delivery Total	Weight	Odds Ratio IV, Random, 95% CI
Bashore_1990	25	358	39	486	34.4%	0.86 [0.51, 1.45]
Murphy_2003	20	291	5	102	9.2%	1.43 [0.52, 3.92]
Robertson_1990	59	147	103	290	56.3%	1.22 [0.81, 1.83]
Total (95% CI)		**796**		**878**	**100.0%**	**1.10 [0.81, 1.49]**
Total events	104		147			

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 1.35$, df = 2 (P = 0.51); $I^2 = 0\%$
Test for overall effect: Z = 0.59 (P = 0.56)

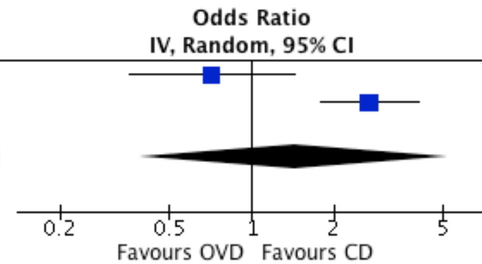
Odds Ratio
IV, Random, 95% CI



C. Neonatal resuscitation

Study or Subgroup	Operative vaginal (OVD) Events	Operative vaginal (OVD) Total	Cesarean delivery Events	Cesarean delivery Total	Weight	Odds Ratio IV, Random, 95% CI
Lowe_1987	60	183	17	42	47.7%	0.72 [0.36, 1.43]
Robertson_1990	81	147	91	290	52.3%	2.68 [1.78, 4.04]
Total (95% CI)		**330**		**332**	**100.0%**	**1.43 [0.39, 5.20]**
Total events	141		108			

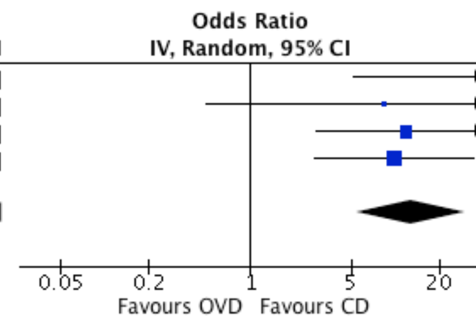
Heterogeneity: $Tau^2 = 0.79$; $Chi^2 = 10.42$, df = 1 (P = 0.001); $I^2 = 90\%$
Test for overall effect: Z = 0.54 (P = 0.59)



D. Birth trauma

Study or Subgroup	Operative vaginal (OVD) Events	Operative vaginal (OVD) Total	Cesarean delivery Events	Cesarean delivery Total	Weight	Odds Ratio IV, Random, 95% CI
Bashore_1990	28	358	0	486	9.4%	83.90 [5.10, 1379.10]
Lowe_1987	16	183	0	42	9.2%	8.37 [0.49, 142.39]
Murphy_2003	56	291	2	102	36.0%	11.91 [2.85, 49.77]
Robertson_1990	13	140	3	290	45.4%	9.79 [2.74, 34.96]
Total (95% CI)		**972**		**920**	**100.0%**	**12.67 [5.37, 29.89]**
Total events	113		5			

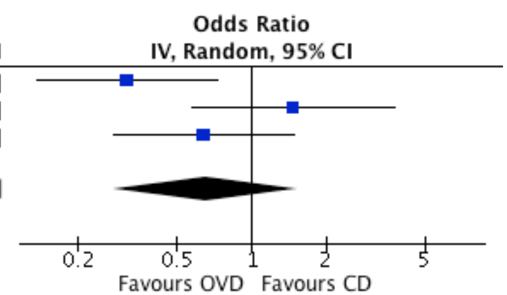
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 2.00$, df = 3 (P = 0.57); $I^2 = 0\%$
Test for overall effect: Z = 5.80 (P < 0.00001)



E. Maternal blood transfusion

Study or Subgroup	Operative vaginal (OVD) Events	Operative vaginal (OVD) Total	Cesarean delivery (CD) Events	Cesarean delivery (CD) Total	Weight	Odds Ratio IV, Random, 95% CI
Bashore_1990	7	358	29	486	34.3%	0.31 [0.14, 0.73]
Lowe_1987	36	183	6	42	31.6%	1.47 [0.58, 3.75]
Murphy_2003	17	291	9	102	34.1%	0.64 [0.28, 1.49]
Total (95% CI)		**832**		**630**	**100.0%**	**0.65 [0.28, 1.54]**
Total events	60		44			

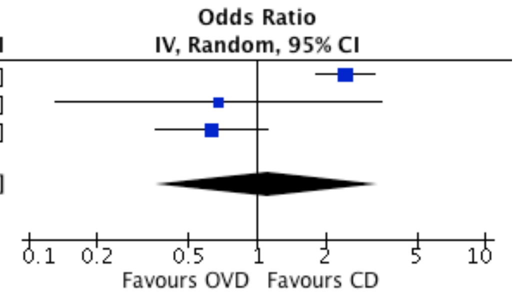
Heterogeneity: $Tau^2 = 0.37$; $Chi^2 = 5.79$, df = 2 (P = 0.06); $I^2 = 65\%$
Test for overall effect: Z = 0.98 (P = 0.33)



F. Obstetric trauma

Study or Subgroup	Operative vaginal (OVD) Events	Operative vaginal (OVD) Total	Cesarean delivery (CD) Events	Cesarean delivery (CD) Total	Weight	Odds Ratio IV, Random, 95% CI
Bashore_1990	159	358	120	486	40.5%	2.44 [1.82, 3.27]
Lowe_1987	6	183	2	42	22.0%	0.68 [0.13, 3.48]
Murphy_2003	43	291	22	102	37.5%	0.63 [0.36, 1.12]
Total (95% CI)		**832**		**630**	**100.0%**	**1.11 [0.36, 3.39]**
Total events	208		144			

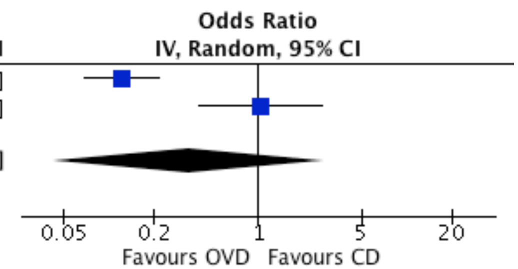
Heterogeneity: $Tau^2 = 0.78$; $Chi^2 = 18.38$, df = 2 (P = 0.0001); $I^2 = 89\%$
Test for overall effect: Z = 0.18 (P = 0.86)



G. Maternal febrile morbidity

Study or Subgroup	Operative vaginal (OVD) Events	Operative vaginal (OVD) Total	Cesarean delivery (CD) Events	Cesarean delivery (CD) Total	Weight	Odds Ratio IV, Random, 95% CI
Bashore_1990	14	358	122	486	51.7%	0.12 [0.07, 0.22]
Lowe_1987	27	183	6	42	48.3%	1.04 [0.40, 2.70]
Total (95% CI)		**541**		**528**	**100.0%**	**0.34 [0.04, 2.80]**
Total events	41		128			

Heterogeneity: $Tau^2 = 2.14$; $Chi^2 = 14.25$, df = 1 (P = 0.0002); $I^2 = 93\%$
Test for overall effect: Z = 1.00 (P = 0.32)



Appendix to Chapter 3

Appendix Table 3.1. International Classification of Diseased and Related Health Problems Tenth Revision, Canada (ICD-10-CA) and Canadian Classification of Health Interventions (CCI) codes used for population selection and to classify determinants (interventions), outcomes, and confounders

Diagnosis/Procedure	ICD-10-CA	CCI	Study use
Single live birth	Z37.0		Inclusion criteria
Single stillbirth	Z37.1		
Midpelvic forceps delivery		5.MD.53.KN, 5.MD.53.KM	
Midpelvic vacuum delivery		5.MD.54.KN, 5.MD.54.KM	
Midpelvic sequential instrumental delivery		5.MD.55.KN, 5.MD.54.KM	
Failed forceps delivery			
Failed instrument	O66.5		
Cesarean delivery with forceps		5.MD.60.RC, 5.MD.60.JZ, 5.MD.60.KC, 5.MD.60.RA, 5.MD.60.RE, 5.MD.60.JW, 5.MD.60.RG	
Failed vacuum delivery			
Failed instrument	O66.5		
Cesarean delivery with vacuum		5.MD.60.RD, 5.MD.60.KA, 5.MD.60.KD, 5.MD.60.RB, 5.MD.60.RF, 5.MD.60.JX, 5.MD.60.RH	
Failed sequential instrumental delivery			
Failed instrument	O66.5		
Cesarean delivery with sequential instruments		5.MD.60.C	
Cesarean delivery with labour			
Cesarean delivery		5.MD.60.KE, 5.MD.60.JY, 5.MD.60.KB, 5.MD.60.KG, 5.MD.60.KF, 5.MD.60.AA, 5.MD.60.KT	
Labour	O62.0, O62.1, O62.3, O63.0, O63.1, O63.9, O74, O75.2, O75.3	5.AC.30, 5.LD.31, 5.MD.40, 5.MD.53.KN, 5.MD.54.KN, 5.MD.55.KN	

Diagnosis/Procedure	ICD-10-CA	CCI	Study use
Therapeutic abortions	O04	5.CA.20, 5.CA.24, 5.CA.88, 5.CA.89, 5.CA.90	Exclusion criteria
Breech presentation	O32.1, O64.1	5.MD.56	
Double forceps application (Scanzoni maneuver)		5.MD.53.KS, 5.MD.53.KP	
Forceps rotation only with manually assisted delivery (DeLee key-in-lock maneuver)		5.MD.53.JE, 5.MD.53.JD	
Chronic hypertension	O10, O11		
Preeclampsia	O14		
Eclampsia	O15		
Diabetes	O24		
Placenta praevia	O44		
Placental abruption	O45		
Congenital anomalies	Q		
Failed induction	O61		
Dystocia	O32, O33, O34.0, O34.1, O34.3-O34.9, O62.0, O62.1, O62.2, O62.4, O62.8, O62.9, O63, O66		Cohort definition
Fetal distress	O68, O69.0		
Prolonged second stage	O63.1		
Maternal age	DAD element		Confounder
Parity	DAD element		
Birth weight	DAD element		
Fiscal year	DAD element		
Maternal province of residence	DAD element		
Previous cesarean delivery	O34.20		
Institutional delivery volume	DAD element		
Practitioner	DAD element		
Stillbirth	Z37.1		Primary perinatal composite outcome
Neonatal death	DAD element		
Neonatal convulsions	P90		
Assisted ventilation by endotracheal intubation		1.GZ.31.CA-ND	
Severe birth trauma	P10, P11.0-P11.2, P11.4-P11.5 P12.2, P13.0, P13.2, P13.30, P13.38, P14.0, P14.1, P14.3, P15.0, P15.1		

Diagnosis/Procedure	ICD-10-CA	CCI	Study use
Respiratory distress	P22		Secondary perinatal outcome
Other respiratory conditions	P28		
Fetal asphyxia	P20		
Birth asphyxia	P21		
Intracranial haemorrhage due to hypoxia	P52		
Severe cerebral morbidity	P91		
Maternal death	O95, O96, O97, R96, R98, R99, DAD elements		Primary maternal composite outcome
Severe postpartum haemorrhage	O72 + DAD element (blood transfusion indicator variable)		
Shock	O75.1, T80.5, T886, R57		
Sepsis	O85		
Cardiac complications	O89.1, O74.2, O75.4, I21, I22, I46, I50, J81		
Acute renal failure	O90.4, N99.0, N17, N19		
Obstetric embolism	O88		
Evacuation of incisional haematoma		5.PC.73.JS	
Obstetric trauma	O70.2, O70.3, O71.3-O71.9	5.PC.80.JQ, 5.PC.80.JH	Secondary maternal outcome
3rd/4th degree perineal lacerations	O70.2, O70.3	5.PC.80.JQ	
Postpartum infection	O85, O86		
Postpartum haemorrhage	O72		
Postpartum haemorrhage – retained placenta	O72.0		
Postpartum haemorrhage – atonic	O72.1		
Postpartum haemorrhage – delayed	O72.2		

DAD, Discharge Abstract Database

Appendix Table 3.2. Additional details regarding maternal, infant and obstetric risk factors among women delivering term singletons by midpelvic operative vaginal delivery (OVD) or cesarean delivery with labor, Canada (excluding Quebec), 2003-2012 (N=187,234)

Maternal/neonatal characteristics	Attempted midpelvic forceps (n=24,274)	Attempted midpelvic vacuum (n=23,525)	Attempted sequential midpelvic OVD (n=4,012)	Cesarean delivery (n=135,423)	P-value
	No. (%)	No. (%)	No. (%)	No. (%)	
Maternal age (yr)					<0.0001
< 20	888 (11.3)	1001 (12.8)	199 (2.5)	5758 (73.4)	
20-24	3359 (11.8)	3545 (12.5)	676 (2.4)	20821 (73.3)	
25-29	7850 (13.6)	7242 (12.6)	1376 (2.4)	41198 (71.4)	
30-34	8144 (13.5)	7670 (12.7)	1236 (2.1)	43194 (71.7)	
35-39	3447 (12.6)	3413 (12.5)	437 (1.6)	20070 (73.3)	
40-44	564 (10.3)	630 (11.5)	85 (1.6)	4203 (76.7)	
≥45	22 (9.7)	24 (10.5)	3 (1.3)	179 (78.5)	
Sex					<0.0001
Female	10973 (13.2)	10429 (12.5)	1593 (1.9)	60322 (72.4)	
Male	13301 (12.8)	13096 (12.6)	2419 (2.3)	75101 (72.3)	
Gestational age (wks)					<0.0001
37	1068 (14.0)	1233 (16.1)	146 (1.9)	5194 (68.0)	
38	2939 (14.7)	3114 (15.6)	441 (2.2)	13481 (67.5)	
39	6311 (15.2)	6168 (14.8)	1026 (2.5)	28069 (67.5)	
40	8551 (13.2)	8430 (13.0)	1457 (2.3)	46318 (71.5)	
41	5405 (10.1)	4580 (8.6)	942 (1.8)	42361 (79.5)	
Birth weight (g)					<0.0001
<2500	208 (8.1)	354 (13.8)	26 (1.0)	1979 (77.1)	
2500-2999	2671 (14.1)	3310 (17.3)	367 (1.9)	12641 (66.6)	
3000-3499	9048 (14.7)	9153 (14.8)	1479 (2.4)	42085 (68.1)	
3500-3999	8820 (13.0)	7774 (11.5)	1522 (2.2)	49764 (73.3)	
4000-4499	3028 (10.3)	2532 (8.6)	533 (1.8)	23337 (79.3)	
≥4500	499 (7.6)	402 (6.1)	85 (1.3)	5617 (85.1)	
Augmentation					<0.0001
Yes	7936 (10.8)	9395 (12.8)	1382 (1.9)	54584 (74.5)	
No	16338 (14.3)	14130 (12.4)	2630 (2.3)	80839 (71.0)	
Induction					<0.0001
Yes	6840 (8.8)	6427 (8.3)	1155 (1.5)	63231 (81.4)	
No	17434 (15.9)	17098 (15.6)	2857 (2.6)	72192 (65.9)	
Episiotomy					<0.0001
Yes	14897 (60.7)	7631 (31.1)	2025 (8.3)	0 (0.0)	

No	9377 (5.8)	15894 (9.8)	1987 (1.2)	135423 (83.2)	
Provider					<0.0001
Obstetrician	23607 (13.5)	20253 (11.6)	3772 (2.2)	127173 (72.8)	
General practitioner	493 (6.1)	2828 (35.0)	204 (2.5)	4569 (56.5)	
Other	174 (4.0)	444 (10.2)	36 (0.8)	3681 (84.9)	
Institutional delivery volume					<0.0001
High	5930 (24.4)	8537 (23.3)	1068 (2.9)	21125 (57.6)	
Medium	6461 (19.5)	2580 (7.8)	600 (1.8)	23526 (70.9)	
Low	11883 (10.1)	12408 (10.6)	2344 (2.0)	90772 (77.3)	
Province					<0.0001
Newfoundland	281 (9.5)	127 (4.3)	14 (0.5)	2524 (85.7)	
Prince Edward Island	43 (5.4)	42 (5.3)	10 (1.3)	698 (88.0)	
Nova Scotia	443 (6.9)	225 (3.5)	73 (1.1)	5685 (88.5)	
New Brunswick	514 (10.7)	220 (4.6)	81 (1.7)	4003 (83.1)	
Ontario	10956 (12.6)	7708 (8.9)	1351 (1.6)	66649 (76.9)	
Manitoba	421 (6.2)	773 (11.3)	73 (1.1)	5576 (81.5)	
Saskatchewan	762 (11.3)	775 (11.5)	223 (3.3)	4966 (73.8)	
Alberta	6460 (15.0)	11298 (26.2)	1525 (3.5)	23896 (55.3)	
British Columbia	4381 (15.5)	2267 (8.0)	648 (2.3)	21009 (74.2)	
Territories*	13 (2.4)	90 (16.9)	14 (2.6)	417 (78.1)	
Fiscal year					<0.0001
2003	1798 (14.4)	1422 (11.4)	270 (2.2)	8996 (72.1)	
2004	2629 (14.7)	2276 (12.7)	467 (2.6)	12547 (70.0)	
2005	2624 (14.6)	2078 (11.5)	410 (2.3)	12925 (71.7)	
2006	2668 (14.3)	2413 (12.9)	444 (2.4)	13193 (70.5)	
2007	2719 (13.6)	2712 (13.6)	500 (2.5)	14005 (70.3)	
2008	2579 (13.0)	2696 (13.6)	477 (2.4)	14123 (71.1)	
2009	2490 (12.5)	2567 (12.9)	423 (2.1)	14499 (72.6)	
2010	2368 (12.1)	2431 (12.4)	348 (1.8)	14437 (73.7)	
2011	2274 (11.5)	2498 (12.7)	378 (1.9)	14596 (73.9)	
2012	2125 (10.1)	2432 (11.6)	295 (1.4)	16102 (76.8)	

*Territories include North West Territories, Yukon, and Nunavut.

Appendix Table 3.3. Perinatal and maternal trauma among operative vaginal deliveries (OVD) and cesarean deliveries

Outcome	Cesarean		Attempted midpelvic forceps			Attempted midpelvic vacuum			Attempted sequential OVD		
	n	%	n	%	AOR (95% CI)	n	%	AOR (95% CI)	n	%	AOR (95% CI)
Dystocia											
Birth trauma	887	1.51	646	6.45	4.53 (4.08-5.04)	707	11.1	7.13 (6.41-7.93)	220	14.0	9.52 (8.10-11.2)
Intracranial hemorrhage	6	0.01	<5	<0.05	3.91 (1.10-13.9)*	7	0.11	10.7 (3.60-31.9)*	<5	<0.32	12.5 (2.52-61.9)*
Injury to CNS	13	0.02	57	0.57	25.9 (14.2-47.3)*	<5	<0.08	2.83 (0.92-8.67)*	<5	<0.32	11.5 (3.76-35.4)*
Injury to PNS	19	0.03	71	0.71	27.6 (16.5-46.1)	35	0.55	19.9 (11.2-35.4)	14	0.89	34.0 (16.8-68.8)
Injury to scalp	561	0.95	343	3.42	3.56 (3.10-4.09)	588	9.19	8.94 (7.90-10.1)	173	11.0	11.0 (9.15-13.2)
Injury to skeleton	162	0.28	69	0.69	2.81 (2.10-3.75)	50	0.78	2.63 (1.89-3.65)	9	0.57	2.01 (1.02-3.96)
Obstetric trauma	1652	2.81	2193	21.9	10.1 (9.41-10.8)	867	13.5	5.09 (4.65-5.57)	330	21.0	8.82 (7.72-10.1)
Perineal laceration-3rd/4th degree	<5	<0.01	1789	17.9	-	706	11.0	-	287	18.3	-
Cervical laceration	164	0.28	52	0.52	1.82 (1.32-2.50)	25	0.39	1.08 (0.70-1.67)	6	0.38	1.14 (0.50-2.59)
High vaginal laceration	35	0.06	246	2.46	37.6 (26.2-53.8)	42	0.66	9.21 (5.83-14.5)	22	1.40	18.9 (11.0, 32.5)
Injury to pelvic organ/joint	859	1.46	74	0.74	0.54 (0.42-0.69)	58	0.91	0.56 (0.43- 0.74)	13	0.83	0.56 (0.32-0.97)
Pelvic hematoma	43	0.07	23	0.23	3.14 (1.89-5.22)*	10	0.16	2.14 (1.07-4.25)*	<5	<0.32	3.48 (1.25-9.72)*
Extension of uterine incision	643	1.09	33	0.33	0.31 (0.22-0.44)	42	0.66	0.57 (0.42-0.79)	<5	<0.32	0.23 (0.09-0.61)
Fetal distress											
Birth trauma	1256	1.64	974	6.83	4.08 (3.74-4.45)	1715	10.0	5.54 (5.11-6.00)	421	17.3	10.3 (9.15-11.7)
Intracranial hemorrhage	9	0.01	13	0.09	7.77 (3.32-18.2)*	14	0.08	6.97 (3.02-16.1)*	15	0.61	52.7 (23.0-120.5)*
Injury to CNS	29	0.04	73	0.51	13.5 (8.70-20.8)	14	0.08	2.32 (1.21-4.47)	18	0.74	20.4 (11.2-37.3)
Injury to PNS	25	0.03	85	0.60	19.8 (12.6-31.2)	60	0.35	10.7 (6.55-17.5)	15	0.61	18.9 (9.84-36.3)
Injury to scalp	764	1.00	533	3.74	3.46 (2.09-3.88)	1461	8.53	7.53 (6.85-8.28)	329	13.5	12.3 (10.7-14.2)
Injury to skeleton	222	0.29	93	0.65	2.34 (1.83-3.00)	109	0.64	2.41 (1.89-3.08)	19	0.78	2.42 (1.50-3.90)
Obstetric trauma	2439	3.18	3234	22.7	9.08 (8.56-9.62)	1962	11.5	3.80 (3.56-4.06)	559	22.9	8.65 (7.79-9.61)
Perineal lacerations-3rd/4th degree	5	0.01	2587	18.2	-	1667	9.73	-	452	18.5	-
Cervical laceration	238	0.31	83	0.58	1.66 (1.29-2.14)	51	0.30	0.63 (0.46-0.86)	23	0.94	2.35 (1.52-3.64)
High vaginal laceration	51	0.07	403	2.83	39.4 (29.3-52.8)	96	0.56	7.44 (5.25-10.5)	45	1.84	23.6 (15.7-35.5)
Injury to pelvic organ/joint	1310	1.71	114	0.80	0.48 (0.39-0.58)	80	0.47	0.22 (0.18-0.28)	32	1.31	0.71 (0.50-1.01)
Pelvic hematoma	52	0.07	47	0.33	5.27 (3.51-7.92)	22	0.13	1.95 (1.15-3.30)	7	0.29	4.39 (1.97-9.77)
Extension of uterine incision	903	1.18	46	0.32	0.27 (0.20-0.37)	39	0.23	0.16 (0.12-0.22)	25	1.02	0.79 (0.53-1.18)

AOR, adjusted odds ratio; CI, confidence interval; CNS, central nervous system; PNS, peripheral nervous system. Adjusted odds ratios estimated using logistic regression with cesarean delivery as the reference group. All models adjusted for maternal age, parity, birth weight, previous cesarean delivery, province, and fiscal year.

* Crude odds ratio reported as adjusted odds ratio was undefined due to small numbers.

Appendix Table 3.4. Adjusted rate differences (per 100 deliveries) and number needed to treat (NNT) for perinatal and maternal outcomes following attempted midpelvic operative vaginal deliveries (OVD) compared with cesarean delivery

Outcome	**Attempted midpelvic forceps**			**Attempted midpelvic vacuum**			**Attempted midpelvic sequential OVD**		
Dystocia	**ARD**	**95% CI**	**NNT**	**ARD**	**95% CI**	**NNT**	**ARD**	**95% CI**	**NNT**
Severe perinatal morbidity/mortality*	0.93	(0.66−1.27)	107	1.02	(0.69−1.44)	98	1.69	(1.01−2.68)	59
Severe birth trauma†	0.95	(0.63−1.41)	105	1.04	(0.68−1.58)	96	1.46	(0.83−2.53)	69
Respiratory distress‡	0.52	(0.04−1.00)	192	0.40	(-0.12−1.04)	250	2.60	(1.32−4.16)	38
Other respiratory conditions§	0.36	(0.05−0.73)	281	0.45	(0.07−0.89)	225	0.16	(-0.45−1.07)	624
Birth trauma	5.33	(4.65−6.10)	19	9.25	(8.17−10.5)	11	12.9	(10.7−15.4)	8
Severe maternal morbidity/mortality‖	0.31	(0.05−0.63)	323	-0.09	(-0.35−0.23)	-1060	0.22	(-0.30−1.00)	464
Severe postpartum hemorrhage¶	0.59	(0.34−0.89)	170	0.15	(-0.06−0.44)	654	0.64	(0.15−1.41)	156
Postpartum infection**	-0.55	(-0.71−-0.36)	-182	-0.64	(-0.80−-0.40)	-157	-0.43	(-0.78−0.17)	-231
Postpartum hemorrhage	11.3	(10.3−12.5)	9	4.65	(3.77−5.64)	21	7.08	(5.27−9.20)	14
Obstetric trauma	25.6	(23.6−27.6)	4	11.5	(10.5−13.1)	9	22.0	(19.3−26.1)	5
Perineal lacerations-3rd/4th degree	17.9	(17.1−18.6)	6	11.0	(10.3−11.8)	9	18.3	(16.4−20.2)	5
High vaginal laceration	2.18	(1.50−3.14)	46	0.49	(0.29−0.80)	205	1.07	(0.60−1.88)	94
Injury to pelvic organs/joints	-0.67	(-0.85−-0.45)	-149	-0.64	(-0.85−-0.37)	-155	-0.64	(-0.99−-0.04)	-155
Extension of uterine incision	-0.76	(-0.85−-0.61)	-132	-0.47	(-0.63−-0.23)	-213	-0.84	(-1.00−-0.43)	-119
Fetal distress									
Severe perinatal morbidity/mortality*	0.61	(0.35−0.91)	164	0.21	(0.00−0.47)	469	2.19	(1.43−3.17)	46
Asst. ventilation (endotracheal)	-0.14	(-0.31−0.08)	-726	-0.44	(-0.58−-0.26)	-228	0.19	(-0.25−0.83)	532
Severe birth trauma†	0.84	(0.58−1.18)	120	0.71	(0.49−1.01)	141	1.86	(1.22−2.82)	54
Respiratory distress‡	0.14	(-0.35−0.63)	710	-0.21	(-0.63−0.28)	-473	4.02	(2.61−5.71)	25
Other respiratory conditions§	0.34	(-0.04−0.75)	296	0.11	(-0.23−0.49)	888	2.18	(1.16−3.34)	46
Fetal asphyxia	-0.50	(-0.67−-0.29)	-202	-0.48	(-0.65−-0.29)	-209	0.93	(0.34−1.72)	108
Severe cerebral morbidity††	0.05	(-0.04−0.18)	1921	-0.01	(-0.08−0.09)	-9126	0.41	(0.15−0.84)	245
Birth trauma	5.045	(4.49−5.65)	20	7.44	(6.73−8.19)	13	15.2	(13.4−17.5)	7
Severe maternal morbidity/mortality‖	0.37	(0.14−0.63	273	-0.54	(-0.67−-0.39)	-184	0.57	(0.09−1.21)	176
Severe postpartum hemorrhage¶	0.70	(0.48−0.96)	143	-0.12	(-0.23−0.01)	-818	0.62	(0.23−1.19)	160
Postpartum infection**	-0.76	(-0.88−-0.61)	-132	-0.93	(-1.04−-0.80)	-108	-0.41	(-0.75−0.07)	-241
Postpartum hemorrhage	9.07	(8.24−9.94)	11	3.64	(3.10−4.22)	28	7.37	(5.91−9.06)	14
Obstetric trauma	25.7	(24.1−27.4)	4	8.91	(8.15−9.74)	11	24.3	(21.6−27.4)	4
Perineal laceration-3rd/4th degree	18.2	(17.5−18.8)	6	9.69	(9.29−10.2)	10	18.5	(17.0−20.1)	5
High vaginal lac	2.56	(1.88−3.45)	39	0.43	(0.28−0.63)	233	1.50	(0.98−2.30)	67
Injury to pelvic organs/joints	-0.89	(-1.08−-0.67)	-113	-1.333	(-1.40-1.23)	-75	-0.50	(-0.85−0.02)	-202
Extension of uterine incision	-0.86	(-0.94−-0.74)	-116	-0.99	(-1.04−-0.92)	-101	-0.25	(-0.55−0.21)	-404

Number needed to treat refers to the number of cesarean deliveries that would need to be performed to avoid one case of the outcome of interest.
Adjusted rate differences estimated using cesarean delivery as the reference group. All models adjusted for maternal age, parity, birth weight, previous cesarean delivery, province, and fiscal year.
ARD, Adjusted risk difference; CI, confidence interval; NNT, number needed to treat.
* Severe perinatal morbidity/mortality includes stillbirth, neonatal death, convulsions, assisted ventilation by endotracheal tube, and severe birth trauma.
† Severe birth trauma included intracranial laceration and hemorrhage, skull fracture, severe injury to CNS, severe injury to PNS, long bone injury, subaponeurotic (subgaleal) hemorrhage, injury to liver, and injury to spleen.
‡ Respiratory distress included respiratory distress syndrome, transient tachypnoea of the newborn and other neonatal respiratory distress.
§ Other respiratory conditions included atelectasis, cyanotic attacks, apnea, respiratory failure and other respiratory conditions.
|| Severe maternal morbidity/mortality refers to composite severe maternal morbidity and mortality (see text).
¶ Severe postpartum hemorrhage includes postpartum hemorrhage requiring transfusion.
** Post-partum infection includes sepsis, infection of obstetric surgical wound, infection of the genital tract following delivery, urinary tract infection following delivery, genitourinary tract infections following delivery, pyrexia of unknown origin following delivery and other specified, puerperal infection.
†† Severe cerebral morbidity included hypoxic ischemic encephalopathy, cerebral ischemia, cerebral irritability, and cerebral depression.

Appendix Table 3.5 Adjusted odds ratios (AOR) and 95% confidence intervals (CI) assessing potential modification of the effect of midpelvic operative vaginal delivery on perinatal and maternal morbidity/mortality by institutional volume (stratified by instrument used and indication for operative delivery)

		Dystocia			Fetal distress		
		Institutional delivery volume			Institutional delivery volume		
Outcome	**Attempted midpelvic instrument(s)**	**Low AOR (95% CI)**	**Medium AOR (95% CI)**	**High AOR (95% CI)**	**Low AOR (95% CI)**	**Medium AOR (95% CI)**	**High AOR (95% CI)**
Severe perinatal morbidity/ mortality	Forceps	**3.02 (2.23-4.09)**	**3.60 (2.42-5.35)**	**1.71 (1.02-2.88)**	1.38 (1.15, 1.64)	1.07 (0.85-1.34)	1.86 (1.11-3.11)
	Vacuum	3.44 (2.55-4.64)	3.62 (2.21-5.93)	1.42 (0.59-3.39)	1.114 (0.93-1.33)	0.74 (0.53-1.02)	1.50 (1.06-2.13)
	Sequential	4.92 (3.07-7.89)	6.37 (3.20-12.7)	0.84 (0.11-6.18)	2.30 (1.71- 3.10)	1.39 (0.75- 2.56)	4.04 (2.42-6.75)
Severe maternal morbidity/ mortality	Forceps	1.10 (0.85-1.43)	1.31 (0.96-1.80)	1.40 (0.95-2.05)	1.41 (1.16-1.72)	1.04 (0.80-1.34)	1.14 (0.66-1.98)
	Vacuum	1.09 (0.83-1.42)	0.83 (0.49-1.39)	0.89 (0.41-1.94)	**0.76 (0.60-0.97)**	**0.63 (0.42-0.95)**	**0.32 (0.19-0.52)**
	Sequential	0.99 (0.57-1.72)	2.19 (1.18-4.08)	0.44 (0.06-3.16)	1.61 (1.09-2.38)	1.39 (0.71-2.73)	1.31 (0.65-2.64)

Bold text denotes statistically significant modification of the effect of mode of delivery on study outcomes by institutional delivery volume.
Adjusted odds ratios estimated using logistic regression with cesarean delivery as the reference group.
All models adjusted for maternal age, parity, birth weight, previous cesarean delivery, and fiscal year.
Severe perinatal morbidity/mortality includes stillbirth, neonatal death, neonatal convulsions, assisted ventilation by endotracheal intubation, and severe birth trauma.
Severe maternal morbidity/mortality includes maternal death, severe postpartum hemorrhage, shock, sepsis, cardiac complications, acute renal failure, obstetric embolism, and evacuation of incisional hematoma.

Appendix Table 3.6. Adjusted odds ratios and 95% confidence intervals showing the effects of successful and failed operative vaginal delivery on composite perinatal and maternal morbidity/mortality by instrument used and indication

	Dystocia				Fetal distress			
	Severe perinatal morbidity/mortality		Severe maternal morbidity/mortality		Severe perinatal morbidity/mortality		Severe maternal morbidity/mortality	
Midpelvic instrument(s)	**Success AOR (95% CI)**	**Failed AOR (95% CI)**	**Success AOR (95% CI)**	**Failed AOR (95% CI)**	**Success AOR (95% CI)**	**Failed AOR (95% CI)**	**Success AOR (95% CI)**	**Failed AOR (95% CI)**
Forceps	2.80 (2.22-3.54)	4.12 (2.72-6.24)	1.19 (0.98-1.43)	1.48 (1.01-2.19)	1.29 (1.12-1.49)	2.40 (1.78-3.24)	1.25 (1.07-1.47)	1.56 (1.07-2.28)
Vacuum	3.34 (2.54-4.40)	2.72 (1.71-4.31)	0.69 (0.51-0.92)	1.70 (1.21-2.39)	1.05 (0.91-1.22)	1.90 (1.40-2.59)	0.49 (0.40-0.61)	1.29 (0.88-1.91)
Sequential	4.97 (3.22-7.68)	3.79 (1.86-7.72)	1.24 (0.78-1.97)	0.95 (0.42-2.14)	2.19 (1.66-2.89)	3.22 (2.15-4.85)	1.03 (0.69-1.55)	2.82 (1.79-4.43)

AOR, adjusted odds ratio; CI, confidence interval; ICH, intracranial hemorrhage.

Adjusted odds ratios estimated using logistic regression with cesarean delivery as the reference group. All models adjusted for maternal age, parity, birth weight, previous cesarean delivery, region, and fiscal year.

Severe perinatal morbidity/mortality includes stillbirth, neonatal death, neonatal convulsions, assisted ventilation by endotracheal intubation, and severe birth trauma.

Severe maternal morbidity/mortality includes maternal death, severe postpartum hemorrhage, shock, sepsis, cardiac complications, acute renal failure, obstetric embolism, and evacuation of incisional hematoma.

Appendix Table 3.7. Perinatal and maternal outcome rates and adjusted odds ratios among attempted midpelvic vacuum deliveries with the inclusion of sequential midpelvic instrumentation

	Attempted midpelvic vacuum including sequential midpelvic instrument use					
	Dystocia (n=7,973)			Fetal distress (n=19,564)		
Outcome	**n**	**%**	**AOR (95% CI)**	**n**	**%**	**AOR (95% CI)**
Perinatal						
Composite morbidity/mortality	121	1.52	3.45 (2.76-4.32)	362	1.85	1.30 (1.15-1.48)
Stillbirth	<5	<0.06	0.92 (0.12-7.37)§	<5	<0.03	0.56 (0.07-4.55)¶
Neonatal death	<5	<0.06	-	<5	<0.03	0.59 (0.18-1.98)¶
Neonatal convulsions	12	0.15	1.15 (0.62-2.14)	55	0.28	0.99 (0.73-1.34)
Asst. ventilation (endotracheal)	26	0.33	1.19 (0.78-1.81)	158	0.81	0.66 (0.55-0.78)
Severe birth trauma*	87	1.09	14.8 (10.2-21.4)	174	0.89	11.6 (8.55-15.8)
Respiratory distress†	349	4.38	1.17 (1.04-1.31)	1257	6.43	0.98 (0.92-1.05)
Other respiratory conditions‡	167	2.09	1.20 (1.02-1.42)	767	3.92	1.08 (0.99-1.18)
Fetal asphyxia	18	0.23	0.96 (0.59-1.57)	237	1.21	0.83 (0.71-0.95)
Birth asphyxia	24	0.30	2.60 (1.63-4.14)	65	0.33	1.01 (0.76-1.33)
ICH due to hypoxia	11	0.14	9.02 (3.74-21.8)§	23	0.12	2.45 (1.44-4.18)
Severe cerebral morbidity‖	18	0.23	1.98 (1.16-3.38)	69	0.35	1.23 (0.92-1.63)
Maternal						
Composite morbidity/mortality	109	1.37	0.97 (0.79-1.20)	176	0.90	0.68 (0.58-0.81)
Maternal death	<5	<0.06	-	0	0.00	-
Severe postpartum hemorrhage¶	84	1.05	1.34 (1.05-1.70)	128	0.65	0.95 (0.77-1.17)
Shock	<5	<0.06	1.02 (0.35-2.95)§	5	0.03	0.63 (0.25-1.63)¶
Sepsis	10	0.13	0.55 (0.29-1.06)	14	0.07	0.30 (0.17-0.52)
Cardiac complication**	15	0.19	0.61 (0.36-1.04)	31	0.16	0.49 (0.33-0.73)
Acute renal failure	<5	<0.06	1.05 (0.24-4.63)§	<5	<0.03	0.17 (0.02-1.26)¶
Obstetric embolism	<5	<0.06	-	5	0.03	0.48 (0.19-1.21)¶
Evacuation of incisional hematoma	0	0.00	-	6	0.03	0.49 (0.21-1.14)¶
Postpartum infection††	56	0.70	0.54 (0.41-0.71)	94	0.48	0.38 (0.30-0.47)
Postpartum hemorrhage	826	10.4	1.99 (1.83-2.17)	1794	9.17	1.85 (1.74-1.97)
Retained placenta	97	1.22	6.56 (4.94-8.73)	220	1.12	8.21 (6.40-10.5)
Atonic	705	8.84	1.78 (1.63-1.94)	1508	7.71	1.62 (1.51-1.73)
Delayed/secondary	23	0.29	2.39 (1.48-3.86)	71	0.36	4.68 (3.26-6.72)

AOR, adjusted odds ratio; CI, confidence interval; ICH, intracranial hemorrhage.

Adjusted odds ratios estimated using logistic regression with cesarean delivery as the reference group. All models adjust for maternal age, parity, birth weight, previous cesarean delivery, region, and fiscal year.

* Severe birth trauma included intracranial laceration and hemorrhage, skull fracture, severe injury to CNS, severe injury to PNS, long bone injury, subaponeurotic (subgaleal) hemorrhage, injury to liver, and injury to spleen.

† Respiratory distress included respiratory distress syndrome, transient tachypnoea of the newborn and other neonatal respiratory distress.

‡ Other respiratory conditions included atelectasis, cyanotic attacks, apnea, respiratory failure and other respiratory conditions.

§ Crude odds ratio reported as adjusted odds ratio was undefined due to small numbers.

‖ Severe cerebral morbidity included hypoxic ischemic encephalopathy, cerebral ischemia, cerebral irritability, and cerebral depression.

¶ Severe postpartum hemorrhage includes a combination of postpartum hemorrhage and transfusion codes.

** Cardiac complications include cardiac arrest, cardiac failure, myocardial infarction and pulmonary embolism.

†† Post-partum infection includes sepsis, infection of obstetric surgical wound, infection of the genital tract following delivery, urinary tract infection following delivery, genitourinary tract infections following delivery, pyrexia of unknown origin following delivery and other specified, puerperal infection.

Appendix Table 3.8. Perinatal and maternal trauma among operative vaginal deliveries and cesarean deliveries with prolonged second stage of labour

Outcome	Cesarean		Attempted midpelvic forceps			Attempted midpelvic vacuum			Attempted sequential OVD		
	n	%	n	%	AOR (95% CI)	n	%	AOR (95% CI)	n	%	AOR (95% CI)
Dystocia											
Birth trauma	194	2.09	304	6.41	3.23 (2.68-3.88)	307	11.0	5.40 (4.47-6.52)	100	15.1	7.92 (6.11-10.3)
Intracranial hemorrhage	<5	<0.05	<5	<0.11	1.96 (0.28-13.9)*	<5	<0.18	5.02 (0.84-30.1)*	<5	<0.75	7.02 (0.64-77.5)*
Injury to CNS	<5	<0.05	25	0.53	16.4 (4.96-54.4)*	<5	<0.18	3.35 (0.68-16.6)*	<5	<0.75	9.38 (1.56-56.2)*
Injury to PNS	7	0.08	30	0.63	8.45 (3.71-19.3)*	8	0.29	3.83 (1.39-10.6)*	<5	<0.75	8.06 (2.35-27.6)*
Injury to scalp	143	1.54	158	3.33	2.19 (1.74-2.77)	263	9.46	5.46 (4.40-6.77)	78	11.8	7.22 (5.37-9.70)
Injury to skeleton	24	0.26	35	0.74	2.98 (1.75-5.06)	18	0.65	2.16 (1.16-4.05)	<5	<0.75	1.88 (0.64-5.49)*
Obstetric trauma	589	6.33	1085	22.9	4.51 (4.04-5.02)	427	15.4	2.70 (2.35-3.09)	147	22.2	4.24 (3.46-5.19)
Perineal laceration-3rd/4th degree	<5	<0.05	888	18.7	-	341	12.3	-	135	20.4	-
Cervical laceration	73	0.78	27	0.57	0.72 (0.47-1.13)*	17	0.61	0.78 (0.46-1.32)*	<5	<0.75	0.19 (0.03-1.38)*
High vaginal laceration	12	0.13	132	2.78	22.0 (12.2-39.8)	17	0.61	4.92 (2.34-10.3)	8	1.21	9.31 (3.78-22.9)
Injury to pelvic organ/joint	331	3.56	39	0.82	0.24 (0.17-0.34)	34	1.22	0.35 (0.24-0.50)	<5	<0.75	0.18 (0.07-0.48)
Pelvic hematoma	7	0.08	12	0.25	3.37 (1.33-8.56)*	5	0.18	2.39 (0.76-7.54)*	<5	<0.75	2.01 (0.25-16.3)*
Extension of uterine incision	268	2.88	13	0.27	0.11 (0.06-0.19)	21	0.76	0.29 (0.18-0.46)	<5	0.15	0.06 (0.01-0.40)
Fetal distress											
Birth trauma	154	2.69	253	8.12	3.26 (2.65-4.02)	269	12.8	5.09 (4.13-6.28)	99	20.5	9.47 (7.18-12.5)
Intracranial hemorrhage	<5	<0.09	5	0.16	3.07 (0.73-12.9)*	<5	<0.24	2.72 (0.55-13.5)*	<5	<1.03	15.9 (3.55-71.3)*
Injury to CNS	5	0.09	20	0.64	7.51 (2.81-20.0)†	<5	<0.24	1.13 (0.22-5.85)†	9	1.86	22.1 (7.33-66.6)†
Injury to PNS	<5	<0.09	27	0.87	13.9 (4.82-39.8)†	8	0.38	5.69 (1.69-19.1)†	6	1.24	21.0 (5.83-75.3)†
Injury to scalp	108	1.88	139	4.46	2.21 (1.71-2.86)	235	11.2	5.00 (3.92-6.36)	78	16.1	8.16 (5.95-11.2)
Injury to skeleton	25	0.44	30	0.96	2.23 (1.30-3.82)	20	0.95	2.14 (1.16-3.94)	6	1.24	2.90 (1.17-7.23)
Obstetric trauma	464	8.09	710	22.8	3.34 (2.94-3.80)	329	15.6	1.99 (1.71-2.33)	111	22.9	3.23 (2.55-4.08)
Perineal lacerations-3rd/4th degree	<5	<0.09	567	18.2	-	270	12.8	-	88	18.2	-
Cervical laceration	49	0.85	17	0.55	0.64 (0.37-1.11)*	10	0.47	0.55 (0.28-1.09)*	<5	<1.03	0.97 (0.35-2.69)*
High vaginal laceration	13	0.23	96	3.08	13.7 (7.67-24.5)†	13	0.62	2.68 (1.24-5.80)†	7	1.45	6.25 (2.48-15.8)†
Injury to pelvic organ/joint	299	5.21	32	1.03	0.20 (0.14-0.29)	25	1.19	0.19 (0.13-0.30)	11	2.27	0.40 (0.22-0.74)
Pelvic hematoma	6	0.10	12	0..39	-	0	0.00	-	<5	<1.03	-
Extension of uterine incision	219	3.82	16	0.51	0.13 (0.08-0.22)*	7	0.33	0.08 (0.04-0.18)*	11	2.27	0.59 (0.32-1.08)*

AOR, adjusted odds ratio; CI, confidence interval; CNS, central nervous system; PNS, peripheral nervous system. Adjusted odds ratios estimated using logistic regression with cesarean delivery as the reference group. Models adjusted for maternal age, parity, birth weight, previous cesarean delivery, province of maternal residence and fiscal year.
† Models adjusted for age, parity and birth weight.
* Crude odds ratio reported as adjusted odds ratio was undefined due to small numbers.

Appendix Table 3.9. Adjusted rate differences (per 100 deliveries) and number needed to treat (NNT) for perinatal and maternal outcomes following attempted midpelvic operative vaginal deliveries (OVD) compared with cesarean delivery with prolonged second stage of labour

	Attempted midpelvic forceps				Attempted midpelvic vacuum				Attempted midpelvic sequential OVD			
Dystocia	**RD**	**95% CI**		**NNT**	**RD**	**95% CI**		**NNT**	**RD**	**95% CI**		**NNT**
Severe perinatal morbidity/mortality*	0.53	0.16	1.08	188	0.53	0.11	1.18	188	1.44	0.48	3.20	70
Severe birth trauma†	0.69	0.30	1.40	145	0.60	0.22	1.34	168	1.46	0.54	3.58	69
Respiratory distress‡	0.81	0.13	1.66	123	0.94	0.10	1.98	106	4.19	2.14	7.01	24
Birth asphyxia	-0.03	-0.13	0.18	-2879	0.23	0.01	0.69	437	0.10	-0.13	1.10	1020
Cardiac failure/dysrhythmia	0.12	-0.26	0.61	861	0.18	-0.26	0.80	554	1.17	0.19	2.81	85
Severe cerebral morbidity	0.21	0.02	0.57	480	-0.10	-0.15	0.14	-1002	0.43	0.03	1.65	231
Birth trauma	4.65	3.50	6.01	21	9.18	7.24	11.51	11	14.44	10.66	19.40	7
Meconium aspiration syndrome	0.07	-0.04	0.34	1386	0.24	0.03	0.73	412	0.18	-0.05	1.25	542
Bacterial sepsis	0.28	0.04	0.69	356	-0.10	-0.22	0.21	-1034	-	-	-	-
Severe maternal morbidity/mortality‖	0.31	-0.15	0.94	320	-0.21	-0.66	0.41	-468	0.43	-0.48	2.06	234
Severe postpartum hemorrhage¶	0.53	0.09	1.14	188	-0.08	-0.43	0.46	-1198	1.04	0.10	2.73	96
Cardiac complication	-0.24	-0.32	-0.05	-417	-0.17	-0.30	0.12	-587	-	-	-	-
Obstetric trauma	22.23	19.25	25.46	4	10.77	8.55	13.24	9	20.52	15.58	26.54	5
Perineal laceration	18.70	17.70	19.90	5	12.30	11.10	13.50	8	20.40	17.50	23.60	5
Uterine incision extension	-2.56	-2.71	-2.33	-39	-2.05	-2.36	-1.56	-49	-2.71	-2.85	-1.73	-37
Postpartum infection**	-0.62	-0.85	-0.28	-160	-0.54	-0.84	-0.07	-185	-0.18	-0.79	1.08	-568
Postpartum hemorrhage	12.71	10.63	15.08	8	4.38	2.80	6.18	23	11.06	7.40	15.59	9
Fetal distress												
Severe perinatal morbidity/mortality*	0.47	-0.14	1.29	214	1.53	-0.56	0.86	65	2.91	0.27	5.50	34
Assisted ventilation (endotracheal)	-0.50	-0.81	-0.03	-199	-0.78	-1.05	-0.33	-128	0.18	-0.64	1.91	551
Severe birth trauma†	1.48	0.60	3.37	68	1.26	0.47	3.08	79	3.66	1.37	9.39	27
Respiratory distress‡	-0.34	-1.41	0.88	-297	-0.20	-1.41	1.35	-495	3.64	0.81	7.54	28
Assisted ventilation	-1.42	-1.90	-0.73	-71	-1.48	-2.04	-0.76	-67	-0.31	-1.55	1.76	-322
Fetal asphyxia	-0.52	-0.75	-0.10	-194	-0.34	-0.66	0.21	-294	0.36	-0.44	2.13	276

Cardiac failure/dysrhythmia	1.97	0.91	3.28	51	-0.36	-1.13	0.66	-274	3.97	1.64	7.29	25
Severe cerebral morbidity††	-0.07	-0.20	0.25	-1405	0.04	-0.16	0.51	2811	0.74	0.09	2.54	134
Birth trauma	6.07	4.43	8.11	16	10.98	8.41	14.18	9	22.75	16.60	30.89	4
Severe maternal morbidity/mortality‖	-0.48	-0.96	0.20	-209	-1.05	-1.46	-0.44	-96	-0.83	-1.55	0.76	-121
Sepsis	-0.21	-0.30	0.06	-488	-0.32	-0.36	-0.01	-314	-0.16	-0.34	1.17	-621
Obstetric trauma	18.94	15.70	22.66	5	8.01	5.75	10.76	12	18.05	12.54	24.92	6
Perineal laceration	18.10	16.90	19.60	6	12.70	11.50	14.30	8	18.10	15.00	21.90	6
Uterine incision extension	-3.32	-3.51	-2.98	-30	-3.51	-3.67	-3.13	-28	-1.57	-2.60	0.31	-64
Postpartum infection**	-1.05	-1.37	-0.59	-95	-1.13	-1.46	-0.55	-88	-0.92	-1.54	0.61	-109
Postpartum hemorrhage	10.28	7.88	12.93	10	3.51	1.63	5.65	28	6.59	3.00	11.22	15

Number needed to treat refers to the number of cesarean deliveries that would need to be performed to avoid one case of the outcome of interest.

Adjusted rate differences estimated using cesarean delivery as the reference group. All models adjusted for maternal age, parity, birth weight, previous cesarean delivery, province, and fiscal year.

RD, risk difference; CI, confidence interval; NNT, number needed to treat.

* Severe perinatal morbidity/mortality includes stillbirth, neonatal death, convulsions, assisted ventilation by endotracheal tube, and severe birth trauma.

† Severe birth trauma included intracranial laceration and hemorrhage, skull fracture, severe injury to CNS, severe injury to PNS, long bone injury, subaponeurotic (subgaleal) hemorrhage, injury to liver, and injury to spleen.

‡ Respiratory distress included respiratory distress syndrome, transient tachypnoea of the newborn and other neonatal respiratory distress.

§ Other respiratory conditions included atelectasis, cyanotic attacks, apnea, respiratory failure and other respiratory conditions.

|| Severe maternal morbidity/mortality refers to composite severe maternal morbidity and mortality (see text).

¶ Severe postpartum hemorrhage includes postpartum hemorrhage requiring transfusion.

** Post-partum infection includes sepsis, infection of obstetric surgical wound, infection of the genital tract following delivery, urinary tract infection following delivery, genitourinary tract infections following delivery, pyrexia of unknown origin following delivery and other specified, puerperal infection.

†† Severe cerebral morbidity included hypoxic ischemic encephalopathy, cerebral ischemia, cerebral irritability, and cerebral depression.

Appendix Table 3.10. Adjusted odds ratios (AOR) and 95% confidence intervals (CI) assessing potential modification of the effect of midpelvic operative vaginal delivery on perinatal and maternal morbidity and mortality by institutional volume (stratified by instrument used and indication for operative delivery)

Outcome	Attempted midpelvic instrument(s)	Dystocia					Fetal distress				
		Institutional delivery volume					Institutional delivery volume				
		Low		Medium		High	Low		Medium		High
		AOR (95% CI)	P-value	AOR (95% CI)	P-value	AOR (95% CI)	AOR (95% CI)	P-value	AOR (95% CI)	P-value	AOR (95% CI)
Severe perinatal morbidity/ mortality	Forceps	1.78 (1.01-3.14)	0.30	2.49 (1.26-4.92)	0.08	1.02 (0.46-2.28)	1.29 (0.83-2.00)	0.60	0.94 (0.57-1.56)	0.32	1.86 (0.59-5.80)
	Vacuum	1.68 (0.91-3.08)	0.27	2.72 (1.26-5.89)	0.09	0.73 (0.16-3.32)	0.86 (0.50-1.48)	0.08	0.91 (0.37-2.24)	0.10	2.48 (0.96-6.44)
	Sequential	4.17 (1.93-9.00)	0.30	2.72 (0.77-9.60)	0.47	1.28 (0.17-9.82)	2.12 (1.06-4.27)	0.06	1.16 (0.27- 5.00)	0.05	8.43 (2.94-24.1)
Severe maternal morbidity/ mortality	Forceps	0.98 (0.64-1.52)	0.43	1.32 (0.80-2.18)	0.72	1.19 (0.69-2.06)	0.77 (0.49-1.22)	0.49	0.83 (0.48-1.41)	0.41	0.49 (0.31-1.48)
	Vacuum	0.94 (0.60-1.50)	0.30	0.78 (0.38-1.62)	0.45	0.49 (0.14-1.66)	0.52 (0.29-0.92)	0.45	0.76 (0.31-1.84)	0.25	0.31 (0.11-0.87)
	Sequential	1.45 (0.72-2.94)	0.39	1.09 (0.33-3.64)	0.56	0.59 (0.08-4.40)	0.67 (0.24-1.86)	0.51	1.06 (0.25-4.52)	0.35	0.35 (0.05-2.64)

AOR, adjusted odds ratio; CI, confidence interval.

Adjusted odds ratios estimated using logistic regression with cesarean delivery as the reference group.

All models adjusted for maternal age, parity, and birth weight.

P-values are expressing the difference in the effect of mode of delivery on severe perinatal and maternal morbidity/mortality by institutional delivery volume (low/medium/high) with cesarean delivery at high delivery volume institutions as the reference group.

Severe perinatal morbidity/mortality includes stillbirth, neonatal death, neonatal convulsions, assisted ventilation by endotracheal intubation, and severe birth trauma.

Severe maternal morbidity/mortality includes maternal death, severe postpartum hemorrhage (requiring transfusion), shock, sepsis, cardiac complications, acute renal failure, obstetric embolism, and evacuation of incisional hematoma.

Appendix Table 3.11. Adjusted odds ratios and 95% confidence intervals showing the effects of provider type on composite perinatal and maternal morbidity and mortality, by instrument used and indication, in operative deliveries with prolonged second stage of labour

Midpelvic instrument(s)	Dystocia						Fetal distress					
	Severe perinatal morbidity/mortality			Severe maternal morbidity/mortality			Severe perinatal morbidity/mortality			Severe maternal morbidity/mortality		
	Obstetrician AOR (95% CI)	**Non-obstetrician AOR (95% CI)**	**P-value**	**Obstetrician AOR (95% CI)**	**Non-obstetrician AOR (95% CI)**	**P-value**	**Obstetrician AOR (95% CI)**	**Non-obstetrician AOR (95% CI)**	**P-value**	**Obstetrician AOR (95% CI)**	**Non-obstetrician AOR (95% CI)**	**P-value**
Forceps	1.73 (1.18-2.53)	2.22 (0.20-25.3)*	0.89	1.19 (0.90-1.57)	0.36 (0.05-2.80)*	0.27	1.25 (0.92-1.72)	0.77 (0.08-7.04)†	0.62	0.75 (0.54-1.05)	1.56 (0.14-17.5)†	0.71
Vacuum	1.69 (1.06-2.70)	3.30 (0.63-17.3)*	0.41	0.74 (0.49-1.11)	1.10 (0.45-2.69)*	0.45	0.97 (0.65-1.44)	0.87 (0.23-3.29)†	0.62	0.48 (0.31-0.77)	1.40 (0.25-7.75)†	0.55
Sequential	2.96 (1.56-5.60)	9.07 (0.76-107.6)*	0.43	1.01 (0.52-1.93)	4.30 (1.12-16.5)*	0.05	2.71 (1.67-4.40)	-	0.99	0.64 (0.30-1.39)	-	0.99

AOR, adjusted odds ratio; CI, confidence interval; ICH, intracranial hemorrhage.

Adjusted odds ratios estimated using logistic regression with cesarean delivery as the reference group. All models adjusted for maternal age, parity, birth weight, previous cesarean delivery, province of maternal residence, and fiscal year.

P-values are expressing the difference in the effect of mode of delivery on severe perinatal and maternal morbidity/mortality by provider type (obstetrician/non-obstetrician) with cesarean delivery by obstetricians as the reference group.

*Adjusted for birth weight and parity.

† Crude odds ratio reported as adjusted odds ratio was undefined due to small numbers.

Severe perinatal morbidity/mortality includes stillbirth, neonatal death, neonatal convulsions, assisted ventilation by endotracheal intubation, and severe birth trauma.

Severe maternal morbidity/mortality includes maternal death, severe postpartum hemorrhage (requiring transfusion), shock, sepsis, cardiac complications, acute renal failure, obstetric embolism, and evacuation of incisional hematoma.

Appendix Table 3.12. Adjusted odds ratios and 95% confidence intervals showing the effects of successful and failed operative vaginal delivery on composite perinatal and maternal morbidity/mortality by instrument used and indication

	Dystocia						Fetal distress					
	Severe perinatal morbidity/mortality			Severe maternal morbidity/mortality			Severe perinatal morbidity/mortality			Severe maternal morbidity/mortality		
Midpelvic instrument(s)	**Success AOR (95% CI)**	**Failed AOR (95% CI)**	**P-value**	**Success AOR (95% CI)**	**Failed AOR (95% CI)**	**P-value**	**Success AOR (95% CI)**	**Failed AOR (95% CI)**	**P-value**	**Success AOR (95% CI)**	**Failed AOR (95% CI)**	**P-value**
Forceps	1.69 (1.14-2.52)	2.35 (1.11-4.97)	0.69	1.14 (0.85-1.51)	1.31 (0.70-2.44)	0.61	1.23 (0.88-1.71)	1.57 (0.78-3.17)	0.90	0.74 (0.53-1.05)	0.83 (0.38-1.81)	0.92
Vacuum	1.59 (1.06-2.64)	2.60 (1.31-5.16)	0.27	0.70 (0.45-1.09)	1.35 (0.77-2.37)	0.05	1.19 (0.79-1.80)	0.74 (0.32-1.71)	0.44	0.44 (0.27-0.72)	0.70 (0.32-1.53)	0.45
Sequential	3.47 (1.79-6.72)	1.91 (0.46-7.94)	0.50	1.43 (0.77-2.68)	0.78 (0.19-3.19)	0.49	2.47 (1.36-4.50)	3.66 (1.73-7.78)	0.43	0.35 (0.11-1.13)	1.32 (0.48-3.67)	0.12

AOR, adjusted odds ratio; CI, confidence interval.

Adjusted odds ratios estimated using logistic regression with cesarean delivery as the reference group. All models adjusted for maternal age, parity, birth weight, previous cesarean delivery, region, and fiscal year.

P-values are expressing the difference in the effect of mode of delivery on severe perinatal and maternal morbidity and mortality by outcome of operative vaginal procedure (success/failure) with cesarean delivery as the reference group.

Severe perinatal morbidity/mortality includes stillbirth, neonatal death, neonatal convulsions, assisted ventilation by endotracheal intubation, and severe birth trauma.

Severe maternal morbidity/mortality includes maternal death, severe postpartum hemorrhage (requiring transfusion), shock, sepsis, cardiac complications, acute renal failure, obstetric embolism, and evacuation of incisional hematoma.

Appendix Table 3.13. Perinatal and maternal outcome rates and adjusted odds ratios among attempted midpelvic vacuum deliveries with the inclusion of sequential midpelvic instrumentation

	Attempted midpelvic vacuum including sequential midpelvic instrument use	
Outcome	**Dystocia (n=3,443) AOR (95% CI)**	**Fetal distress (n=2,591) AOR (95% CI)**
Perinatal		
Composite morbidity/mortality	2.02 (1.35-3.01)	1.36 (0.97-1.90)
Stillbirth	-	-
Neonatal death	-	-
Neonatal convulsions	1.29 (0.55-3.04)[‡]	0.81 (0.36-1.83)[‡]
Asst. ventilation (endotracheal)	0.76 (0.38-1.50)[‡]	0.58 (0.36-0.93)[‡]
Severe birth trauma[*]	4.95 (2.61-9.37)	10.3 (4.76-22.2)
Respiratory distress[†]	1.51 (1.23-1.84)	1.07 (0.89-1.28)
Fetal asphyxia	0.51 (0.19-1.34)[‡]	0.83 (0.51-1.35)
Birth asphyxia	2.00 (1.00-4.01)	0.74 (0.33-1.66)[‡]
Intracranial hemorrhage due to hypoxia	13.5 (2.97-61.8)[§]	1.66 (0.37-7.43)[§]
Severe cerebral morbidity[‖]	1.01 (0.40-2.59)[§]	1.57 (0.75-3.28)[§]
Birth trauma	5.30 (4.42-6.35)	4.80 (3.92-5.87)
Maternal		
Composite morbidity/mortality	0.91 (0.65-1.26)	0.52 (0.35-0.77)
Maternal death	-	-
Severe postpartum hemorrhage[¶]	1.05 (0.71-1.54)	0.66 (0.41-1.05)
Shock	0.68 (0.08-6.04)[§]	-
Sepsis	0.68 (0.25-1.80)[§]	0.21 (0.05-0.90)[§]
Cardiac complication[**]	0.45 (0.19-1.07)[§]	0.44 (0.18-1.07)[‡]
Acute renal failure	2.70 (0.17-43.2)[§]	-
Obstetric embolism	1.08 (0.21-5.57)[§]	-
Evacuation of incisional hematoma	-	-
Obstetric trauma	2.97 (2.62-3.37)	2.17 (1.87-2.51)
Perineal laceration – 3^{rd}/4^{th} degree	13.8 (12.7-15.0)[††]	13.8 (12.5-15.2)[††]
Uterine incision extension	0.24 (0.16-0.38)	0.18 (0.11-0.29)[‡]
Postpartum infection[‡‡]	0.65 (0.43-0.98)	0.44 (0.27-0.72)
Postpartum hemorrhage	1.77 (1.55-2.03)	1.48 (1.27-1.72)

AOR, adjusted odds ratio; CI, confidence interval.

Adjusted odds ratios estimated using logistic regression with cesarean delivery as the reference group. All models adjusted for maternal age, parity, birth weight, previous cesarean delivery, region, and fiscal year.

* Severe birth trauma included intracranial laceration and hemorrhage, skull fracture, severe injury to CNS, severe injury to PNS, long bone injury, subaponeurotic (subgaleal) hemorrhage, injury to liver, and injury to spleen.

† Respiratory distress included respiratory distress syndrome, transient tachypnoea of the newborn and other neonatal respiratory distress.

‡ Adjusted for maternal age, birth weight, parity, and previous cesarean delivery.

§ Crude odds ratio reported as adjusted odds ratio was undefined due to small numbers.

|| Severe cerebral morbidity included hypoxic ischemic encephalopathy, cerebral ischemia, cerebral irritability, and cerebral depression.

¶ Severe postpartum hemorrhage includes a combination of postpartum hemorrhage and transfusion codes.

** Cardiac complications include cardiac arrest, cardiac failure, myocardial infarction and pulmonary embolism.

†† Due to low occurrence of perineal laceration in the reference group (<0.09) relative estimates were not estimable; proportions and 95% confidence intervals are provided.

‡‡ Post-partum infection includes sepsis, infection of obstetric surgical wound, infection of the genital tract following delivery, urinary tract infection following delivery, genitourinary tract infections following delivery, pyrexia of unknown origin following delivery and other specified, puerperal infection.

Appendix to Chapter 4

Appendix Table 4.1. 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 (interventions), outcomes, and confounders

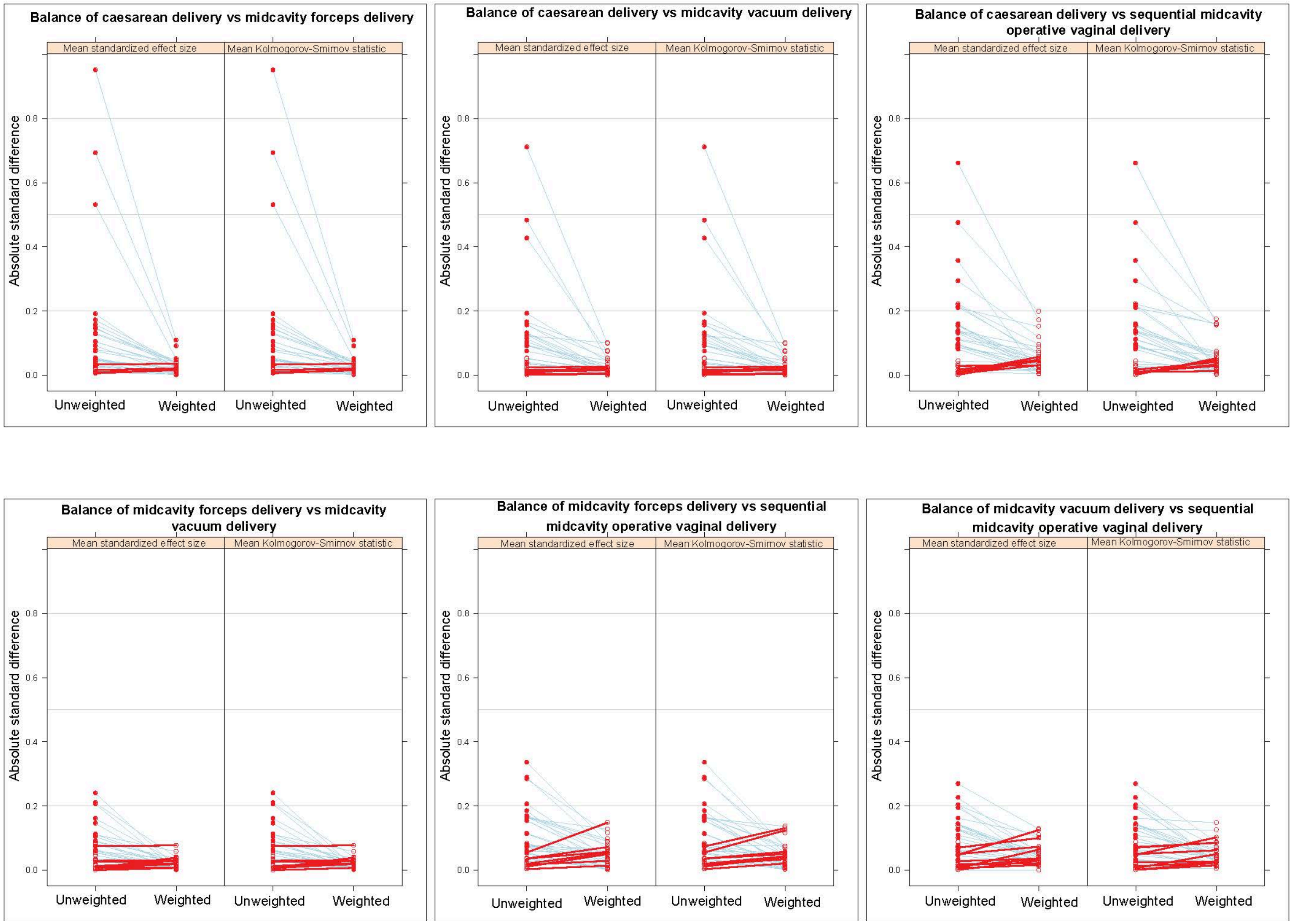
Diagnosis/Procedure	ICD-10-CA	CCI	Study use
Single live birth	BCPDR data element		
Midcavity forceps delivery		5.MD.53	
Midcavity vacuum delivery		5.MD.54	
Midcavity sequential instrumental delivery		5.MD.55	
Failed forceps delivery			
Failed instrument	O66.5		
Cesarean delivery with forceps		5.MD.60.RC, 5.MD.60.JZ, 5.MD.60.KC, 5.MD.60.RA, 5.MD.60.RE, 5.MD.60.JW, 5.MD.60.RG	
Failed vacuum delivery			
Failed instrument	O66.5		
Cesarean delivery with vacuum		5.MD.60.RD, 5.MD.60.KA, 5.MD.60.KD, 5.MD.60.RB, 5.MD.60.RF, 5.MD.60.JX, 5.MD.60.RH	Inclusion criteria
Failed sequential instrumental delivery			
Failed instrument	O66.5		
Cesarean delivery with sequential instruments		5.MD.60.C	
Cesarean delivery in second stage of labour		5.MD.60.KE, 5.MD.60.JY, 5.MD.60.KB, 5.MD.60.KG, 5.MD.60.KF, 5.MD.60.AA, 5.MD.60.KT + BCPDR element for duration of second stage of labour (only deliveries with value > 0 included)	
Gestational age 37–41 weeks	BCPDR data element		
Therapeutic abortions	O04	5.CA.20, 5.CA.24, 5.CA.88, 5.CA.89, 5.CA.90	
Non-vertex presentation	O32.1, O64.1	5.MD.56 + BCPDR indicator variable for baby presentation during labour	
Chronic hypertension	O10, O11		Exclusion criteria
Preeclampsia	O14		
Eclampsia	O15		
Diabetes	O24		
Placenta praevia	O44		
Placental abruption	O45		
Congenital anomalies	Q		

Table S1 (cont'd). 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 (interventions), outcomes, and confounders

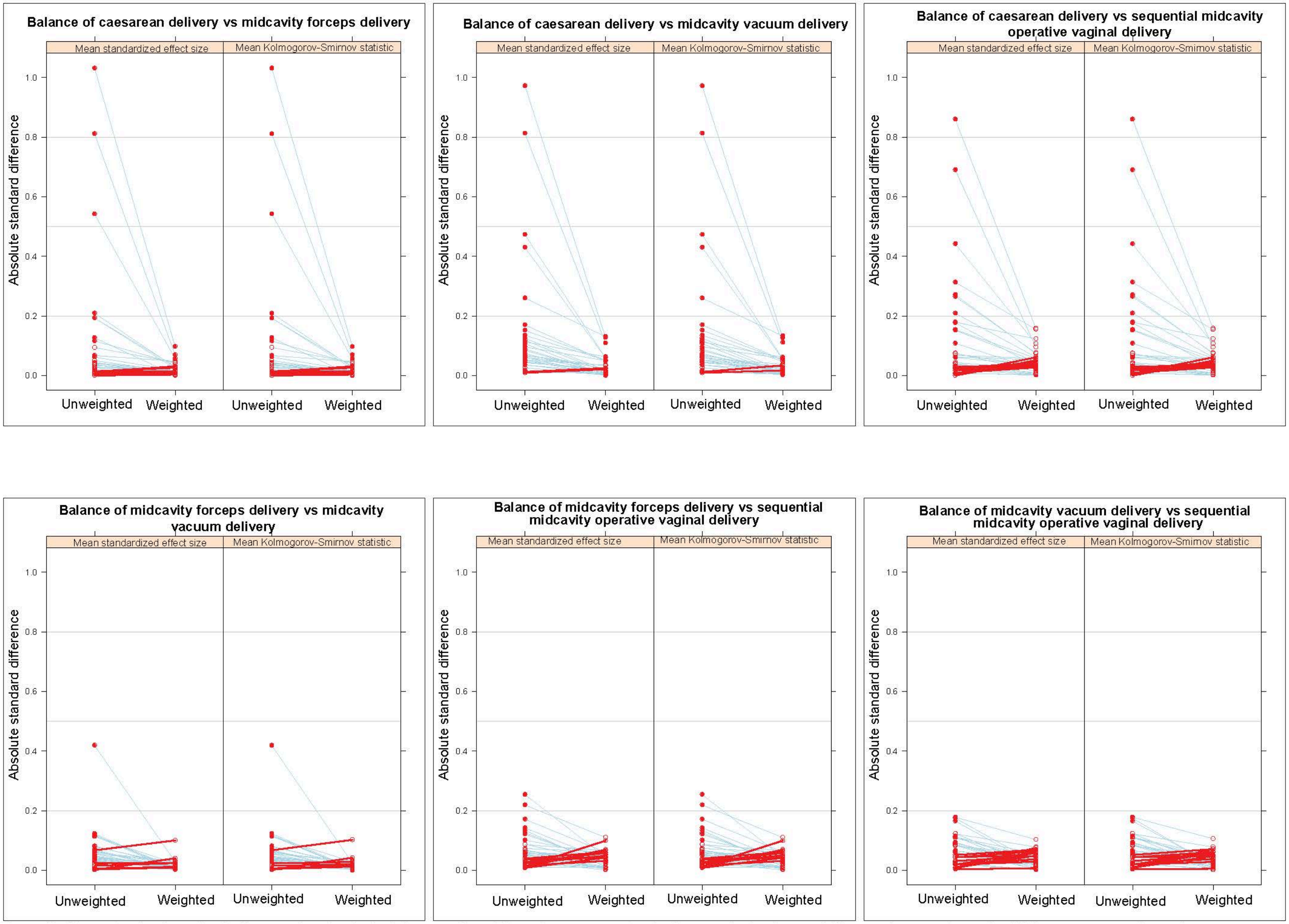
Diagnosis/Procedure	ICD-10-CA	CCI	Study use
Dystocia	O32, O33, O34.0, O34.1, O34.3–O34.9, O62.0, O62.1, O62.2, O62.4, O62.8, O62.9, O63, O66		Cohort definition
Fetal distress	O68, O69.0		
Maternal age	BCPDR element		Potential confounder /effect modifier
Parity	BCPDR element		
Pre-pregnancy weight	BCPDR element		
Previous Cesarean delivery	O34.20,O66.40, O75.7		
Birth weight	BCPDR element		
Fiscal year	BCPDR element		
Practitioner	BCPDR element		
Prolonged second stage	O63.1		
Position of the fetal head	BCPDR element		
Stillbirth	BCPDR element		Primary perinatal composite outcome
Neonatal death	BCPDR element		
Neonatal convulsions	P90		
Assisted ventilation by endotracheal intubation	BCPDR element	1.GZ.31.CA-ND	
5-minute Apgar < 4	BCPDR element		
Severe birth trauma	P10, P11.0–P11.2, P11.4–P11.5 P12.2, P13.0, P13.2, P13.30, P13.38, P14.0, P14.1, P14.3, P15.0, P15.1		
Respiratory distress	P22		Secondary perinatal outcome
Severe postpartum haemorrhage	O72 + BCPDR element (blood transfusion indicator variable)		Primary maternal composite outcome
Shock	O75.1, T80.5, T886, R57		
Sepsis	O85		
Cardiac complications	O89.1, O74.2, O75.4, I21, I22, I46, I50, J81		
Acute renal failure	O90.4, N99.0, N17, N19		
Obstetric embolism	O88		
Obstetric trauma	O70.2, O70.3, O71.3–O71.9	5.PC.80.JQ, 5.PC.80.JH	Secondary maternal outcome
3rd/4th degree perineal lacerations	O70.2, O70.3 + BCPDR element	5.PC.80.JQ	
Postpartum haemorrhage	O72		
Postpartum haemorrhage – retained placenta	O72.0		
Postpartum haemorrhage – atonic	O72.1		
Postpartum haemorrhage – delayed	O72.2		

BCPDR, British Columbia Perinatal Database Registry

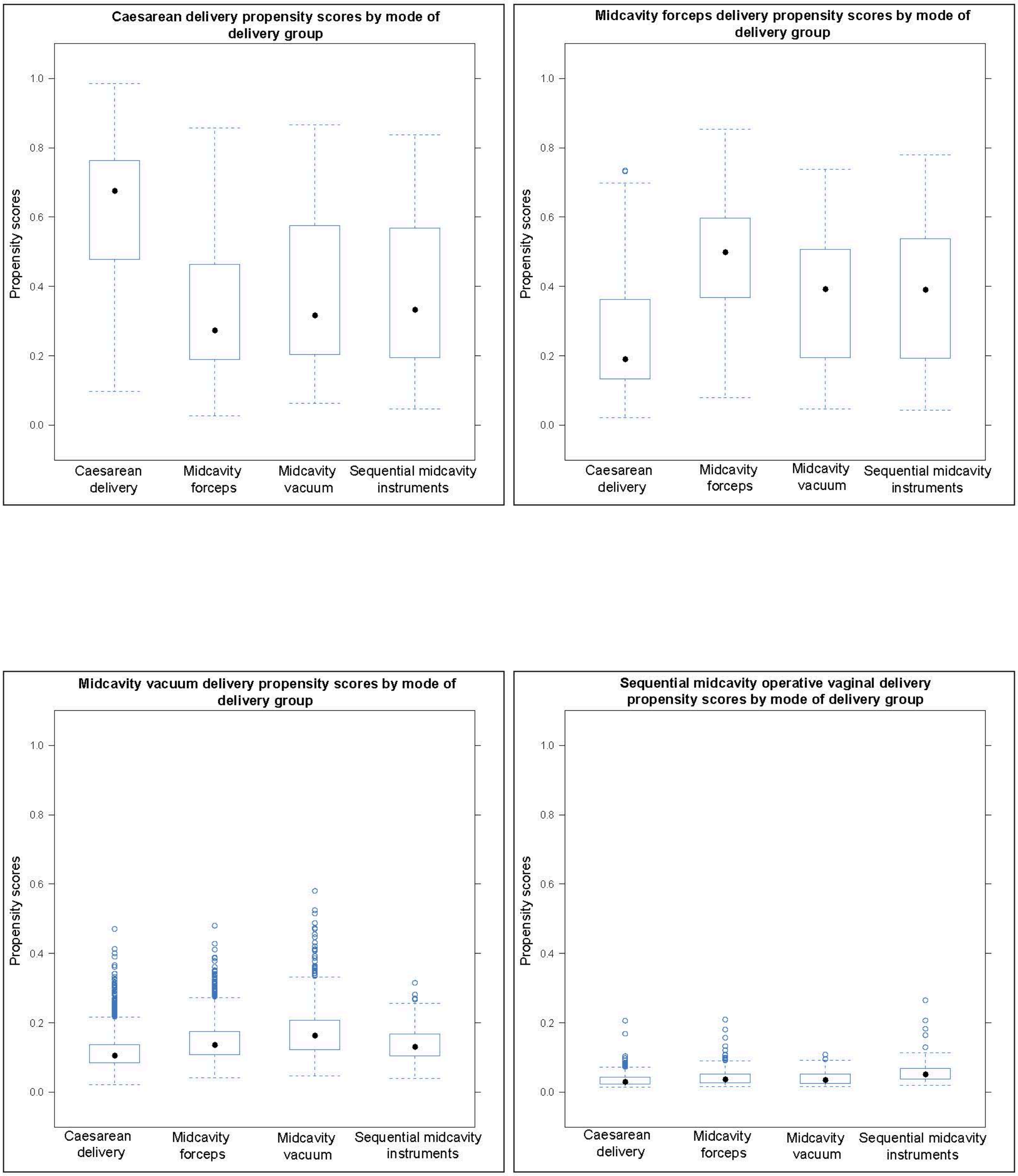
Appendix Figure 4.1. Propensity score unweighted and weighted effect size plots for the dystocia cohort.



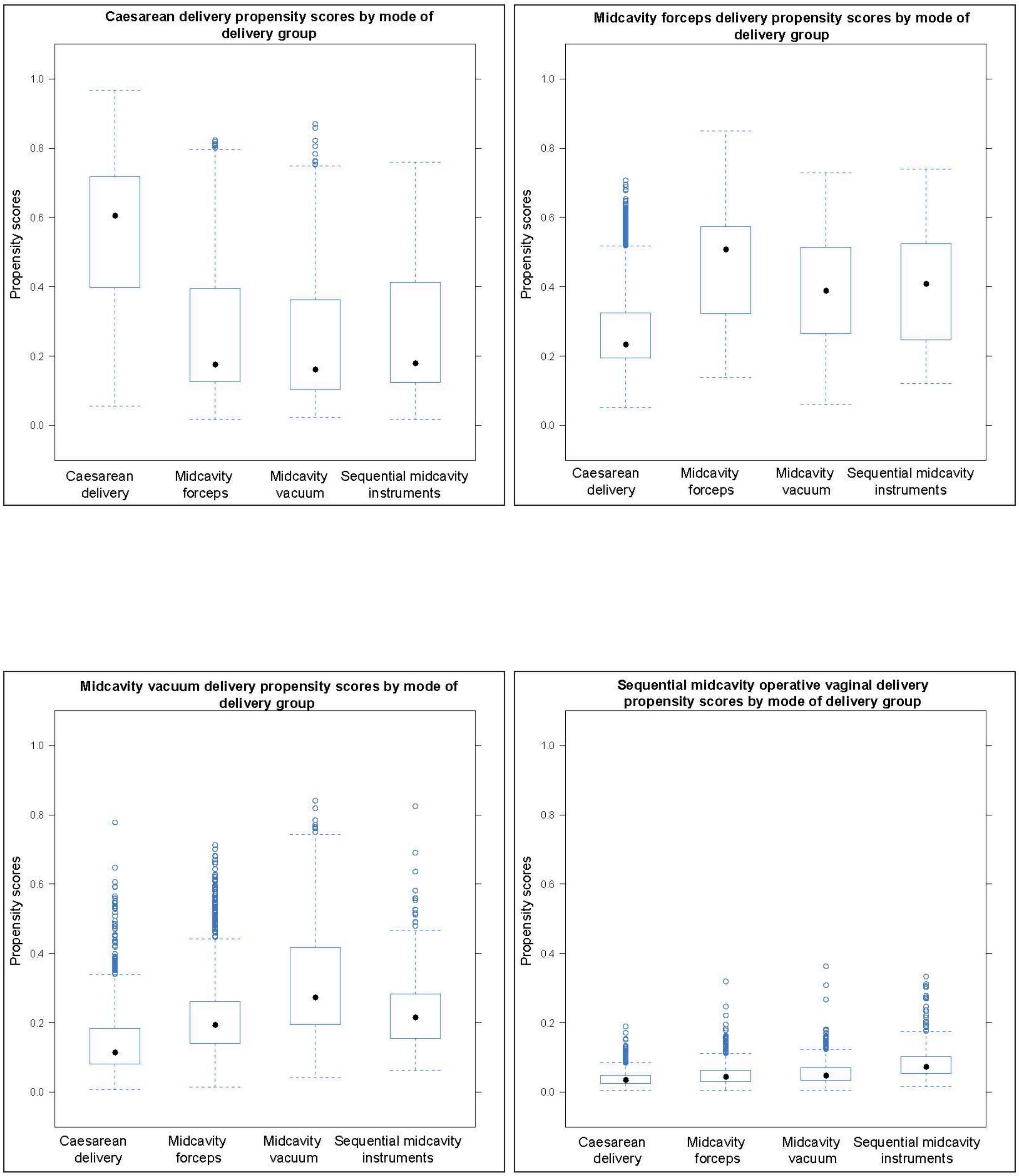
Appendix Figure 4.2. Propensity score unweighted and weighted effect size plots for the fetal distress cohort.



Appendix Figure 4.3. Overlap assessment. Each panel presents box plots by treatment group of the estimated propensity scores for one of the mode of delivery groups in the dystocia cohort



Appendix Figure 4.4. Overlap assessment. Each panel presents box plots by treatment group of the estimated propensity scores for one of the mode of delivery groups in the fetal distress cohort



Appendix Table 4.2. Numbers and rates of the components of composite perinatal and maternal outcomes by attempted mode of delivery, British Columbia, 2004–2014

	Cesarean delivery		**Midpelvic forceps**		**Midpelvic vacuum**		**Sequential midpelvic OVD**	
Outcome	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Dystocia								
Severe perinatal morbidity/mortality	20	0.83	30	1.70	15	2.17	7	3.52
Stillbirth*	<5	<0.21	<5	<0.28	0	0.00	0	0.00
Neonatal death	0	0.00	0	0.00	0	0.00	<5	<2.51
Convulsions	<5	<0.21	<5	<0.28	<5	<0.72	0	0.00
Assisted ventilation by endotracheal tube	6	0.25	9	0.51	<5	<0.72	<5	<2.51
5-min Apgar <4	7	0.29	6	0.34	<5	<0.72	0	0.00
Severe birth trauma†	7	0.29	17	0.96	7	1.01	<5	<2.51
Respiratory distress‡	60	1.49	64	3.63	33	4.78	9	4.52
Birth trauma	28	1.16	71	4.03	53	7.68	23	11.6
Severe maternal morbidity	19	0.79	21	1.19	10	1.45	<5	<2.51
Severe postpartum haemorrhage§	12	0.50	17	0.96	9	1.30	<5	<2.51
Shock	<5	<0.21	<5	<0.28	0	0.00	0	0.00
Sepsis	5	0.21	<5	<0.28	0	0.00	<5	<2.51
Obstetric embolism	<5	<0.21	0	0.00	<5	<0.72	0	0.00
Cardiac complication¶	<5	<0.21	<5	<0.28	0	0.00	0	0.00
Acute renal failure	0	0.00	0	0.00	0	0.00	0	0.00
Postpartum haemorrhage**	111	4.62	374	21.2	96	13.9	35	17.6
Obstetric trauma††	92	3.83	465	26.4	80	11.6	45	22.6
Severe perineal laceration ($3^{rd}/4^{th}$ degree)	<5	<0.21	405	23.0	71	10.3	42	21.1
Fetal distress								
Severe perinatal morbidity/mortality	40	1.89	59	2.66	32	2.62	6	2.09
Stillbirth*	0	0.00	<5	<0.23	0	0.00	0	0.00
Neonatal death	0	0.00	<5	<0.23	0	0.00	0	0.00
Convulsions	9	0.42	7	0.32	6	0.49	<5	<1.74
Assisted ventilation by endotracheal tube	24	1.13	24	1.08	19	1.55	<5	<1.74
5-min Apgar <4	7	0.33	7	0.32	6	0.49	<5	<1.74
Severe birth trauma†	5	0.24	25	1.13	8	0.65	<5	<1.74
Respiratory distress‡	151	7.13	162	7.31	81	6.62	26	9.06
Birth trauma	39	1.84	98	4.42	65	5.31	27	9.41
Severe maternal morbidity	14	0.66	34	1.53	7	0.57	5	1.74
Severe postpartum haemorrhage§	7	0.33	29	1.31	<5	<0.41	<5	<1.74
Shock	<5	<0.24	0	0.00	0	0.00	0	0.00
Sepsis	<5	<0.24	<5	<0.23	<5	<0.41	<5	<1.74
Obstetric embolism	0	0.00	0	0.00	<5	<0.41	0	0.00
Cardiac complication¶	<5	<0.24	<5	<0.23	0	0.00	0	0.00
Acute renal failure	<5	<0.24	0	0.00	0	0.00	0	0.00
Postpartum haemorrhage**	107	5.05	438	19.8	151	12.4	51	17.8
Obstetric trauma††	101	4.77	535	24.2	121	9.89	74	25.8
Severe perineal laceration ($3^{rd}/4^{th}$ degree)	<5	<0.24	439	19.8	104	8.50	63	22.0

OVD, operative vaginal delivery.

Reference group in regression models is Cesarean delivery.

Results adjusted for maternal age, parity, pre-pregnancy weight, birth weight, income quintile, and year of birth.

*Only stillbirths that occurred after the onset of labour were included.
†Severe birth trauma included intracranial laceration and haemorrhage, skull fracture, severe injury to CNS, severe injury to PNS, long bone injury, subaponeurotic haemorrhage, injury to liver, and injury to spleen.
‡Respiratory distress included RDS (hyaline membrane disease, idiopathic respiratory distress syndrome) and transient tachypnoea of the newborn and other neonatal respiratory distress.
§Severe postpartum haemorrhage includes a postpartum haemorrhage requiring transfusion.
¶Cardiac complications included cardiac arrest, cardiac failure, myocardial infarction and pulmonary embolism.
**Postpartum haemorrhage (PPH) included atonic PPH, 3rd stage PPH, delayed PPH, and PPH due to coagulation defects.
††Obstetric trauma included 3rd/4th degree perineal laceration, cervical laceration, uterine rupture during labour, high vaginal laceration, other obstetric injury to pelvic organs, and obstetric damage to pelvic joints and ligaments.

Appendix Table 4.3. Adjusted rate ratios (ARR) and 95% confidence intervals (CI) for composite severe perinatal and maternal morbidity and mortality following deliveries by attempted midpelvic operative vaginal delivery compared with Cesarean delivery, stratified by position of fetal head at delivery, British Columbia, 2004–2014

		Anterior				**Posterior/Transverse**				
Outcome	**Attempted midpelvic instrument(s)**	**Outcome rate in Cesarean delivery (%)**	**ARR**	**95% CI**		**Outcome rate in Cesarean delivery (%)**	**AOR**	**95% CI**		**P-value for inter-action**
Dystocia										
Severe perinatal morbidity/ mortality	Forceps		1.65	0.78	3.52		3.14	1.03	10.4	0.18
	Vacuum	1.46	1.94	0.79	4.79	0.73	5.40	1.57	18.6	0.14
	Sequential		4.08	1.34	12.4		5.86	0.81	42.4	0.63
Severe maternal morbidity	Forceps		2.11	0.72	6.18		1.84	0.52	6.52	0.79
	Vacuum	0.65	2.28	0.66	7.88	1.09	2.51	0.69	9.13	0.86
	Sequential		1.34	0.15	12.2		2.40	0.30	19.3	0.78
Severe perineal lacerations ($3^{rd}/4^{th}$ deg)*	Forceps		21.6	19.4	24.0		36.7	30.1	43.8	-
	Vacuum	0.00	11.5	8.77	15.0	0.00	4.88	2.25	10.2	-
	Sequential		23.9	17.0	32.5		22.7	12.8	37.0	-
Fetal distress										
Severe perinatal morbidity/ mortality	Forceps		1.27	0.69	2.34		1.29	0.46	3.65	0.87
	Vacuum	2.46	**0.97**	**0.48**	**1.96**	1.61	**3.00**	**1.28**	**7.01**	**0.03**
	Sequential		0.75	0.24	2.36		2.09	0.47	9.27	0.15
Severe maternal morbidity	Forceps		3.73	1.05	13.2		1.40	0.39	5.06	0.21
	Vacuum	0.45	1.34	0.31	5.70	0.99	0.72	0.09	5.69	0.52
	Sequential		3.54	0.71	17.8		2.88	0.38	21.8	0.69
Severe perineal lacerations ($3^{rd}/4^{th}$ deg)*	Forceps		20.5	18.5	22.6		24.6	19.8	30.2	-
	Vacuum	0.00	8.85	7.08	11.0	0.00	9.79	5.92	15.8	-
	Sequential		18.8	13.7	25.2		35.6	23.2	50.2	-

Adjusted for parity, pre-pregnancy weight, and infant birth weight.

Bold text denotes statistically significant differences between ARRs in deliveries to infants with a fetal head in occiput anterior vs occiput posterior/transverse position at delivery.

*Rate (%) and 95% CI provided for severe perineal lacerations as relative estimates were not estimable due to low rate in the reference group.

Appendix Table 4.4. 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 cesarean delivery, stratified by prolonged second stage of labour, British Columbia, 2004–2014

Outcome	**Attempted midcavity instrument(s)**	**No prolonged second stage of labour (n=1,787)**				**Prolonged second stage of labour (n=3,270)**			
		Outcome rate in Cesarean delivery (%)	**ARR**	**95% CI**		**Outcome rate in Cesarean delivery (%)**	**ARR**	**95% CI**	
Perinatal morbidity/ mortality	Forceps	1.24	2.70	1.23	5.92	0.56	2.36	0.98	5.69
	Vacuum		2.92	1.15	7.41		3.60	1.27	10.23
	Sequential		2.66	0.57	12.5		7.77	2.40	25.2
Birth trauma	Forceps	0.93	6.71	3.08	14.61	1.32	2.86	1.65	4.96
	Vacuum		12.5	5.62	27.7		5.56	3.05	10.1
	Sequential		21.8	8.58	55.1		7.29	3.33	16.0
Respiratory distress	Forceps	1.96	**2.88**	**1.56**	**5.32**	2.85	**1.06**	**0.67**	**1.66**
	Vacuum		1.74	0.74	4.09		1.99	1.19	3.34
	Sequential		3.09	1.00	9.58		1.43	0.55	3.72
Maternal morbidity	Forceps	0.72	1.70	0.56	5.18	0.83	1.56	0.72	3.39
	Vacuum		1.74	0.43	7.01		2.16	0.83	5.64
	Sequential		2.20	0.25	19.5		1.35	0.17	10.7
Postpartum haemorrhage	Forceps	4.03	5.61	3.72	8.45	5.01	5.80	4.41	7.64
	Vacuum		3.88	2.35	6.39		3.39	2.36	4.87
	Sequential		5.68	2.84	11.4		4.18	2.47	7.06
Obstetric trauma	Forceps	2.90	**14.4**	**9.28**	**22.2**	4.45	**7.68**	**5.78**	**10.2**
	Vacuum		3.51	1.97	6.27		3.36	2.30	4.91
	Sequential		**14.4**	**7.47**	**27.6**		**5.50**	**3.29**	**9.18**
Severe perineal lacerations ($3^{rd}/4^{th}$ deg)*	Forceps	0.00	24.6	21.0	28.7	0.00	22.34	20.1	24.7
	Vacuum		7.75	5.07	11.7		11.81	9.09	15.2
	Sequential		24.0	15.8	34.8		19.35	13.4	27.2

Adjusted for maternal age, parity, pre-pregnancy weight, infant birth weight, income quintile and year of birth.
Bold text denotes statistically significant differences between ARRs with and without prolonged second stage of labour.
*Rate (%) and 95% CI provided for severe perineal lacerations as relative estimates were not estimable due to low rate in the reference group.

Appendix Table 4.5. 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 cesarean delivery, stratified by prolonged second stage of labour, British Columbia, 2004–2014.

Outcome	Attempted midcavity instrument(s)	No prolonged second stage of labour (n=3,891)				Prolonged second stage of labour (n=1,953)			
		Outcome rate in Cesarean delivery (%)	ARR	95% CI		Outcome rate in Cesarean delivery (%)	ARR	95% CI	
Perinatal morbidity/ mortality	Forceps		1.47	0.86	2.52		1.48	0.78	2.81
	Vacuum	1.78	1.24	0.67	2.31	2.03	2.58	1.17	5.69
	Sequential		0.82	0.24	2.78		2.07	0.58	7.44
Birth trauma	Forceps		2.58	1.56	4.25		2.86	1.58	5.17
	Vacuum	1.78	3.66	2.18	6.13	1.92	2.42	1.09	5.37
	Sequential		5.32	2.71	10.4		8.17	3.55	18.8
Respiratory distress	Forceps		1.09	0.80	1.47		1.08	0.74	1.56
	Vacuum	6.89	0.78	0.53	1.13	7.46	1.86	1.19	2.93
	Sequential		1.22	0.69	2.14		1.73	0.84	3.55
Maternal morbidity	Forceps		5.58	1.94	16.1		0.86	0.32	2.29
	Vacuum	0.32	1.95	0.54	7.04	1.13	0.35	0.04	2.75
	Sequential		5.92	1.45	24.1		1.05	0.13	8.60
Postpartum haemorrhage	Forceps		5.91	4.30	8.12		4.11	2.97	5.68
	Vacuum	3.97	3.89	2.74	5.53	6.55	1.87	1.16	3.02
	Sequential		4.52	2.79	7.32		4.84	2.69	8.70
Obstetric trauma	Forceps		7.92	5.78	10.86		5.36	3.86	7.45
	Vacuum	3.89	2.89	2.00	4.17	5.99	2.25	1.39	3.62
	Sequential		9.66	6.29	14.8		5.44	3.00	9.87
Severe perineal lacerations ($3^{rd}/4^{th}$ deg)*	Forceps	0.00	19.8	17.9	21.9	0.00	19.8	17.1	22.9
	Vacuum		8.25	6.68	10.2		9.49	6.46	13.7

Adjusted for maternal age, parity, pre-pregnancy weight, infant birth weight, income quintile and year of birth.
Bold text denotes statistically significant differences between ARRs with and without prolonged second stage of labour.
*Rate (%) and 95% CI provided for severe perineal lacerations as relative estimates were not estimable due to low rate in the reference group.

Appendix to Chapter 5

Appendix Table 5.1. International Classification of Diseases and Related Health Problems Tenth Revision, Canada (ICD-10-CA) and Canadian Classification of Health Interventions (CCI) codes used for population selection and to classify determinants (interventions), outcomes, and confounders

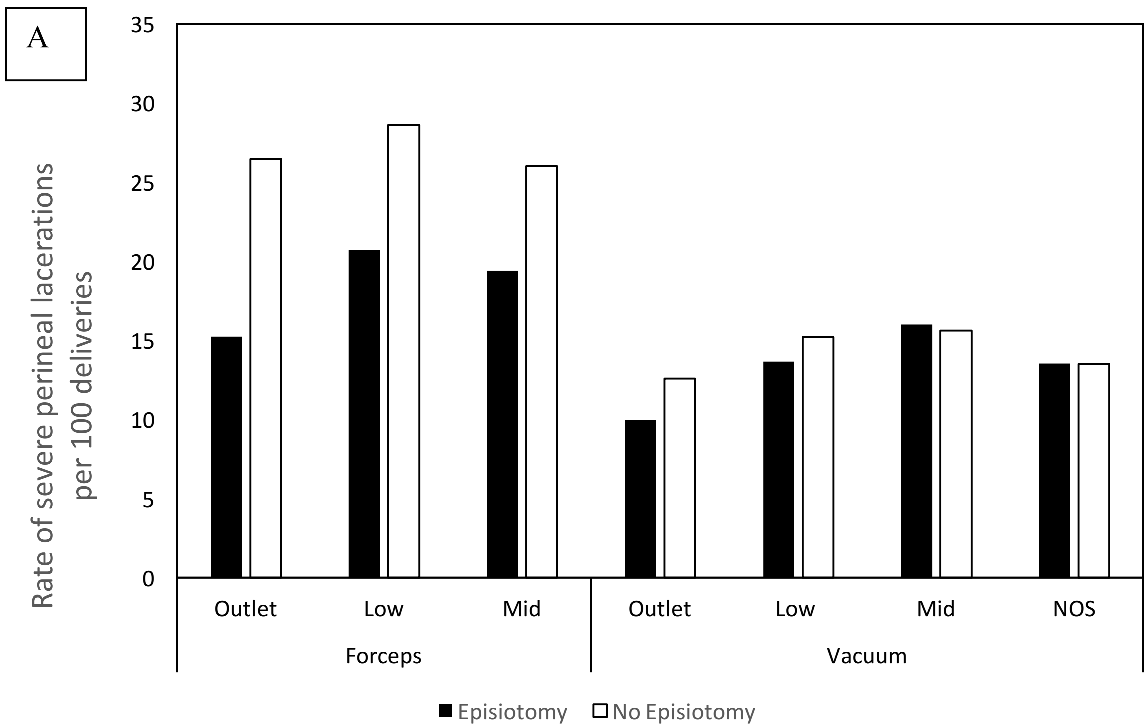
Diagnosis/Procedure	ICD-10-CA	CCI	Study use
Single live birth	Z37.0		
Single stillbirth	Z37.1		
Midpelvic forceps delivery		5.MD.53.KN, 5.MD.53.KM	
Midpelvic vacuum delivery		5.MD.54.KN, 5.MD.54.KM	
Midpelvic sequential instrumental delivery		5.MD.55.KN, 5.MD.54.KM	
Failed forceps delivery			
Failed instrument	O66.5		
Cesarean delivery with forceps		5.MD.60.RC, 5.MD.60.JZ, 5.MD.60.KC, 5.MD.60.RA, 5.MD.60.RE, 5.MD.60.JW, 5.MD.60.RG	
Failed vacuum delivery			
Failed instrument	O66.5		
Cesarean delivery with vacuum		5.MD.60.RD, 5.MD.60.KA, 5.MD.60.KD, 5.MD.60.RB, 5.MD.60.RF, 5.MD.60.JX, 5.MD.60.RH	Inclusion criteria
Failed sequential instrumental delivery			
Failed instrument	O66.5		
Cesarean delivery with sequential instruments		5.MD.60.C	
Cesarean delivery with labour			
Cesarean delivery		5.MD.60.KE, 5.MD.60.JY, 5.MD.60.KB, 5.MD.60.KG, 5.MD.60.KF, 5.MD.60.AA, 5.MD.60.KT	
Labour	O62.0, O62.1, O62.3, O63.0, O63.1, O63.9, O74, O75.2, O75.3	5.AC.30, 5.LD.31, 5.MD.40, 5.MD.53.KN, 5.MD.54.KN, 5.MD.55.KN	

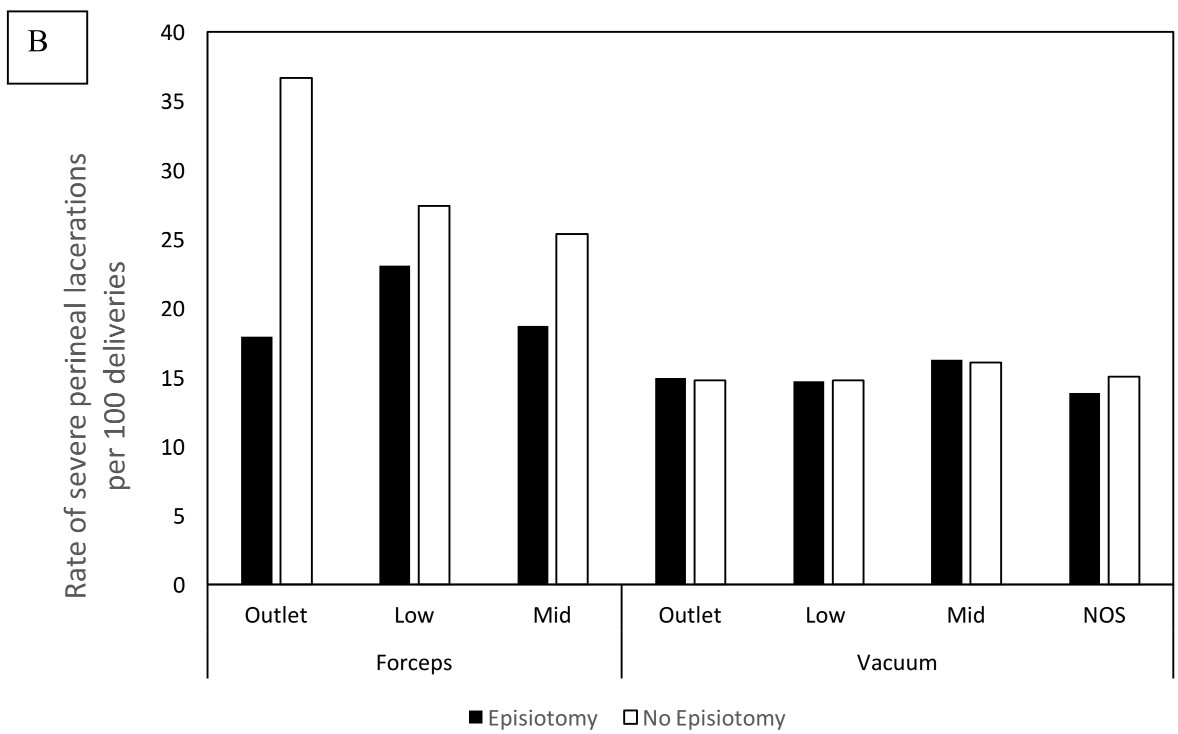
Diagnosis/Procedure	ICD-10-CA	CCI	Study use
Therapeutic abortions	O04	5.CA.20, 5.CA.24, 5.CA.88, 5.CA.89, 5.CA.90	Exclusion criteria
Breech presentation	O32.1, O64.1	5.MD.56	
Double forceps application (Scanzoni maneuver)		5.MD.53.KS, 5.MD.53.KP	
Forceps rotation only with manually assisted delivery (DeLee key-in-lock maneuver)		5.MD.53.JE, 5.MD.53.JD	
Chronic hypertension	O10, O11		
Preeclampsia	O14		
Eclampsia	O15		
Diabetes	O24		
Placenta praevia	O44		
Placental abruption	O45		
Congenital anomalies	Q		
Failed induction	O61		
Dystocia	O32, O33, O34.0, O34.1, O34.3-O34.9, O62.0, O62.1, O62.2, O62.4, O62.8, O62.9, O63, O66		Cohort definition
Fetal distress	O68, O69.0		
Prolonged second stage	O63.1		
Maternal age	DAD element		Confounder
Parity	DAD element		
Birth weight	DAD element		
Fiscal year	DAD element		
Maternal province of residence	DAD element		
Previous cesarean delivery	O34.20		
Institutional delivery volume	DAD element		
Practitioner	DAD element		
Stillbirth	Z37.1		Primary perinatal composite outcome
Neonatal death	DAD element		
Neonatal convulsions	P90		
Assisted ventilation by endotracheal intubation		1.GZ.31.CA-ND	
Severe birth trauma	P10, P11.0-P11.2, P11.4-P11.5 P12.2, P13.0, P13.2, P13.30, P13.38, P14.0, P14.1, P14.3, P15.0, P15.1		

Diagnosis/Procedure	ICD-10-CA	CCI	Study use
Respiratory distress	P22		Secondary perinatal outcome
Other respiratory conditions	P28		
Fetal asphyxia	P20		
Birth asphyxia	P21		
Intracranial haemorrhage due to hypoxia	P52		
Severe cerebral morbidity	P91		
Maternal death	O95, O96, O97, R96, R98, R99, DAD elements		Primary maternal composite outcome
Severe postpartum haemorrhage	O72 + DAD element (blood transfusion indicator variable)		
Shock	O75.1, T80.5, T886, R57		
Sepsis	O85		
Cardiac complications	O89.1, O74.2, O75.4, I21, I22, I46, I50, J81		
Acute renal failure	O90.4, N99.0, N17, N19		
Obstetric embolism	O88		
Evacuation of incisional haematoma		5.PC.73.JS	
Obstetric trauma	O70.2, O70.3, O71.3-O71.9	5.PC.80.JQ, 5.PC.80.JH	Secondary maternal outcome
3rd/4th degree perineal lacerations	O70.2, O70.3	5.PC.80.JQ	
Postpartum infection	O85, O86		
Postpartum haemorrhage	O72		
Postpartum haemorrhage – retained placenta	O72.0		
Postpartum haemorrhage – atonic	O72.1		
Postpartum haemorrhage – delayed	O72.2		

DAD, Discharge Abstract Database

Appendix Figure 5.1. Third- and fourth-degree perineal laceration rates among operative vaginal deliveries stratified by instrument, pelvic station and episiotomy use. Panel A presents deliveries with dystocia and Panel B presents deliveries with fetal distress.





Appendix Table 5.2. P values for chi-square tests for heterogeneity and linear trend in odds ratios (OR) and proportions between outlet, low, and mid-pelvic operative vaginal deliveries (OVD) compared with cesarean deliveries, with prolonged second stage of labor, Canada (excluding Quebec), 2003-2013

	Dystocia				**Fetal distress**			
Outcome	**Forceps**		**Vacuum**		**Forceps**		**Vacuum**	
	P for heterogeneity in OR*	P for linear trend in OR†	P for heterogeneity in OR*	P for linear trend in OR†	P for heterogeneity in OR*	P for linear trend in OR†	P for heterogeneity in OR*	P for linear trend in OR†
Severe perinatal morbidity/ mortality	0.34	0.54	0.43	0.41	0.12	0.15	0.27	0.28
Birth trauma	0.12	0.32	**0.0002**	**<0.0001**	0.22	0.35	**<0.0001**	**<0.0001**
Severe maternal morbidity/ mortality	0.16	0.18	0.32	0.73	0.28	0.92	0.31	0.64
Obstetric trauma	**0.004**	0.32	**0.0006**	**<0.0001**	0.10	**0.02**	0.16	0.13
Severe perineal laceration (3/4th degree)	-	0.54‡	-	**<0.0001**‡	-	**0.0009**‡	-	0.28‡

*Breslow-Day chi-square test for heterogeneity in odds ratios for outlet, low and midpelvic OVD.
†Mantel-Haenszel chi-square test for linear trend in odds ratios for outlet, low and midpelvic OVD.
‡Cochran-Armitage test for linear trend in proportions for outlet, low and midpelvic OVD.

Appendix Table 5.3. Adjusted odds ratios (AOR) and 95% confidence intervals (CI) showing modification of the effect of operative vaginal delivery (vs cesarean delivery) on perinatal and maternal outcomes by institutional delivery volume (stratified by instrument applied and indication)

Outcome	Instrument	Institutional delivery volume*					
		Dystocia			Fetal distress		
		Low	Medium	High	Low	Medium	High
		AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
Perinatal morbidity/mortality	Forceps	1.96 (1.08-3.55)	1.78 (1.03-3.07)	1.19 (0.69-2.07)	0.95 (0.55-1.63)	1.15 (0.70-1.77)	1.22 (0.80-1.86)
	Vacuum	1.47 (0.85-2.55)	1.47 (0.88-2.45)	1.50 (0.88-2.55)	1.19 (0.77-1.85)	0.82 (0.53-1.26)	1.02 (0.66-1.57)
Maternal morbidity/mortality	Forceps	0.79 (0.52-1.20)	1.51 (0.99-2.31)	0.90 (0.63-1.28)	0.64 (0.39-1.03)	0.97 (0.59-1.59)	0.75 (0.48-1.15)
	Vacuum	0.66 (0.46-0.94)	0.78 (0.51-1.20)	0.56 (0.37-0.84)	0.42 (0.27-0.64)	0.54 (0.33-0.89)	0.38 (0.23-0.64)
Birth trauma	Forceps	2.86 (2.18-3.76)	3.70 (2.74-4.99)	2.72 (2.02-3.65)	3.12 (2.27-4.30)	3.99 (2.71-5.88)	2.28 (1.70-3.08)
	Vacuum	3.96 (3.09-5.06)	3.25 (2.44-4.32)	4.58 (3.46-6.06)	3.34 (2.50-4.48)	3.52 (2.43-5.09)	3.38 (2.54-4.48)
Obstetric trauma	Forceps	**4.87 (4.02-5.90)**	**7.17 (5.94-8.66)**	**4.28 (3.72-4.91)**	**5.18 (4.13-6.50)**	**5.22 (4.22-6.46)**	**3.14 (2.67-3.70)**
	Vacuum	**2.82 (2.35-3.39)**	**4.21 (3.51-5.06)**	**2.16 (1.86-2.51)**	**2.95 (2.38-3.67)**	**3.17 (2.58-3.90)**	**1.55 (1.30-1.84)**
Severe perineal laceration ($3^{rd}/4^{th}$ degree)†	Forceps	21.4 (20.4-22.5)	21.1 (19.7-22.6)	27.4 (24.8-30.3)	21.0 (19.1-23.0)	23.2 (21.2-25.2)	23.8 (22.2-25.4)
	Vacuum	14.2 (13.6-14.9)	13.4 (12.2-14.6)	8.2 (6.2-10.8)	13.7 (12.6-14.9)	17.3 (15.9-18.7)	14.0 (12.8-15.4)

*Institutional delivery volume was calculated based on tertiles of the annual frequency of deliveries by operative vaginal delivery or cesarean delivery. In the dystocia cohort, the low, medium and high groups were defined as <85 deliveries per year, 85-170 deliveries per year, and >170 deliveries per year, respectively. In the fetal distress cohort, the low, medium and high groups were defined as <200 deliveries per year, 200-400 deliveries per year, and >400 deliveries per year, respectively.

† Estimates are expressing proportions and 95% confidence intervals.

Bold text denotes statistically significant effect modification by institutional delivery volume defined as p for interaction<0.01.

Appendix Table 5.4. Sensitivity analyses showing impact of including failed instrumental deliveries in the attempted operative vaginal delivery category, term singleton deliveries, Canada (excluding Quebec), 2003-2013.

Outcome Dystocia cohort		**Cesarean delivery n=9300**	**Forceps All (model 1)* n=9648**	**Forceps All (model 2)† n=10186**	**Vacuum All (model 1)* n=15614**	**Vacuum All (model 2)† n=16233**	**Vacuum All (model 3)‡ n=18527**
Severe perinatal morbidity/mortality	%	0.66	0.93	0.96	0.86	0.89	0.97
	AOR (95% CI)	Ref	1.56 (1.13-2.17)	1.60 (1.16-2.21)	1.44 (1.06-1.97)	1.47 (1.08-1.99)	1.59 (1.18-2.13)
Severe birth trauma	%	0.17	0.68	0.66	0.49	0.51	0.59
	AOR (95% CI)	Ref	4.64 (2.68-8.03)	4.39 (2.54-7.60)	3.35 (1.94-5.77)	3.40 (1.98-5.84)	3.95 (2.33-6.71)
Birth trauma	%	2.09	5.97	5.94	8.04	8.17	8.85
	AOR (95% CI)	Ref	3.24 (2.74-3.82)	3.19 (2.70-3.76)	4.11 (3.52-4.80)	4.16 (3.56-4.85)	4.53 (3.89-5.27)
Severe maternal morbidity/mortality	%	1.65	1.53	1.56	0.98	1.03	1.17
	AOR (95% CI)	Ref	1.03 (0.81-1.29)	1.04 (0.83-1.30)	0.64 (0.51-0.81)	0.67 (0.53-0.83)	0.75 (0.61-0.93)
Obstetric trauma	%	6.33	24.9	24.0	15.0	14.8	16.3
	AOR (95% CI)	Ref	5.34 (4.85-5.88)	5.04 (4.58-5.55)	2.89 (2.63-3.18)	2.81 (2.55-3.09)	3.15 (2.86-3.45)
Severe perineal laceration (3rd/4th degree)	% (95% CI)	<0.05	21.9 (21.1-22.8)	20.8 (20.0-21.6)	13.9 (13.3-14.4)	13.3 (12.8-13.9)	14.7 (14.2-15.2)

Outcome Fetal distress cohort		**Cesarean delivery n=5734**	**Forceps All (model 1)* n=5917**	**Forceps All (model 2)† n=6313**	**Vacuum All (model 1)* n=9237**	**Vacuum All (model 2)† n=9670**	**Vacuum All (model 3)‡ n=11046**
Severe perinatal morbidity/mortality	%	1.80	1.94	1.96	1.78	1.76	2.01
	AOR (95% CI)	Ref	1.14 (0.87-1.49)	1.15 (0.88-1.50)	1.03 (0.80-1.32)	1.01 (0.79-1.30)	1.17 (0.92-1.49)
Severe birth trauma	%	0.16	0.88	0.87	0.70	0.70	0.91
	AOR (95% CI)	Ref	6.68 (3.28-13.6)	6.51 (3.20-13.2)	5.25 (2.60-10.6)	5.20 (2.58-10.5)	6.78 (3.41-13.5)
Birth trauma	%	2.69	7.15	7.10	8.51	8.60	9.69
	AOR (95% CI)	Ref	2.97 (2.45-3.59)	2.91 (2.41-3.51)	3.35 (2.80-4.00)	3.37 (2.82-4.02)	3.84 (3.22-4.57)
Severe maternal morbidity/mortality	%	2.18	1.59	1.60	0.93	0.96	1.02
	AOR (95% CI)	Ref	0.77 (0.59-1.01)	0.77 (0.59-1.01)	0.43 (0.32-0.57)	0.44 (0.33-0.58)	0.47 (0.36-0.61)
Obstetric trauma	%	8.09	26.3	25.2	16.0	15.6	17.2
	AOR (95% CI)	Ref	4.23 (3.78-4.73)	3.98 (3.56-4.45)	2.28 (2.04-2.55)	2.19 (1.96-2.45)	2.46 (2.21-2.74)
Severe perineal laceration (3rd/4th degree)	% (95% CI)	<0.09	22.8 (21.8-23.9)	21.4 (20.4-22.5)	14.9 (14.2-15.7)	14.3 (13.6-15.0)	15.6 (14.9-16.3)

* All (model 1) includes only successful operative vaginal deliveries.

†All (model 2) includes successful (model 1) and failed operative vaginal deliveries, in their respective instrument categories.

‡ All (model 3) includes attempted and failed operative vaginal deliveries (model 2) and includes sequential instrumentation in the vacuum delivery group. Bold text denotes statistically significant associations.

Appendix Table 5.5. Sensitivity analyses comparing perinatal and maternal morbidity/mortality by mode of delivery following a failed trial of vacuum delivery, term singleton deliveries, Canada (excluding Quebec), 2003-2013.

		Failed trial of vacuum followed by		
Outcome Dystocia cohort		**Cesarean n=619**	**Successful forceps n=2138**	**Attempted forceps* n=2294**
Severe perinatal morbidity/mortality	%	1.62	1.50	1.48
	AOR (95% CI)	Ref	1.07 (0.51-2.22)	1.06 (0.51-2.18)
Severe birth trauma	%	0.97	1.22	1.18
	AOR (95% CI)	Ref	1.50 (0.61-3.71)	1.45 (0.59-3.57)
Birth trauma	%	11.6	13.4	13.6
	AOR (95% CI)	Ref	1.22 (0.92-1.61)	1.23 (0.94-1.63)
Severe maternal morbidity/mortality	%	2.26	2.20	2.14
	AOR (95% CI)	Ref	1.05 (0.57-1.94)	1.01 (0.55-1.87)
Obstetric trauma	%	8.72	28.7	27.0
	AOR (95% CI)	Ref	4.36 (3.24-5.87)	4.00 (2.98-5.38)
Severe perineal laceration†	% (95% CI)	0.00	26.4 (24.6-28.3)	24.6 (22.9-26.4)

		Failed trial of vacuum followed by		
Outcome Fetal distress cohort		**Cesarean n=433**	**Successful forceps n=1231**	**Attempted forceps* n=1376**
Severe perinatal morbidity/mortality	%	1.39	3.57	3.78
	AOR (95% CI)	Ref	2.84 (1.19-6.79)	2.99 (1.26-7.06)
Severe birth trauma	%	<1.15	2.44	2.40
	AOR (95% CI)	Ref	3.68 (1.11-12.16)‡	3.82 (1.16 12.6)
Birth trauma	%	10.6	17.1	17.3
	AOR (95% CI)	Ref	1.74 (1.24-2.46)	1.78 (1.27-2.50)
Severe maternal morbidity/mortality	%	1.62	1.30	1.45
	AOR (95% CI)	Ref	0.80 (0.33-1.96) ‡	0.90 (0.38-2.14)
Obstetric trauma	%	7.39	31.0	28.6
	AOR (95% CI)	Ref	5.90 (4.02-8.65)	5.22 (3.56-7.64)
Severe perineal laceration†	% (95% CI)	0.00	27.9 (25.4-30.4)	24.9 (22.7-27.3)

Models adjusted for maternal age, parity, birth weight, and year of birth.

* Includes successful and failed forceps attempts following a failed trial of vacuum delivery

† Rate (%) and 95% CI provided for severe perineal lacerations as relative estimates were not estimable due to low rate (0.00%) in the reference group.

‡ Crude odds ratio reported as adjusted odds ratio was undefined due to small numbers.

Appendix Table 5.6. Detailed numbers and rates of the components of composite study outcomes by mode of operative delivery

Outcome	Cesarean delivery		Forceps		Vacuum	
Dystocia cohort	**No.**	**%**	**No.**	**%**	**No.**	**%**
Severe perinatal morbidity/mortality	61	0.66	90	0.93	135	0.86
Stillbirth	0	0.00	<5	<0.05	<5	<0.03
Neonatal death	0	0.00	0	0.00	<5	<0.03
Neonatal seizures	16	0.17	9	0.09	25	0.16
Asst. ventilation (endotracheal)	35	0.38	17	0.18	43	0.28
Severe birth trauma	16	0.17	66	0.68	77	0.49
Intracranial hemorrhage	<5	<0.05	<5	<0.05	6	0.04
Subaponeurotic hemorrhage	<5	<0.05	0	0.00	14	0.09
Skull fracture	<5	<0.05	<5	<0.05	<5	<0.03
Severe central nervous system injury	<5	<0.05	<5	<0.05	<5	<0.03
Severe peripheral nervous system injury	7	0.08	60	0.62	54	0.35
Femur injury	<5	<0.05	0	0.00	0	0.00
Humerus injury	0	0.00	<5	<0.05	<5	<0.03
Birth trauma	194	2.09	576	5.97	1255	8.04
Intracranial hemorrhage	<5	<0.05	<5	<0.05	<5	<0.03
Injury to central nervous system	<5	<0.05	39	0.40	8	0.05
Injury to peripheral nervous system	7	0.08	60	0.62	54	0.35
Injury to scalp	143	1.54	303	3.14	1062	6.80
Injury to skeleton	24	0.26	70	0.73	128	0.82
Injury – other	28	0.30	161	1.67	65	0.42
Severe maternal morbidity/mortality	153	1.65	148	1.53	153	0.98
Maternal death	0	0.00	0	0.00	0	0.00
Severe postpartum hemorrhage*	97	1.04	122	1.26	117	0.75
Severe atonic postpartum hemorrhage	86	0.92	98	1.02	85	0.54
Shock	<5	<0.05	6	0.06	6	0.04
Sepsis	20	0.22	11	0.11	12	0.08
Cardiac complication†	36	0.39	9	0.09	13	0.08
Acute renal failure	<5	<0.05	<5	<0.05	<5	<0.03
Obstetric embolism	5	0.05	0	0.00	<5	<0.03
Obstetric trauma	589	6.33	2400	24.9	2341	15.0
Perineal laceration-3rd/4th degree	<5	<0.05	2117	21.9	2162	13.9
Cervical laceration	73	0.78	33	0.34	33	0.21
High vaginal laceration	12	0.13	240	2.49	86	0.55
Injury to pelvic organ/joint	331	3.56	28	0.29	28	0.18
Pelvic hematoma	7	0.08	22	0.23	31	0.20
Extension of uterine incision	268	2.88	<5	<0.05	<5	<0.03

Appendix Table 5.6. cont'd. Detailed numbers and rates of the components of composite study outcomes by mode of operative delivery

Outcome	Cesarean delivery		Forceps		Vacuum	
Fetal distress cohort	**No.**	**%**	**No.**	**%**	**No.**	**%**
Severe perinatal morbidity/mortality	103	1.80	115	1.94	164	1.78
Stillbirth	0	0.00	0	0.00	<5	<0.05
Neonatal death	<5	<0.09	<5	<0.08	<5	<0.05
Neonatal seizures	23	0.40	14	0.24	28	0.30
Asst. ventilation (endotracheal)	80	1.40	55	0.93	81	0.88
Severe birth trauma	9	0.16	52	0.88	65	0.70
Intracranial hemorrhage	<5	<0.09	<5	<0.08	<5	<0.05
Subaponeurotic hemorrhage	0	0.00	<5	<0.08	18	0.19
Skull fracture	<5	<0.09	<5	<0.08	<5	<0.05
Severe central nervous system injury	<5	<0.09	<5	<0.08	<5	<0.05
Severe peripheral nervous system injury	<5	<0.09	43	0.73	36	0.39
Femur injury	0	0.00	0	0.00	0	0.00
Humerus injury	0	0.00	<5	<0.08	<5	<0.05
Birth trauma	154	2.69	423	7.15	786	8.51
Intracranial hemorrhage	<5	<0.09	<5	<0.08	<5	<0.05
Injury to central nervous system	5	0.09	33	0.56	6	0.06
Injury to peripheral nervous system	<5	<0.09	43	0.73	36	0.39
Injury to scalp	108	1.88	236	3.99	662	7.17
Injury to skeleton	25	0.44	40	0.68	71	0.77
Injury – other	23	0.40	123	2.08	57	0.62
Severe maternal morbidity/mortality	125	2.18	94	1.59	86	0.93
Maternal death	0	0.00	0	0.00	0	0.00
Severe postpartum hemorrhage*	72	1.26	73	1.23	62	0.67
Severe atonic postpartum hemorrhage	65	1.13	59	1.00	34	0.37
Shock	<5	<0.09	<5	<0.08	<5	<0.05
Sepsis	21	0.37	10	0.17	12	0.13
Cardiac complication†	28	0.49	7	0.12	7	0.08
Acute renal failure	<5	<0.09	0	0.00	<5	<0.05
Obstetric embolism	5	0.09	<5	<0.08	<5	<0.05
Obstetric trauma	464	8.09	1553	26.3	1477	16.0
Perineal laceration-3rd/4th degree	<5	<0.09	1351	22.8	1379	14.9
Cervical laceration	49	0.85	22	0.37	18	0.19
High vaginal laceration	13	0.23	176	2.97	49	0.53
Injury to pelvic organ/joint	299	5.21	17	0.29	22	0.24
Pelvic hematoma	6	0.10	24	0.41	14	0.15
Extension of uterine incision	219	3.82	<5	<0.08	<5	<0.05

* Severe postpartum hemorrhage includes postpartum hemorrhage with a transfusion.
† Cardiac complications include cardiac arrest, cardiac failure, myocardial infarction and pulmonary embolism.

Appendix to Chapter 6

Appendix Table 6.1 ICD-10-CA and CCI codes used in study. International Classification of Diseases and Related Health Problems Tenth Revision, Canada (ICD-10-CA) and Canadian Classification of Health Interventions (CCI) codes used for the study

Diagnosis/Procedure	ICD-10-CA	CCI	Study use
Single live birth	Z37.0		Inclusion criteria
Forceps delivery		5.MD.53	
Outlet forceps		5.MD.53.KJ, 5.MD.53.KH	
Low forceps		5.MD.53.KL, 5.MD.53.KK	
Mid forceps		5.MD.53.KN, 5.MD.53.KM	
Vacuum delivery		5.MD.54	
Outlet vacuum		5.MD.54.KJ, 5.MD.54.KH	
Low vacuum		5.MD.54.KL, 5.MD.54.KK	
Mid vacuum		5.MD.54.KN, 5.MD.54.KM	
Sequential instrumental delivery		5.MD.55	
Outlet vacuum/ forceps		5.MD.55.KJ, 5.MD.55.KH	
Low vacuum/ forceps		5.MD.55.KL, 5.MD.55.KK	
Mid vacuum/ forceps		5.MD.55.KN, 5.MD.55.KM	
Vacuum with forceps not otherwise specified		5.MD.55.KR, 5.MD.55.KQ	
Cesarean delivery		5.MD.60.KE, 5.MD.60.JY, 5.MD.60.KB, 5.MD.60.KG, 5.MD.60.KF, 5.MD.60.AA, 5.MD.60.KT	
Maternal age	DAD element		Confounder
Parity	DAD element		
Birth weight	DAD element		
Fiscal year	DAD element		
Chronic hypertension	O10, O11		
Preeclampsia	O14		
Eclampsia	O15		
Diabetes	O24		
Obstetric trauma	O70.2, O70.3, O71.3-O71.9	5.PC.80.JQ, 5.PC.80.JH	Primary composite outcomes
Severe birth trauma	P10, P11.0-P11.2, P11.4-P11.5 P12.2, P13.0, P13.2, P13.30, P13.38, P14.0, P14.1, P14.3, P15.0, P15.1		

DAD, Discharge Abstract Database

Appendix Table 6.2. Distribution of components of composite obstetric trauma outcome by mode of delivery

	All deliveries (1 938 913)		**Operative vaginal delivery (207 675)**		**Cesarean delivery (496 361)**		**Spontaneous vaginal delivery (1 234 877)**	
	No.	%	No.	%	No.	%	No.	%
All obstetric trauma	85 842	100	33 095	100	8 395	100	44 352	100
Severe perineal lacerations (3^{rd} and 4^{th} degree)	60 970	71.0	28 550	86.3	39	0.5	32 381	73.0
Injury to bladder/urethra	5 774	6.7	341	1.0	3 735	44.5	1 698	3.8
High vaginal laceration	5 039	5.8	2 015	6.1	205	2.4	2 771	6.2
Cervical laceration	4 530	5.3	758	2.3	892	10.6	2 857	6.4
Other obstetric injury	3 306	3.9	507	1.5	1 105	13.2	1 694	3.8
Repair of uterine incision	2 473	2.9	39	0.1	2 296	27.3	138	0.3
Delayed repair of episiotomy/ Repair of wound dehiscence following episiotomy or obstetrical laceration repair	2 447	2.9	1 056	3.2	47	0.6	1 344	3.0
Hematoma of the pelvis (perineum, vagina, or vulva)	2 180	2.5	487	1.5	262	3.1	1 431	3.2
Injury to the pelvic joints and ligaments	1 186	1.4	154	0.5	447	5.3	585	1.3
Laceration to the broad ligament of the uterus	492	0.6	9	0.0	439	5.2	44	0.1
Repair of wound dehiscence following Cesarean section	514	0.6	14	0.0	471	5.6	29	0.1

Appendix Table 6.3. Distribution of components of composite severe birth trauma outcome by mode of delivery

	All deliveries (1 938 913)		**Operative vaginal delivery (207 675)**		**Cesarean delivery (496 361)**		**Spontaneous vaginal delivery (1 234 877)**	
	No.	%	No.	%	No.	%	No.	%
All severe birth trauma	3 366	100	1 356	100	326	100	1 684	100
Severe peripheral nervous system injury (brachial plexus injury)	2 352	69.9	880	64.9	99	30.4	1 373	81.5
Femur/humerus injury	443	13.2	139	10.3	74	22.7	230	13.7
Subaponeurotic hemorrhage	244	7.2	191	14.1	37	11.3	16	1.0
Intracranial hemorrhage/laceration	226	6.7	123	9.1	57	17.5	123	7.3
Skull fracture	104	3.1	47	3.5	48	14.7	9	0.5
Severe central nervous system injury (brain damage or spinal cord injury)	101	3.0	34	2.5	31	9.5	36	2.1
Injury to the liver/spleen	<5	<0.1	<5	<0.4	<5	<16.9	<5	<0.3

Appendix Table 6.4. Distribution of mode of delivery by obstetric characteristic, term singletons, Canada*, 2004-14

Obstetric characteristic	Vaginal delivery		Cesarean delivery	P-value
	Spontaneous	Operative		
	No. (%)	No. (%)	No. (%)	
Nulliparous women	463 702 (55.2)	152 632 (18.2)	223 438 (26.6)	
Advanced maternal age (≥35 yrs)				<0.001
Yes	38 215 (39.9)	18 029 (18.8)	39 525 (41.3)	
No	425 487 (57.2)	134 603 (18.1)	183 913 (24.7)	
Hypertensive disorders				<0.001
Yes	27 171 (45.4)	9 785 (16.4)	22 852 (38.2)	
No	436 531 (56.0)	142 847 (18.3)	200 586 (25.7)	
Diabetes				<0.001
Yes	16 097 (42.7)	6 562 (17.4)	15 038 (39.9)	
No	447 605 (55.8)	146 070 (18.2)	208 400 (26.0)	
Labour induction				<0.001
Yes	118 773 (50.1)	44 658 (18.8)	73 761 (31.1)	
No	344 929 (57.2)	107 974 (17.9)	149 677 (24.8)	
Macrosomia (>4 000 g)				<0.001
Yes	35 791 (40.6)	14 687 (16.7)	37 590 (42.7)	
No	427 911 (56.9)	137 945 (18.4)	185 848 (24.7)	
Parous women with no previous CD	732 448 (87.8)	45 983 (5.5)	56 185 (6.7)	
Advanced maternal age (≥35 yrs)				<0.001
Yes	156 413 (83.5)	12 742 (6.8)	18 258 (9.7)	
No	576 035 (89.0)	33 241 (5.1)	37 927 (5.9)	
Hypertensive disorders				<0.001
Yes	25 371 (82.3)	1 955 (6.3)	3 513 (11.4)	
No	707 077 (88.0)	44 028 (5.5)	52 672 (6.6)	
Diabetes				<0.001
Yes	34 580 (81.4)	2 783 (6.6)	5 108 (12.0)	
No	697 868 (88.1)	43 200 (5.5)	51 077 (6.5)	
Labour induction				<0.01
Yes	173 213 (87.8)	13 081 (6.6)	10 908 (5.5)	
No	559 235 (87.7)	32 902 (5.2)	45 277 (7.1)	
Macrosomia (>4 000 g)				<0.001
Yes	101 343 (85.2)	7 247 (6.1)	10 318 (8.7)	
No	631 105 (88.2)	38 736 (5.4)	45 867 (6.4)	
Parous women with a previous CD	38 727 (14.6)	9 060 (3.4)	216 738 (81.9)	
Advanced maternal age (≥35 yrs)				<0.001
Yes	9 611 (12.0)	2 333 (2.9)	68 361 (85.1)	
No	29 116 (15.8)	6 727 (3.7)	148 377 (80.5)	
Hypertensive disorders				<0.001
Yes	1 111 (11.7)	232 (2.5)	8 126 (85.8)	
No	37 616 (14.8)	8 828 (3.5)	208 612 (81.8)	
Diabetes				<0.001
Yes	2 021 (10.4)	441 (2.3)	16 933 (87.3)	
No	36 706 (15.0)	8 619 (3.5)	199 805 (81.5)	
Labour induction				<0.001
Yes	6 595 (56.4)	1 416 (12.1)	3 692 (31.6)	
No	32 132 (12.7)	7 644 (3.0)	213 046 (84.3)	
Macrosomia (>4 000 g)				0.06
Yes	4 699 (14.7)	1 047 (3.3)	26 223 (82.0)	
No	34 028 (14.6)	8 013 (3.5)	190 515 (81.9)	