Maternal morbidity and perinatal outcomes among women in rural versus urban areas

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Abstract

Background: Most studies examining geographic barriers to maternity care in industrialized countries have focused solely on fetal and neonatal outcomes. We examined the association between rural residence and severe maternal morbidity, in addition to perinatal mortality and morbidity.

Methods: We conducted a retrospective population-based cohort study of all women who gave birth in British Columbia, Canada, between Jan. 1, 2005, and Dec. 31, 2010. We compared maternal mortality and severe morbidity (e.g., eclampsia) and adverse perinatal outcomes (e.g., perinatal death) between women residing in areas with moderate to no metropolitan influence (rural) and those living in metropolitan areas or areas with a strong metropolitan influence (urban). We used logistic regression analysis to obtain adjusted odds ratios (ORs) and 95% confidence intervals (CIs).

Results: We found a significant association between death or severe maternal morbidity and rural residence (adjusted OR 1.15, 95% CI 1.03–1.28). In particular, women in rural areas had significantly higher rates of eclampsia (adjusted OR 2.70, 95% CI 1.79–4.08), obstetric embolism (adjusted OR 2.16, 95% CI 1.14–4.07) and uterine rupture or dehiscence (adjusted OR 1.96, 95% CI 1.42–2.72) than women in urban areas. Perinatal mortality did not differ significantly between the study groups. Infants in rural areas were more likely than those in urban areas to have a severe neonatal morbidity (adjusted OR 1.14, 95% CI 1.02–1.29), to be born preterm (adjusted OR 1.06, 95% CI 1.01–1.11), to have an Apgar score of less than 7 at 5 minutes (adjusted OR 1.24, 95% CI 1.13–1.31) and to be large for gestational age (adjusted OR 1.14, 95% CI 1.10–1.19). They were less likely to be small for gestational age (adjusted OR 0.90, 95% CI 0.85–0.95) and to be admitted to an neonatal intensive care unit (NICU) (adjusted OR 0.36, 95% CI 0.33–0.38) compared with infants in urban areas.

Interpretation: Compared with women in urban areas, those in rural areas had higher rates of severe maternal morbidity and severe neonatal morbidity, and a lower rate of NICU admission. Maternity care providers in rural regions need to be aware of potentially life-threatening maternal and perinatal complications requiring advanced obstetric and neonatal care.

One of the United Nations' Millennium Development Goals set in 2000 was to reduce maternal mortality by 75% in 15 years,[1] a challenge that spurred an interest in maternal mortality and morbidity. Although maternal death is extremely rare in industrialized countries, Canada is involved in global initiatives to prevent severe maternal morbidity, including eclampsia and sepsis. Women with severe maternal morbidity have almost 400 times higher rates of maternal death.[2]

In Canada, maternal mortality (death during pregnancy or within 42 days after delivery) ranged from 6.1 to 8.2 per 100 000 live births between 2003/04 and 2010/11,[3,4] whereas the rate of severe maternal morbidity ranged from 1.3 to 1.5 per 100 deliveries.[5] Past decades have seen an increase in the number of parturient women with chronic health conditions (e.g., hypertension, diabetes, chronic heart disease and obesity)[6–10] and advanced maternal age.[11,12] These conditions require careful prenatal monitoring and timely obstetric intervention.

Living in a rural or remote location can make access to advanced obstetric and neonatal care difficult and may increase the risk of severe maternal and perinatal morbidity. During 2000–2012, about one-fifth of births in Canada (excluding Quebec) were to women residing in rural and remote areas.[13] Many communities in such areas have seen closures of local maternity services.[14] A 2013 report showed that women living in rural areas of Canada had higher rates of teenage pregnancy, smoking, obesity and sub-

stance use and were more likely to live in socioeconomically disadvantaged neighbourhoods than women in urban areas.[13] The prevalence of chronic medical conditions is also higher among women of child-bearing age living in rural or remote areas than in urban centres.[15] In addition, 17% of women in rural areas had to travel for more than 2 hours to give birth.[13]

Most studies examining geographic barriers to maternity care in industrialized countries focused solely on perinatal death and infant mortality and morbidity, showing elevated rates among infants of women residing in rural areas.[14,16–20] Geographic disparity in severe maternal morbidity has not been adequately examined.

We carried out a study to compare maternal morbidity among women residing in rural areas and those in urban areas. We hypothesized that women in rural areas would have a higher incidence of severe maternal morbidity, mediated in part by the higher prevalence of risk factors and chronic medical conditions among parturient women in rural areas. The secondary objective was to compare fetal and infant health outcomes, including perinatal death and severe neonatal morbidity, between the rural and urban groups.

Methods

Study design

We conducted a retrospective population-based cohort study involving all mothers who gave birth in the province of British Columbia, Canada, between Jan. 1, 2005, and Dec. 31, 2010.

Data collection

Information about maternal characteristics, pregnancy complications, maternal morbidity and birth outcomes was retrieved from the Perinatal Data Registry, a provincial database maintained by Perinatal Services BC. The registry captures more than 99% of births in the province. Trained abstractors collect pregnancy and birth information from hospital charts after discharge using standardized protocols. The abstracted data were shown to be of high quality in a validation study.[21] The database includes detailed information about sociodemographic factors, clinical information about mode of delivery, type of cesarean delivery, prenatal care, obstetric history (e.g., prior abortions, stillbirth and preterm births) and behavioural factors such as smoking, alcohol and drug use.

We obtained data on severe maternal morbidity, severe neonatal morbidity and congenital anomalies from the registry. International Statistical Classification of Diseases and Related Health Problems, 10th revision, Canadian enhancement (ICD-10-CA) and Canadian Classification of Health Interventions (CCI) codes for diagnoses and procedures during maternal and infant hospital admissions[22] were used to abstract these morbidities from hospital discharge reports (Appendices 1 and 2, available at www.cmaj.ca/lookup/suppl/doi:10.1503/cmaj.151382/-/DC1). This information is equivalent to that collected in the Discharge Abstract Database, which contains information on all separations from hospitals in Canada and includes up to 25 diagnostic and 20 procedure codes.[23,24] Data on transfers of infants to another hospital were linked to the delivery hospital data, and the linkage was available up to 2010.

Maternal residence was identified by the 6-digit residential postal code at the time of birth. We used postal code conversion files to identify areas with various degrees of rural isolation: census metropolitan areas, census agglomerations, and census subdivisions with strong, moderate, weak or no metropolitan influence (Appendix 3, available at www.cmaj.ca/lookup/suppl/doi:10.1503/cmaj.151382/-/DC1). The degree of metropolitan influence was determined by the proportion of the resident working population that commutes to a metropolitan area (≥ 30%, 5%–29%, 1%–5% and none, respectively).[25,26] A census metropolitan area is defined as an area with a core population of at least 100 000; a census agglomeration has a core population of 10 000–99 999.[25] We defined urban areas as census metropolitan areas, census agglomerations and subdivisions with a strong metropolitan influence; we included these subdivisions as urban areas because the amenities and health care facilities of metropolitan areas were likely easily available to women residing in these neighbourhoods. We considered census subdivisions with moderate, weak or no metropolitan influence (< 30% of resident workforce commutes to a metropolitan area or census agglomeration) as rural areas.

Low socioeconomic status was defined as living in a neighbourhood with the lowest income quintile, relative to median income based on BC tax returns in 2006.[27]

Outcome measures

The outcome measures were the combined outcome of severe maternal morbidity or maternal death, as well as adverse perinatal outcomes.

Information on maternal death before hospital discharge (including interhospital transfer and hospital discharge after transfer) was obtained from the Perinatal Database Registry and confirmed against hospital discharge data (hospital diagnosis, ICD-10-CA codes O95–O97).

Severe maternal morbidity was identified with the use of criteria developed by the Canadian Perinatal Surveillance System, based on high case-fatality rates, vital organ function damage, high resource utilization (surgical procedures) and important adverse sequelae (e.g., peripartum hysterectomy).[3] Selected ICD-10-CA/CCI codes for diagnoses and procedures during the hospital admission for delivery are listed in Appendix 1. The diagnoses and procedures include obstetric embolism, peripartum cardiomyopathy; heart failure; subarachnoid, intracerebral, subdural or intracranial hemorrhage; transfusion (of any blood product); acute renal failure; and acute liver failure. The composite outcome "severe maternal morbidity" included any of the above stated conditions and those listed in Appendix 1.

In addition, we examined other maternal morbidities, including antepartum hemorrhage, postpartum hemorrhage, preeclampsia, and obstetric trauma (Appendix 1). Antepartum and postpartum hemorrhage were not included in the composite outcome of severe maternal morbidity because we could not clearly distinguish between mild and severe forms of these 2 conditions. Instead, we used blood transfusion, which clearly identified cases of severe hemorrhage, to capture such cases within the composite outcome. We defined preeclampsia as hypertension (pre-existing, or new onset during pregnancy based on 2 blood pressure readings > 140/90 mm Hg), and severe proteinuria (> 1 g/L), in the absence of eclampsia diagnosis. The cut-off for proteinuria was 1 g/L instead of 300 mg/L because this was the only available information on proteinuria.

Adverse perinatal outcomes included fetal death, neonatal death before discharge (including transfers), preterm birth (< 37 and < 34 wk), small for gestational age (< 10th percentile), large for gestational age (> 90th percentile using Canadian reference),[28] Apgar score of less than 7 at 5 minutes, admission to neonatal intensive care unit (NICU) and severe neonatal morbidity. Severe neonatal morbidity was defined as any of the following: respiratory distress syndrome, retinopathy of prematurity, intraventricular hemorrhage (grade 3 or more), intracranial hemorrhage, sepsis, necrotizing enterocolitis, or other conditions listed in Appendix 2, ventilator use for more than 30 days, use of oxygen or continuous positive airway pressure ventilator for more than 30 days, or parenteral nutrition for more than 30 days.

Statistical analysis

We compared maternal mortality and morbidity between rural and urban residence in a univariable analysis using crude odds ratios (ORs) and 95% confidence intervals (CIs). Morbidities that were significantly associated with residence were further examined using logistic regression. The regression model adjusted for demographic characteristics and clinical risk factors occurring during pregnancy, including maternal age (20–34 yr v. < 20 yr and v. ≥ 35 yr), parity (none v. 1–3 and v. ≥ 4), low socioeconomic status, smoking during pregnancy (yes v. no), diabetes mellitus (yes v. no), gestational diabetes (yes v. no) and male sex of fetus.

Because some morbidities are strongly associated with delivery characteristics or may result from the obstetric intervention (e.g., obstetric trauma associated with instrumental vaginal delivery), we performed sensitivity analyses. This second set of logistic regression analyses adjusted for the demographic and clinical risk factors above, as well as for potential confounding factors related to labour and delivery, including prolonged labour, cesarean delivery, instrumental vaginal delivery, analgesia and type of attendant at delivery. Categories of attendant at delivery included family physician (or family medicine resident), midwife (or midwife trainee), and other health professional or no attendant; the reference category was obstetrician/surgeon (or obstetrics resident or fellow).

We compared perinatal outcomes between infants born to women residing in rural versus urban areas using multivariable analyses. In the first step, we used logistic regression to adjust for socioeconomic and demographic factors, obstetric history of previous perinatal death, diabetes mellitus, gestational diabetes, hypertension (pre-existing and new onset during pregnancy), preeclampsia and congenital anomaly. Congenital anomalies were identified by the presence of any ICD-10-CA code for congenital anomaly in the hospital discharge reports. In the second step of the multivariable analyses, we also adjusted for labour and delivery risk factors, including perinatal and neonatal death and morbidity, NICU admission, low Apgar score and preterm birth. Adverse outcomes such as fetal death, small for gestational age at birth and large for gestational age at birth are generally not affected by delivery characteristics; thus, these outcomes were not included in the second regression analysis. Odds ratios for perinatal and neonatal death and morbidity, NICU admission and low Apgar score were also adjusted for preterm birth (< 34 wk and 34–36 wk v. ≥ 37 wk). We performed sensitivity analyses using generalized estimating equations to account for clustering of adverse perinatal and neonatal outcomes in multifetal pregnancies.

We conducted all statistical analyses using SAS version 9.3 (SAS Institute Inc.).

Ethics approval

Ethics approval was granted by the Behavioural Research Ethics Board, University of British Columbia.

Results

Overall, 257 324 women gave birth in BC during the 6-year study period. We excluded 1104 (0.4) because the postal code was missing. Most of the women Of the remaining 256 220 women, most (89.9%, n = 230 365) lived in predominantly urban areas; in particular, 68.3% were in census metropolitan areas, 20.0% in census agglomerations and 1.6% in census subdivisions with a strong metropolitan influence. The remaining 10.1% (n = 25 855) lived in predominantly rural areas, which comprised census subdivisions with moderate (3.3%), weak (6.1%) or no (0.7%) metropolitan influence. Maternal mortality or severe maternal morbidity was 1.52 per 100 deliveries (95% CI 1.47–1.56).

The women in rural areas were more likely than those in urban areas to be younger, to have smoked or consumed alcohol or drugs during the pregnancy, to be grand multiparas (≥ 4 prior births), to have a lower number of prenatal visits, to have pre-existing hypertension and to have a midwife involved in prenatal care (Table 1). They were less likely to be nulliparas and to have pre-existing or gestational diabetes.

Women in rural areas were more likely than their urban counterparts to have a preterm or post-term birth, premature rupture of membranes for more than 24 hours, spontaneous labour, labour augmentation and spontaneous vaginal delivery, and to choose a trial of labour after a prior cesarean delivery (Table 2). They were also more likely to be delivered by a family physician or midwife, to have a home birth and to have a large-for-gestational-age infant (birth weight > 4000 g). The prevalence of congenital anomalies was similar between the rural and urban groups (4.6% and 4.7%, respectively).

The rate of death or severe maternal morbidity was higher among women in rural areas than among those in urban areas 1670.0 v. 1500.0 per 100 000 deliveries; OR 1.11, 95% CI 1.01–1.23) (Table 3). The most common severe morbidity was blood transfusion (595.6 and 512.1 per 100 000 deliveries in rural and urban areas, respectively; OR 1.19, 95% CI 1.00–1.40). The most common maternal morbidity was postpartum hemorrhage (7.6 and 8.0 per 100 deliveries in rural and urban areas, respectively; OR 0.95, 95% CI 0.91–1.00).

Severe maternal morbidities significantly associated with rural residence or those that had a borderline significant association were examined using logistic regression to discern confounding (Table 4). After adjustment for potential confounding factors before delivery, the risk of death or severe maternal morbidity remained significantly higher among women in rural areas (adjusted OR 1.15, 95% CI 1.03–1.28). The association with rural residence also remained significant for eclampsia (adjusted OR 2.70, 95% CI 1.79–4.08), obstetric embolism (adjusted OR 2.16, 95% CI 1.14–4.07), uterine scar dehiscence or rupture (adjusted OR 1.96, 95% CI 1.42–2.72) and "other" severe morbidity (adjusted OR 1.23, 95% CI 1.10–1.38) (Table 4).

In contrast, we found a negative association between rural residence and antepartum hemor-

Table 1: Demographic and clinical characteristics of women who gave birth in British Columbia, 2005–2010, by location of residence

Characteristic	Residence; no. (%) of women		
	Rural area* n = 25 855	Urban area* n = 230 365	p value
Maternal age, yr			< 0.01
< 19	1868 (7.2)	6731 (2.9)	
20–24	5838 (22.6)	31 232 (13.6)	
25–29	7755 (30.0)	63 796 (27.7)	
30–34	6533 (25.3)	75 510 (32.8)	
30–39	3150 (12.2)	43 584 (18.9)	
≥ 40	711 (2.7)	9512 (4.1)	
Low socioeconomic status†	5634 (21.8)	49 660 (21.6)	< 0.01
Drug use during pregnancy	1107 (4.3)	6199 (2.7)	< 0.01
Smoking during pregnancy	4001 (15.5)	21 103 (9.2)	< 0.01
Alcohol use during pregnancy	521 (2.0)	2218 (1.0)	< 0.01
Nullipara	10 879 (42.1)	108 643 (47.2)	< 0.01
Grand multipara (≥ 4 births)‡	1094 (4.2)	3584 (1.6)	< 0.01
Multiple pregnancy	381 (1.5)	3740 (1.6)	0.07
Previous cesarean delivery	3650 (14.1)	33 452 (14.5)	0.08
Prenatal care visits	n = 24 139	n = 212 562	< 0.01
None	71 (0.3)	348 (0.2)	
1–3	1343 (5.6)	7810 (3.7)	
≥ 4	22 725 (94.1)	204 404 (96.2)	
Hypertension in pregnancy§	1504 (5.8)	11 508 (5.0)	< 0.01
Pre-existing diabetes mellitus	94 (0.4)	1049 (0.5)	0.04
Gestational diabetes	746 (2.9)	18 082 (7.8)	< 0.01
Male fetus	13 277 (51.4)	118 172 (51.3)	0.9
Midwife care (any time during pregnancy)	2930 (11.3)	23 330 (10.1)	< 0.01

*See Methods for definitions of rural and urban areas.
†Defined as lowest neighbourhood-level income quintile.
‡Based on maternal recall of prior stillbirths and prior live births.
§Includes pre-existing and new-onset hypertension measured during pregnancy without protenuria.

rhage before 20 weeks' gestation (adjusted OR 0.61, 95% CI 0.53–0.69) and antepartum hemorrhage at 20 weeks or later (adjusted OR 0.62, 95% CI 0.54–0.71). Women in rural areas were also at lower risk of obstetric trauma than their urban counterparts (adjusted OR 0.88, 95% CI 0.81–0.96). In the sensitivity analyses, this negative association attenuated after adjustment for labour and delivery risk factors (adjusted OR 0.92, 95% CI 0.85–1.00). The adjusted ORs for all other significantly elevated morbidity rates remained essentially unchanged after adjustment for labour and delivery risk factors (Table 4).

Table 2: Labour and delivery characteristics of women who gave birth in British Columbia, 2005–2010, by location of residence

Characteristic	Residence; no. (%) of women		*p* value
	Rural area* *n* = 25 855	Urban area* *n* = 230 365	
Gestational age at delivery, wk			< 0.01
20–23	138 (0.5)	1446 (0.6)	
24–31	258 (1.0)	2426 (1.1)	
32–36	2031 (7.9)	17 520 (7.6)	
37–41	22 997 (88.9)	205 906 (89.4)	
42–43	431 (1.7)	3067 (1.3)	
Premature rupture of membranes for > 24 h	1601 (6.2)	16 380 (7.1)	< 0.01
Onset of labour			< 0.01
No labour	3150 (12.2)	33 269 (14.4)	
Spontaneous	17 088 (66.1)	148 455 (64.4)	
Induced	5612 (21.7)	48 577 (21.1)	
Labour augmentation	9206 (35.6)	88 316 (38.3)	< 0.01
Cesarean delivery	7012 (27.1)	70 282 (30.5)	< 0.01
Elective cesarean delivery	2630 (10.2)	26 459 (11.5)	< 0.01
Vaginal delivery†	18 843 (72.9)	160 083 (69.5)	< 0.01
Forceps	421 (1.6)	8678 (3.8)	< 0.01
Vacuum	1686 (6.5)	17 416 (7.6)	< 0.01
Vaginal delivery after prior cesarean delivery			
Successful	767 (3.0)	5740 (2.5)	< 0.01
Failed‡	322 (1.2)	2355 (1.0)	< 0.01
Type of attendant at delivery			< 0.01
Family physician	14 307 (55.3)	86 379 (37.5)	
Midwife	2125 (8.2)	16 054 (7.0)	
Obstetrician	8584 (33.2)	120 180 (52.2)	
Other health professional or no attendant	829 (3.2)	7706 (3.3)	
Home birth	641 (2.5)	4051 (1.8)	< 0.01
Large baby (> 4000 g)	3626 (14.0)	28 521 (12.4)	< 0.01

*See Methods for definitions of rural and urban areas.
†A combination of vacuum and forceps was used in 0.6% v. 0.7% of women living in rural and urban areas, respectively.
‡Intrapartum cesarean delivery.

Perinatal and neonatal mortality did not differ significantly between the rural and urban groups (Table 5). The rate of severe neonatal morbidity was higher in the rural group: a small but significant difference (adjusted OR 1.14, 95% CI 1.02–1.29) was found after adjustment for demographic characteristics and labour and delivery risk factors, including severe maternal morbidity. Infants in the rural group were also more likely to be born before 37 weeks' gestation (adjusted OR 1.06, 95% CI 1.01–1.11). In addition, infants in rural areas were more likely than those in urban areas to have an Apgar score of less than 7 at 5 minutes (adjusted OR 1.24, 95% CI 1.13–1.31) and to be large for gestational age (adjusted OR 1.14, 95% CI 1.10–1.19). In contrast, they were less likely than infants in the urban group to be small for gestational age (adjusted OR 0.90, 95% CI 0.85–0.95) and to be admitted to the NICU (adjusted OR 0.36, 95% CI 0.33–0.38). Rates of NICU admission of more than 1 day's duration were also lower among infants in the rural group (adjusted OR 0.43, 95% CI 0.40–0.47). The results were essentially unchanged after we adjusted for clustering of adverse birth outcomes among twins and triplets.

Interpretation

Our study showed a significant association between rural residence and severe maternal and neonatal morbidity. In particular, we found a significant 2-fold increase in the rates of life-threatening conditions such as eclampsia, obstetric embolism, and uterine dehiscence or rupture among women in rural areas. In contrast, rates of antepartum hemorrhage were significantly lower in this group.

Perinatal mortality did not differ between the rural and urban groups. However, infants born to women residing in rural areas were more likely than those in urban areas to have a severe neonatal morbidity, to be preterm, to be large for gestational age and to have a low Apgar score at 5 minutes. In contrast, infants in the rural group were less likely than those in the urban group to be small for gestational age and to be admitted to the NICU.

Most studies of rural maternity care have focused solely on infant outcomes,[16–20,29,30] and population-based studies examining different components of severe maternal morbidity associated with rural residence in industrialized countries are rare. Our study showed that the risk of

Table 3: Incidence of maternal mortality and severe maternal morbidity among women who gave birth in British Columbia, 2005–2010, by location of residence

Outcome	Rural area		Urban area		OR (95% CI)
	No. of women	Rate per 100 000 deliveries	No. of women	Rate per 100 000 deliveries	
Severe maternal morbidity or death					
Death	< 5	–	< 5	–	8.92 (0.56–142.86)
Eclampsia	30	116.0	99	50.4	2.70 (1.80–4.07)
Cardiac arrest, cardiac failure or myocardial infarction	25	96.7	302	127.6	0.74 (0.49–1.11)
Cardiomyopathy	6	23.2	34	15.6	1.57 (0.66–3.75)
CNS morbidity	< 5	–	49	19.9	0.36 (0.09–1.50)
Obstetric shock	11	42.5	65	29.7	1.51 (0.80–2.86)
Obstetric embolism	12	46.4	51	24.6	2.10 (1.12–3.93)
Uterine scar dehiscence/rupture	46	177.9	237	110.5	1.73 (1.26–2.37)
Renal failure	< 5	–	47	19.9	0.76 (0.27–2.10)
Septicemia	5	19.3	48	20.7	0.93 (0.37–2.33)
Puerperal sepsis	23	89.0	228	98.0	0.90 (0.59–1.38)
Placenta previa with hemorrhage	71	274.6	818	347.0	0.77 (0.61–0.99)
Complications of anesthesia	< 5	–	65	26.5	0.41 (0.13–1.31)
Blood transfusion	154	595.6	1158	512.1	1.19 (1.00–1.40)
Antepartum hemorrhage with coagulation defects	< 5	–	7	3.1	1.27 (0.16–10.34)
Postpartum hemorrhage with transfusion	113	437.1	872	384.4	1.16 (0.95–1.41)
Postpartum hemorrhage with coagulation defects	< 5	7.7	19	8.2	0.94 (0.22–4.03)
Postpartum hemorrhage with embolization/ligation/suture of uterus	11	42.5	166	69.1	0.59 (0.32–1.09)
Hysterectomy	31	119.9	331	141.3	0.83 (0.58–1.21)
Assisted ventilation	9	34.8	111	46.8	0.72 (0.37–1.42)
Evacuation of incisional hematoma	7	27.1	79	33.6	0.79 (0.36–1.71)
Surgical repair of urethra, bladder or intestine	13	50.3	133	57.0	0.87 (0.49–1.54)
Other severe morbidity*	26	100.6	87	44.1	2.66 (1.72–4.13)
Placental abruption	< 5	–	26	11.7	1.37 (0.48–3.93)
Acute abdomen	< 5	–	17	7.4	1.05 (0.24–4.54)
Hepatic failure	< 5	–	8	3.9	2.23 (0.47–10.49)
Death or severe maternal morbidity	431	1670.0	3 453	1500.0	1.11 (1.01–1.23)
Other maternal morbidity		Rate per 100 deliveries		Rate per 100 deliveries	
Antepartum hemorrhage < 20 wk	241	0.9	3607	1.6	0.59 (0.52–0.67)
Antepartum hemorrhage ≥ 20 wk	263	1.0	3619	1.6	0.64 (0.57–0.73)
Preeclampsia (excluding eclampsia)†	303	1.2	2751	1.2	0.98 (0.87–1.11)
Postpartum hemorrhage	1966	7.6	18 309	7.9	0.95 (0.91–1.00)
Obstetric trauma	728	2.8	8320	3.6	0.77 (0.72–0.84)

Note: CI = confidence interval, CNS = central nervous system, OR = odds ratio.
*Includes adult respiratory distress syndrome and hypertensive heart disease during pregnancy.
†Defined as hypertension (> 140/90 on 2 readings) or hypertension in pregnancy and proteinuria, in the absence of eclampsia diagnosis.
As per the data provider requirements, cells with size < 5 and the corresponding rates are suppressed. Some conditions overlap.

severe maternal morbidity was significantly associated with rural residence. The twofold increased risk of eclampsia is particularly concerning, because the rates of preeclampsia were similar between the rural and urban groups. Clinical management of preeclampsia involves careful maternal and fetal monitoring for worsening of symptoms prompting delivery to prevent eclampsia and adverse fetal or infant outcomes.[31,32] Thus, the lack of appropriate clinical management or timely access to advanced obstetric care may have contributed to the higher rate in the rural group.

In contrast, women in rural areas had a lower rate of antepartum hemorrhage, possibly owing to differences in reporting. Differences in reporting of postpartum hemorrhage may exist between individual health care providers, because the diagnosis relies on a subjective estimate of blood loss.[33–35] In contrast, blood transfusions are generally well documented and reported because they follow standard protocols.[36] The rates of more severe conditions including antepartum hemorrhage with coagulation defects and placental abruption, which result in antepartum hemorrhage, were similar (or higher) among women in rural areas than among those in urban areas.

We did not find an association between fetal death or infant death before discharge and rural residence. This is in agreement with findings from some studies,[17,18] but not with others.[19,29,30] The risk of severe neonatal morbidity was higher in the rural group than in the urban group after we adjusted for potential confounding factors related to delivery, obstetric interventions and type of attendant at delivery. This finding suggests that, when stratified by obstetric interventions, infants in rural areas had elevated rates of morbidity. It has been shown that the rates of perinatal mortality and morbidity are elevated among women from rural areas delivering in urban hospitals[18] and among older women who may require timely intervention,[17] and that the risk increases with the distance to the hospital.[19,29,30] All of these findings underscore a need to identify and carefully monitor women in rural areas who have a high-risk pregnancy, because proper clinical management and timely intervention may be crucial to prevent adverse maternal and infant outcomes.

Infants in the rural group of our study were more likely than their urban counterparts to be preterm and to have a low Apgar score at 5 minutes. Despite having increased morbidity, infants in the rural group had a rate of NICU admission that was half that in the urban group. Because highly specialized NICUs are located in metropolitan areas, the threshold for admitting a new-

Table 4: Association between maternal morbidity and rural residence

Variable	Crude OR (95% CI)	Adjusted OR* (95% CI)	Adjusted OR† (95% CI)
Severe maternal morbidity			
Eclampsia	2.70 (1.80–4.07)	2.70 (1.79–4.08)	2.45 (1.59–3.77)
Obstetric embolism	2.10 (1.12–3.93)	2.16 (1.14–4.07)	2.23 (1.18–4.20)
Uterine scar dehiscence/rupture	1.73 (1.26–2.37)	1.96 (1.42–2.72)	1.85 (1.34–2.54)
Placenta previa with hemorrhage	0.77 (0.61–0.99)	0.79 (0.60–1.03)	1.16 (0.90–1.50)
Blood transfusion	1.19 (1.00–1.40)	1.14 (0.95–1.36)	1.09 (0.91–1.31)
Other severe morbidity‡	2.66 (1.72–4.13)	2.17 (1.35–3.50)	2.09 (1.27–3.44)
Death or severe maternal morbidity	1.11 (1.01–1.23)	1.15 (1.03–1.28)	1.23 (1.10–1.38)
Other maternal morbidity			
Antepartum hemorrhage < 20 wk	0.59 (0.52–0.67)	0.61 (0.53–0.69)	–
Antepartum hemorrhage ≥ 20 wk	0.64 (0.57–0.73)	0.62 (0.54–0.71)	–
Postpartum hemorrhage	0.95 (0.91–1.00)	0.98 (0.93–1.03)	0.99 (0.94–1.04)
Obstetric trauma	0.77 (0.72–0.84)	0.88 (0.81–0.96)	0.92 (0.85–1.00)

Note: CI = confidence interval, OR = odd ratio.
*Adjusted for pregnancy risk factors: maternal age, low socioeconomic status, drug use during pregnancy, smoking during pregnancy, multifetal pregnancy, parity (nullipara, grand multipara), gestational diabetes, hypertension in pregnancy, previous cesarean delivery and male fetus.
†Adjusted for pregnancy risk factors above, as well as labour and delivery risk factors: vaginal birth after cesarean delivery, forceps delivery, vacuum delivery, emergency cesarean delivery, premature rupture of membranes, labour induction, labour augmentation, epidural analgesia, spinal analgesia, general anesthesia and attendant at delivery.
‡Includes placental abruption, acute abdomen, liver failure, antepartum hemorrhage with coagulation defects, adult respiratory distress syndrome and hypertensive heart disease during pregnancy.

born to a NICU is likely higher in rural areas. However, the discrepancy in NICU admission rates was unlikely due to short-term NICU admissions (< 1 d), because it existed for longer term NICU admissions. This finding indicates a substantial barrier to advanced neonatal care for infants in rural areas, with possible long-term consequences for neurodevelopmental outcomes.

It is known that infants in rural areas are at increased risk of being large for gestational age and at decreased risk of being small for gestational age,[17–19,30] and our findings support the evidence. The high prevalence of obesity and diabetes in rural population has been implicated in higher rates of large infants.[9,37,38] Surprisingly, we did not observe elevated rates of pre-existing or gestational diabetes among women in rural areas, which may be due to diagnostic or reporting issues in rural British Columbia. In agreement with our study, Grzybowski and colleagues[30] reported an incidence of gestational diabetes of 2.4%–3.6% among women residing 1 hour or more from the nearest maternity service in BC between 2000 and 2004. The relatively high proportion of Asian people in BC's metropolitan population may have also contributed to the higher rate of gestational diabetes in the urban group, because Asian background is an independent risk factor for gestational diabetes.[39,40] The prevalence of obesity in Canada is reported to be 30% among women residing in rural areas and 28% among those in urban areas.[41]

Strengths and limitations

Our study has several distinct strengths. We used population data on all births in the province, including home births. Information on each birth was collected by trained abstractors, and a validation study confirmed good reliability of the collected data.[21] Although most studies of mater-

Table 5: Perinatal and neonatal mortality and morbidity, by location of residence, British Columbia, 2005–2010*

	Rural area		Urban area				
Outcome	No.	Rate per 100 live births†	No.	Rate per 100 live births†	Crude OR (95% CI)	Adjusted OR‡ (95% CI)	Adjusted OR§ (95% CI)
All births	26 241		23 4149				
Fetal death	216	0.82**	2105	0.90**	0.91 (0.79–1.05)	0.90 (0.78–1.04)	
Perinatal death	264	1.01**	2594	1.11**	0.91 (0.80–1.03)	0.90 (0.78–1.02)	0.95 (0.81–1.10)
Live births	26 025		23 2044				
Preterm birth							
< 34 wk	574	2.21	5380	2.32	0.95 (0.87–1.04)	0.91 (0.83–1.01)	1.06 (0.95–1.17)
< 37 wk	1941	7.46	16 561	7.14	1.04 (1.00–1.10)	1.00 (0.95–1.04)	1.06 (1.01–1.11)
Apgar score < 7 at 5 min	520	2.01	3855	1.66	1.21 (1.10–1.33)	1.20 (1.09–1.31)	1.24 (1.13–1.31)
Small for gestational age	1614	6.21	16 241	7.00	0.88 (0.83–0.93)	0.90 (0.85–0.95)	
Large for gestational age	4034	15.51	30 645	13.21	1.21 (1.16–1.25)	1.14 (1.10–1.19)	
NICU admission	1013	3.89	20 018	8.63	0.43 (0.40–0.46)	0.41 (0.38–0.44)	0.36 (0.33–0.38)
Length of NICU admission > 1 d	780	3.00	13 082	5.64	0.52 (0.48–0.56)	0.48 (0.45–0.52)	0.43 (0.40–0.47)
Severe neonatal morbidity¶	417	1.60	3637	1.57	1.02 (0.92–1.13)	1.00 (0.90–1.11)	1.14 (1.02–1.29)
Neonatal death	48	0.18	489	0.21	0.87 (0.65–1.18)	0.89 (0.66–1.02)	0.87 (0.63–1.19)
Death or severe neonatal morbidity¶	451	1.73	3949	1.70	1.02 (0.92–1.12)	1.01 (0.91–1.12)	1.13 (1.01–1.27)

Note: CI = confidence interval, NICU = neonatal intensive care unit, OR = odds ratio.
*Missing values < 1% not shown.
†Unless stated otherwise.
‡Adjusted for pregnancy risk factors: maternal age, low socioeconomic status, drug use during pregnancy, smoking during pregnancy, multifetal pregnancy, parity (nullipara, grand multipara), diabetes mellitus, gestational diabetes, hypertension in pregnancy, previous cesarean delivery, prior perinatal death, congenital anomaly and male fetus.
§Adjusted for pregnancy risk factors above, as well as labour and delivery risk factors: vaginal birth after cesarean, forceps delivery, vacuum delivery, emergency cesarean delivery, premature rupture of membranes, labour induction, labour augmentation, epidural analgesia, spinal analgesia, general anesthesia and attendant at delivery. Outcomes other than preterm birth were also adjusted for very preterm birth (20–33 wk) and late preterm birth (34–36 wk).
¶Includes any of the following: respiratory distress syndrome, retinopathy of prematurity, intraventricular hemorrhage (grade 3 or more), intracranial hemorrhage, sepsis, necrotizing enterocolitis, ventilator use for more than 30 days, use of oxygen or continuous positive airway pressure ventilator for more than 30 days, parenteral nutrition for more than 30 days.
**Rate per 100 total births.

nity care have focused on adverse infant outcomes, our study examined specific components of severe maternal morbidity. Defining "rural" is notoriously difficult.[42] Our definition excluded neighbourhoods with a strong metropolitan influence and included only those with a higher degree of rural isolation. Degree of rural isolation is increasingly used in health research rather than a rural–urban divide based solely on the number of residents (≤ 10 000 for definition of rural communities).[15,19,42] Another strength of our study is the adjustment for the confounding effect of many individual risk factors (e.g., obstetric history and pre-existing hypertension), differences in obstetric care (e.g., type of attendant) and obstetric interventions (e.g., cesarean delivery). Data collection on pregnancy complications and outcomes occurred before our study, which reduces the risk of misclassification and recall bias.

The limitations of our study include the lack of individual information on the time needed to travel to the nearest health care facility, the Aboriginal status of women and some clinical factors such as body mass index. Even if these factors attenuated our results, the public health implications remain, including the need for increased vigilance by maternity care providers in rural regions.

We performed multiple statistical comparisons. Thus, some of the significant results may have occurred by chance. However, the consistency of our results showing elevated rates for several related morbidities suggests true associations. This was a large population-based study; thus, some of the statistically significant differences in maternal characteristics between the rural and urban groups may not be clinically important. For example, the prevalence of pre-existing diabetes differed significantly between the rural and urban groups ($p = 0.04$), but it may not be clinically important (0.4% v. 0.5%). Despite the large study population, however, we did not have enough statistical power to evaluate differences in maternal death and some rare morbidities (e.g., adult respiratory distress syndrome).

We were not able to adjust for clustering of adverse outcomes in multiple deliveries to individual women over the study period (i.e., if a woman had 2 or more deliveries between 2005 and 2010), which may have slightly overestimated the precision of results in our multivariable analyses (i.e., the 95% CIs are slighter narrower). However, this effect is likely minimal and smaller than the effect of clustering of infant birth outcomes in multifetal pregnancies that we accounted for in the sensitivity analysis (with no change in the results). We adjusted for multiparity and for prior adverse pregnancy outcomes.

Lastly, as with any large administrative databases, some maternal morbidity may not have been captured by the Perinatal Database Registry owing to coding omissions or other errors.

We did not aim to test specific hypotheses about the effects of health care system, maternity transfer patterns and regionalization of maternity care on severe maternal morbidity. Further research, including quantitative and qualitative analyses, is needed to disentangle differential effects of the organization of the health care system and of underlying health risk factors on maternal morbidity.

Conclusion

In Canada, medical care is available to all residents through universal medical insurance. However, rural maternity care poses distinct challenges defined predominantly by geographic barriers. In our study, women residing in rural areas had elevated rates of severe maternal morbidity, including eclampsia, obstetric embolism and uterine dehiscence or rupture. The rate of severe neonatal morbidity was higher and the rate of NICU admission lower among infants in rural areas than among their urban counterparts. In the wake of maternity unit closures in rural areas, the emphasis should remain on monitoring for potentially life-threatening maternal and perinatal complications requiring advanced obstetric and neonatal care.

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