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Secular trends in pregnancy rates, delivery outcomes, and related health care utilization among women with congenital heart disease

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Abstract

Background: The number of women with congenital heart disease (CHD) of reproductive age is increasing, yet a description of trends in pregnancy and delivery outcomes in this population is lacking.

Objective: To assess secular trends in pregnancy rates, delivery outcomes, and related health care utilization in the adult female CHD population in Quebec, Canada.

Methods: The Quebec CHD database was used to construct a cohort with all women with CHD aged 18-45 years between 1992 and 2004. Pregnancy and delivery rates were determined yearly and compared to the general population. Secular trends in pregnancy and delivery rates were assessed with linear regression. The cesarean delivery rate in the CHD population was compared to the general population. Predictors of cesarean section were determined with multivariable logistic regression. Cox regression, adjusted for comorbidities, was used to analyze the impact of cesarean sections on 1-year health care use following delivery.

Results: About 14 878 women were included. A total of 10 809 pregnancies were identified in 5641 women, of whom 4551 (80%) and 2528 (45%) experienced at least one delivery and/or abortion, respectively. Absolute yearly numbers and rates of pregnancies and deliveries increased during the study period ($P < .05$). The increment in cesarean section rates was more pronounced among women with CHD than among the general population. Gestational diabetes (OR 1.50, 95% CI [1.13, 1.99]), gestational hypertension (OR 1.81, 95% CI [1.27, 2.57]), and preeclampsia (OR 1.59, 95% CI [1.11, 2.8]) were independent predictors of cesarean delivery. Cesarean sections were associated with postpartum cardiac-hospitalization within 1 year following delivery (HR = 2.35, 95% CI [1.05, 5.28]).

Conclusions: Yearly numbers and rates of pregnancies and deliveries in adult females with CHD rose significantly during the study period. Cesarean sections led to increased health care utilization. Further research is required to determine causes of high cesarean section rates in this patient population.

KEYWORDS

adult congenital heart disease, delivery, pregnancy, women's health

1 | INTRODUCTION

Women of childbearing age represent an increasingly important proportion of patients with congenital heart disease (CHD).[1] Since pregnancy among women with CHD is associated with significant maternal morbidity—including arrhythmia, heart failure, and thromboembolic events—close interdisciplinary collaboration is required to address the needs of this complex population.[2-5] Moreover, since CHD is estimated to occur in 2-16% of infants of patients with CHD, changes in the female CHD population combined with increasing pregnancy rates may further influence overall CHD prevalence.[6] As a result, rising pregnancy rates could lead to an increased demand for specialized care in both adults and children.[1] In order to facilitate planning by public health authorities, a population-based description of reproductive outcomes and health care utilization of women with CHD is currently required.

We performed a population-based retrospective study of women with CHD in the province of Quebec, Canada. The primary objective was to determine yearly pregnancy numbers and rates in the female CHD population of reproductive age, as compared to the general population. We further sought to measure yearly delivery and abortive outcome rates among pregnant women with CHD during our study period. We aimed to identify predictors of method of delivery and future health services utilization in our cohort.

2 | METHODS

2.1 | Data source

The *Quebec CHD database* is a population-based registry of more than 70 000 patients with CHD in the Province of Quebec, Canada. A detailed description of the methodology used to construct this database was described previously.[1] In summary, this database was built using three distinct provincial data sources comprising information on all residents of Quebec, linked by a single encrypted patient identifier. Information on physician billing and drug claims was obtained from the *Régie de l'Assurance Maladie du Québec* (RAMQ) database. Data on all investigations and procedures for every hospitalization in Quebec was obtained through the *Maintenance et Exploitation des Données pour l'Étude de la Clientèle Hospitalière* (Med-Echo) database. Information on hospital service use was obtained using *the Quebec Health Insurance Board* (QHIB), which regulates all medical and hospital services rendered in the province. Diagnostic codes for all three databases adhered to the International Classification of Disease, Ninth Revision (ICD-9). Patients were identified as having CHD if they had an ICD-9 diagnosis or procedure code for CHD. Provider codes identified diagnoses made by family physicians or cardiovascular medical specialists, and procedures performed by cardiovascular surgeons. We used a previously defined hierarchical algorithm to classify patients with CHD as having severe CHD, shunts, valvular disease, or other CHD (see Table S1 of the supplemental appendix).[1,7] Women with severe CHD carried one of the following diagnoses: truncus arteriosus, transposition of the great arteries, tetralogy of Fallot, univentricular heart, Ebstein's anomaly, atrioventricular canal defect, or hypoplastic left-heart syndrome. Shunts included the following diagnoses: ventricular septal defect, atrial septal defect, patent ductus arteriosus, and unspecified defects of septal closure. Valvular diseases were defined as: anomalies of the pulmonary artery, anomalies of the pulmonary valve, congenital tricuspid valve disease, congenital aortic stenosis, congenital aortic insufficiency, congenital mitral stenosis, or congenital mitral insufficiency. All other diagnoses except aortic coarctation were classified as "other CHD," including: other unspecified anomalies of the aorta, anomalies of the pulmonary artery, anomalies of the great veins, other unspecified anomalies of the heart, and other unspecified anomalies of the circulation (see Table S1 of the supplementary appendix).

2.2 | Study population

We constructed a cohort of all women of reproductive age (18-45 years old) with CHD using the Quebec CHD database. Our study period was from January 1, 1992 to December 31, 2004. This cohort constituted the "pregnancy eligibility cohort."

Women with either a delivery or an abortive outcome identified within the pregnancy eligibility cohort constituted the "pregnancy cohort." Patients with both a procedure code for a delivery and a diagnosis code for either a delivery or pregnancy/delivery complication occurring within a maximal interval of 6 weeks were considered as having had a delivery (See Table S2 of the supplemental appendix). This time frame defined the peripartum period. A subsequent delivery was identified when more than 9 months (280 days) elapsed between two procedure codes for delivery. Abortive outcomes were identified using a single diagnosis or procedure code that occurred more than 4 weeks after another delivery or abortive outcomes (See Table S2 of the supplemental appendix). This was to ensure that coded events were not merely complications. Diagnosis and Procedure codes for pregnancy, delivery, and abortive outcomes were only included if they were ascribed by a general practitioner, family doctor, gynecologist, obstetrician, or obstetrician-gynecologist. Sample cases were extracted and individually reviewed for coding accuracy by two authors (NB and AJM).

Women with a delivery occurring at least 5 years following a prior delivery episode were included in a "postpartum cohort." We excluded women with more recent delivery from this sub-cohort in order to prevent accounting for overlapping adverse outcomes from a previous pregnancy.

2.3 | Outcomes

We defined pregnancy as our primary outcome of interest. Secondary outcomes included delivery, delivery methods (cesarean section or vaginal delivery), and abortive outcomes. Health service utilization was assessed by length of hospital stay following delivery (0-3 days, 4-7 days, and ≥ 8 days) as well as postpartum hospitalizations and outpatient cardiology visit within the first year following

delivery. Hospitalizations were defined as cardiac when associated with a diagnosis of CHD. An outpatient cardiology visit was defined as a cardiology, thoracic surgery, cardiac surgery, or cardiovascular-thoracic surgery visit.

2.4 | Covariates

Covariates included preexisting diabetes (defined as a composite of type 1 and 2 diabetes), gestational diabetes, hypertensive disorders of pregnancy (including chronic hypertension, gestational hypertension, and preeclampsia/eclampsia), type of CHD (including severe, shunts, valves, coarctation of the aorta, and others), prior cardiac surgery, prior episode of arrhythmia, and prior episode of congestive heart failure, diagnosed within 5 years preceding index delivery episode (see Table S3 of the supplementary appendix).

2.5 | Statistical analysis

Descriptive statistics including proportions, medians, and interquartile ranges (IQR) were used to outline baseline characteristics of women with CHD. Yearly absolute numbers and rates of pregnancies, deliveries, and abortive outcomes per 1000 women at risk were determined using the pregnancy eligibility cohort as denominator. Linear regression was used to analyze the impact of calendar time on pregnancy and delivery rates. For this analysis, pregnancy (including deliveries and abortive outcomes) was the dependent variables and calendar year was the independent variable. Delivery and cesarean section rates among women with CHD were compared to the general Quebec population using data from the *Canadian Socio-Economic Information Management System* (Statistics Canada) and the *Institut de la statistique du Quebec*. In order to compare age-specific delivery rates of the general female Quebec population, results were stratified in the following five age categories: 18-19 years, 20-24 years, 25-29 years, 30-34 years, and 35-39 years. Predictors of cesarean section delivery were identified using a multivariable logistic regression model, which included CHD lesion type, prior history of cardiac surgery, arrhythmia or CHD, and comorbidities (ie, chronic hypertension, gestational hypertension, preeclampsia, preexistent diabetes, or gestational diabetes). Lengths of hospitalization in women with caesarian section and vaginal deliveries were compared using a two-way Chi-square test. Odds ratio (OR) and their 95% confidence intervals (CI) were also measured by logistic regression to determine whether delivery method (caesarian section or vaginal) was associated with length of postpartum hospital stay. Estimates were adjusted for age, CHD lesion severity, and preexisting hypertension or diabetes. Cox regression models were used to identify predictors of cardiac hospitalizations and outpatient visits to a cardiologist within 1-year following delivery. Estimates were reported using hazard ratios (HRs) and 95% CI, and were adjusted for age, CHD lesion severity, as well as a prior history of hypertension, diabetes, heart failure, and arrhythmia. All statistical analyses were performed using SAS statistical software version 9.2 (SAS Institute Inc., Cary, NC, USA).

2.6 | Ethical considerations

The study and use of the database were approved by the McGill University Health Center Research Ethics Board and provincial government agencies.

3 | RESULTS

3.1 | Study population and baseline characteristics

There were 71 467 patients identified with CHD between 1983 and 2005 (Figure 1). Of these, 14 878 women aged 18-45 years between 1992 and 2004 were included in the pregnancy eligibility cohort. Within this cohort, 5641 (38%) women became pregnant. While we recorded a total of 6954 deliveries, including vaginal deliveries (n = 5231) and cesarean section deliveries (n = 1723), 3855 abortive outcomes occurred in 2528 women. Thus, of the 5641 (38%) of women who became pregnant, more women had deliveries (n = 4551, 80%) than abortive outcomes (n = 2528, 45%).

There were no differences in types of CHD lesions between women in the pregnancy eligibility and pregnancy cohorts (Table 1). About half of the women in both cohorts had shunt lesions. On average, women delivered by cesarean section were older (28.7 years [24.6-32.6] vs 27.4 years [23.0-31.5]), and had more comorbidities such as preexistent diabetes (8.2% vs 5.0%), gestational diabetes (10.7% vs 6.9%), gestational hypertension (8.4% vs 4.0%), and preeclampsia (7.8% vs 4.2%) when compared to women with vaginal delivery (P < .05 for all, Table 1).

3.2 | Pregnancies, deliveries and abortive outcomes

From 1992 to 2004, the absolute numbers and rates of pregnancies and deliveries per 1000 eligible women with CHD increased from 720 to 955 and 458 to 640, respectively (Figure 2A and B). Abortive outcome rates per 1000 women with CHD decreased from 1992 to 2004 (−1.108/year, P = .001). Delivery rates among patients aged 18-24 years with CHD remained lower than that of the general population over time (Results not shown). In the 25-29 year age group, the gap was narrowing in the most recent years, although delivery rates in patients with CHD remained lower than the general population (Figure 3A). In contrast, women aged 35-39 years with CHD were having more children than age-matched controls from the general population (Figure 3B).

3.3 | Health services utilization

As of 1996, there was an increase in rates of cesarean section delivery among women with CHD, which reflected the general Quebec population trends (Figure 4). Accordingly, rates of cesarean sections among women with CHD and the general Quebec population increased from 22.0% and 16.7% in 1996-1997 to 25.3% and 18.5% in 2000-2001, respectively. The increment in cesarean section rates was greater in the CHD population (+1.01) than the general Quebec population

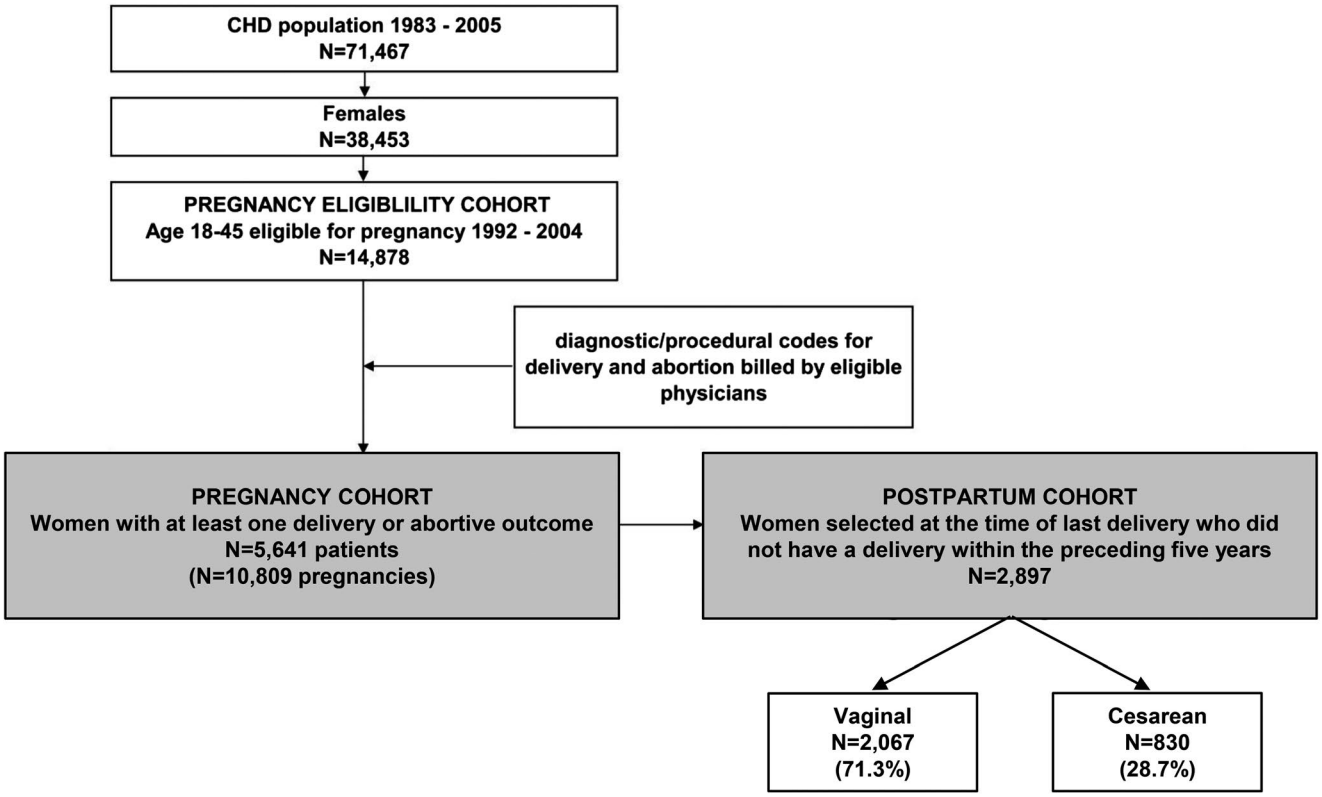

FIGURE 1 Flow chart of the study population. CHD, congenital heart disease

TABLE 1 Baseline characteristics of women with CHD with at least one pregnancy during the study period

		Postpartum cohort		
	Pregnancy cohort	Cesarean	Vaginal	
	N = 5641	*N* = 830	*N* = 2067	*P* value
Median number of pregnancies per patient (IQR)	2 (1, 2)	-	-	-
Median age at time of delivery (IQR)	-	30 (26, 34)	29 (25, 33)	<.0001
CHD related				
Lesion Category				
Severe *N* (%)	727 (13)	101 (12)	254 (12)	.9292
Shunts *N* (%)	2586 (46)	374 (45)	958 (46)	.5297
Coarctation *N* (%)	138 (2.5)	17 (2.0)	51 (2.5)	.5005
Valve *N* (%)	715 (13)	120 (14)	260 (12)	.1755
Other *N* (%)	1475 (26)	218 (26)	544 (26)	.9765
Cardiac surgery *N* (%)	89 (1.6)	6 (0.7)	27 (1.3)	.1810
Arrhythmia *N* (%)	404 (7.2)	62 (7.5)	148 (7.2)	.7713
Congestive heart failure *N* (%)	111 (2)	17 (2.1)	39 (1.9)	.7754
Preexisting cardiovascular comorbidities[a]				
Chronic hypertension	273 (4.8)	69 (8.3)	135 (6.5)	.0901
Gestational hypertension	209 (3.7)	70 (8.4)	83 (4.0)	<.0001
Preeclampsia/eclampsia	213 (3.8)	65 (7.8)	86 (4.2)	<.0001
Type 1 and 2 diabetes	229 (4.1)	68 (8.2)	103 (5.0)	.0009
Gestational diabetes	289 (5.1)	89 (10.7)	142 (6.9)	.0005

[a]Preexisting cardiovascular comorbidities were defined in the 5 years preceding the last delivery (for the postpartum cohort) and first pregnancy (for the pregnancy cohort).

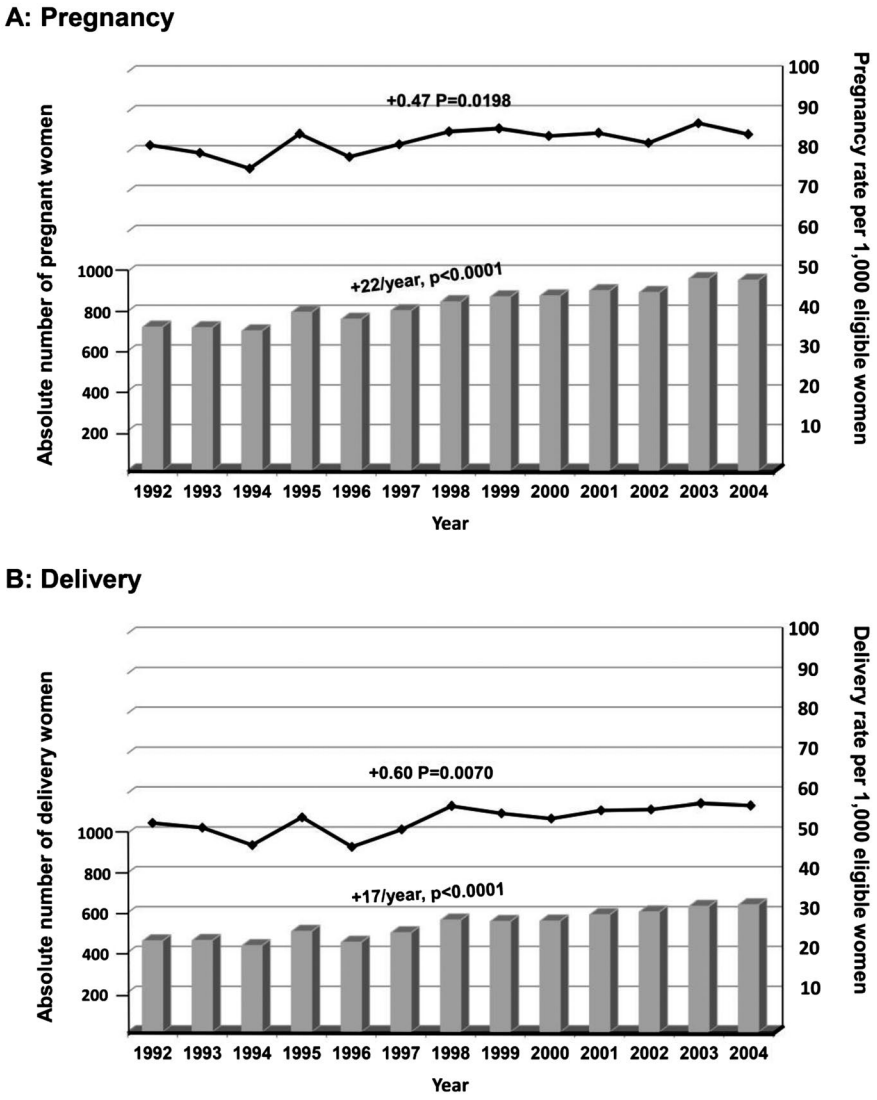

FIGURE 2 Absolute yearly numbers and rates of pregnancies (A) and deliveries (B) among women with CHD eligible to become pregnant. CHD, congenital heart disease

(+0.38). On multivariable analysis, gestational diabetes (OR 1.50, 95% CI [1.13, 1.99]), gestational hypertension (OR 1.81, 95% CI [1.27, 2.57]), and preeclampsia (OR 1.59, 95% CI [1.11, 2.8]) were independent predictors of cesarean delivery (Figure 5).

Cesarean sections were associated with a longer hospitalization than vaginal deliveries. Women with cesarean deliveries compared to women with vaginal deliveries had a hospital stay of ≥ 8 days in 15% vs 3%, 4-7 days in 72% vs 24%, and 0-3 days in 13% vs 73% of delivery hospitalizations ($P < .0001$ for all). A history of arrhythmia was the strongest predictor of future cardiac hospitalization (HR 7.49, 95% CI [3.19-17.60]), followed by cesarean section delivery during index pregnancy (HR 2.37, 95% CI [1.05, 5.38]) (Figure 6A). Severe CHD (HR = 1.89, 95% CI [1.48-2.40]), prior CHF (HR = 2.67, 95% CI [1.76-4.06]), and prior arrhythmias (HR = 3.12, 95% CI [2.41-4.03]) were all predictive of an outpatient cardiology visit, whereas cesarean sections were not (Figure 6B).

4 | DISCUSSION

In this population-based provincial cohort, we observed an increase in absolute numbers and rates of pregnancy among women with CHD, while these remained stable in the general population. Women with CHD aged 18-24 years had lower rates of pregnancy while women aged 35-39 years had higher rates of pregnancy than age-matched controls. The use of cesarean sections among women with CHD increased over time and was higher than the general population. This delivery mode increased health care utilization by lengthening postpartum hospital stay and doubling the risk for future inpatient cardiac hospitalization.

Increasing pregnancy numbers and rates among women with CHD have also been found in population-based studies in the United States, and this could be due to several factors.[8-10] First, the fact that more patients with CHD are known to survive to reproductive

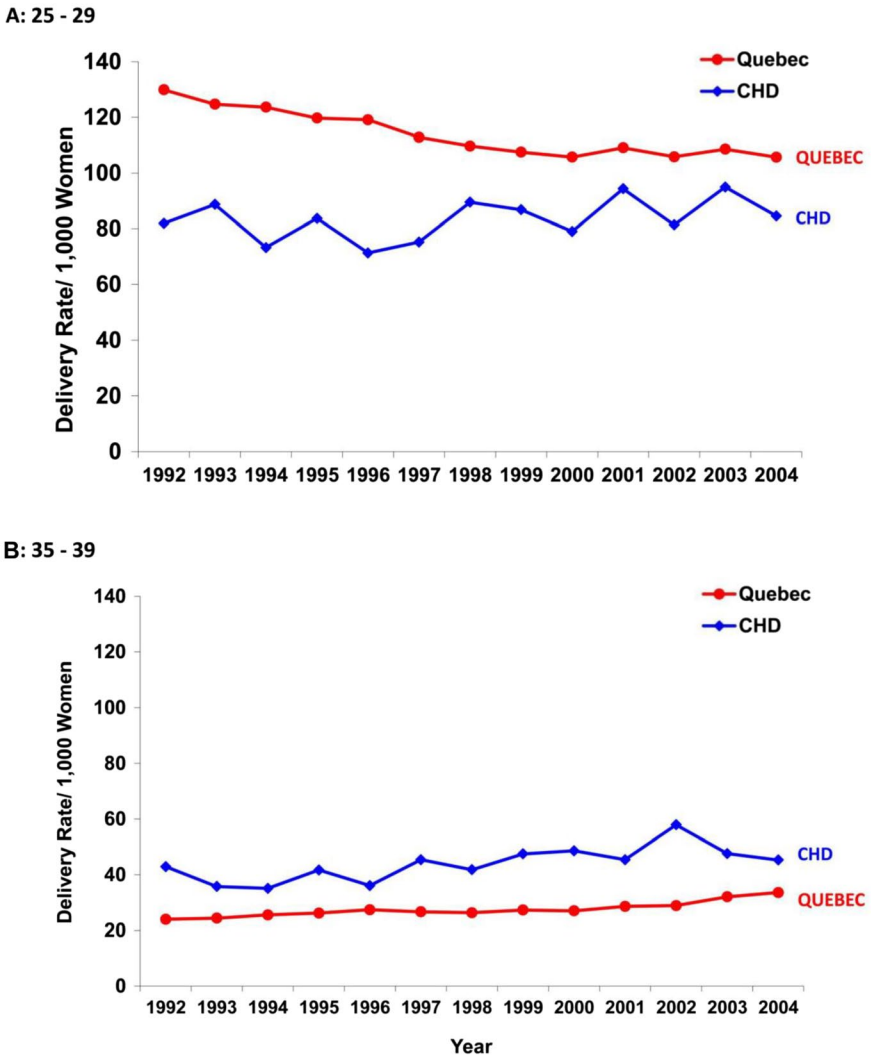

FIGURE 3 Delivery rates for women aged 25-29 years (A) and 35-39 years (B) from 1992 to 2004 among women with CHD compared to age-matched controls from the general Quebec population. CHD, congenital heart disease

age may explain the increase in absolute pregnancy numbers.[1] Moreover, pregnancy rates may have increased due to early surgical correction of maternal heart defects further enabling normal cardiovascular physiology to be restored from a very young age. Integration of pre-conception counseling into routine prenatal care may also have contributed to improved understanding of pregnancy-related risks among women of reproductive age with CHD.[11-15] We observed higher pregnancy rates among women with advanced maternal age in the CHD group than in the general population group. This could be explained by increased risk of subfertility and fetal loss among women with CHD, potentially delaying pregnancy onset.[16-20] Later, pregnancy may also have reflected temporal trends in medical practice, with clinicians advocating for better counseling and antenatal care in the more recent years rather than avoidance of pregnancy.[21,22]

Women with CHD had more cesarean deliveries than those without. Several other investigators have also found higher cesarean section rates among women with CHD when compared to pregnant controls.[3,8-10,23] This trend may have further progressed since the cesarean delivery rates within the National Inpatient Sample in the United States from 2000 through 2010 were 40.7% (95% CI [39.7, 41.6]) and 32.3% (95% CI [32.2, 32.3]) among women with and without CHD, respectively.[9] Data from the Registry On Pregnancy And Cardiac disease (ROPAC) suggested similar cesarean section rates internationally within a sample of women with CHD from 2007 through 2011.[4]

Gestational diabetes, gestational hypertension, and pre-eclampsia were independently associated cesarean delivery. Although an increased prevalence of these coexisting conditions at baseline potentially due to older maternal age at conception may have explained the increased cesarean section rates among women with CHD,[24,25] the prevalence of these disorders in our CHD group was not higher than worldwide prevalence estimates.[26,27] A German cohort study reported increased cesarean section rates among women with CHD despite them having less preeclampsia and diabetes than controls.[23] In addition, obstetric

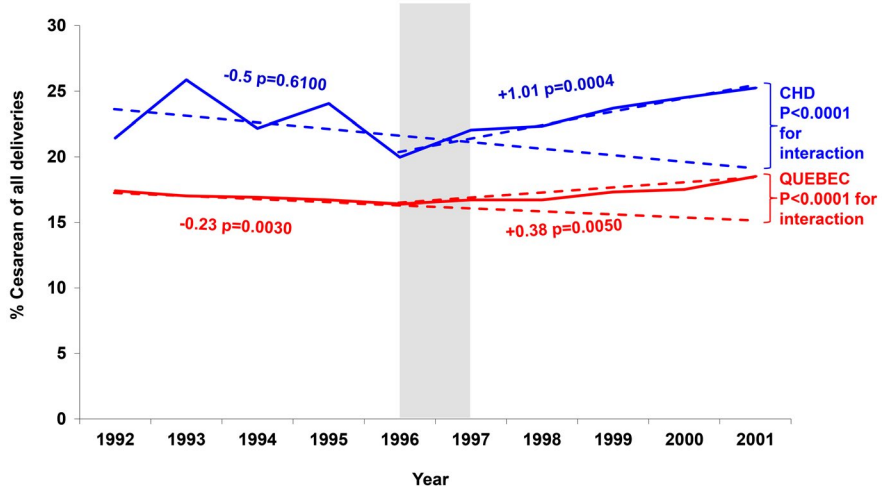

FIGURE 4 Cesarean section deliveries as a proportion of all deliveries among women with CHD compared to the general Quebec population. CHD, congenital heart disease

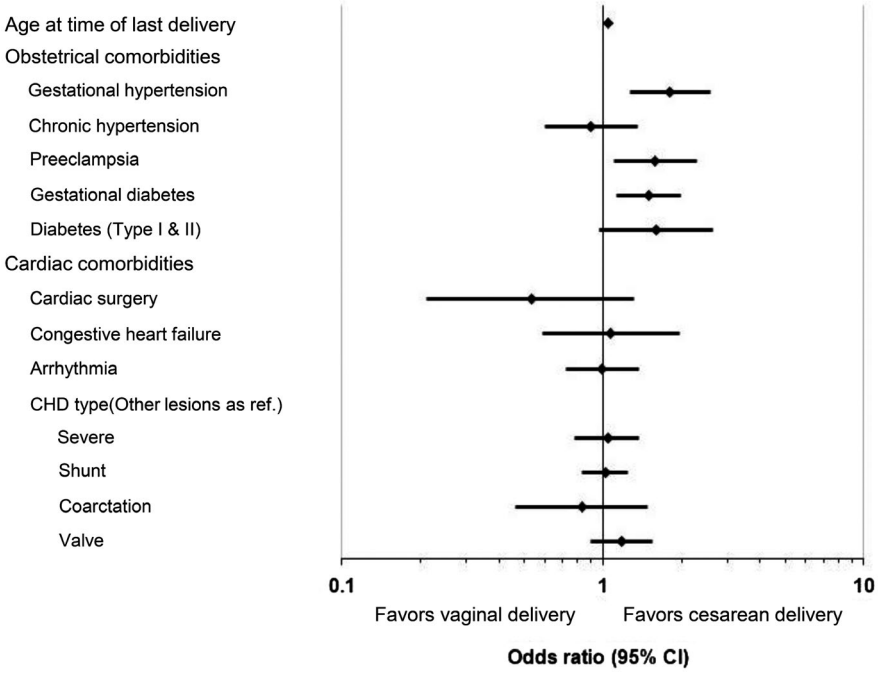

FIGURE 5 Predictors of mode of delivery. CHD, congenital heart disease

conditions represented only 37.5% of indications for primary cesarean section in women with CHD, whereas these conditions constituted 84.3% of indications in controls.[23] This study also highlighted that women with CHD were more likely to have had a previous cesarean section.[23] Thus, increasing numbers and rates of cesarean sections may be partially explained by a long-held incorrect belief that an elective cesarean section is the safest delivery method for women with CHD, and by patients' prior obstetrical history.[23,28] In the ROPAC cohort, planned cesarean sections were not associated with improved maternal outcomes.[29] As a result, current international consensus guidelines on the management of cardiovascular disease during pregnancy suggest that cesarean sections do not carry any maternal or fetal benefit except in very select cases, and that delivery mode should mainly be guided by obstetric indications.[5]

In addition to their known association with severe maternal morbidity—including hemorrhage, infections, and thromboembolic disease—we also demonstrated that cesarean sections were associated with increased health care utilization related to length of postpartum hospital stay and cardiac hospitalization within 1 year among the CHD population.[5,30] This increase in hospitalization may have been due to postoperative arrhythmia, fluid shifts, and hemodynamic instability exacerbating underlying CHD. Thus, a change of practice towards more vaginal deliveries in this population could

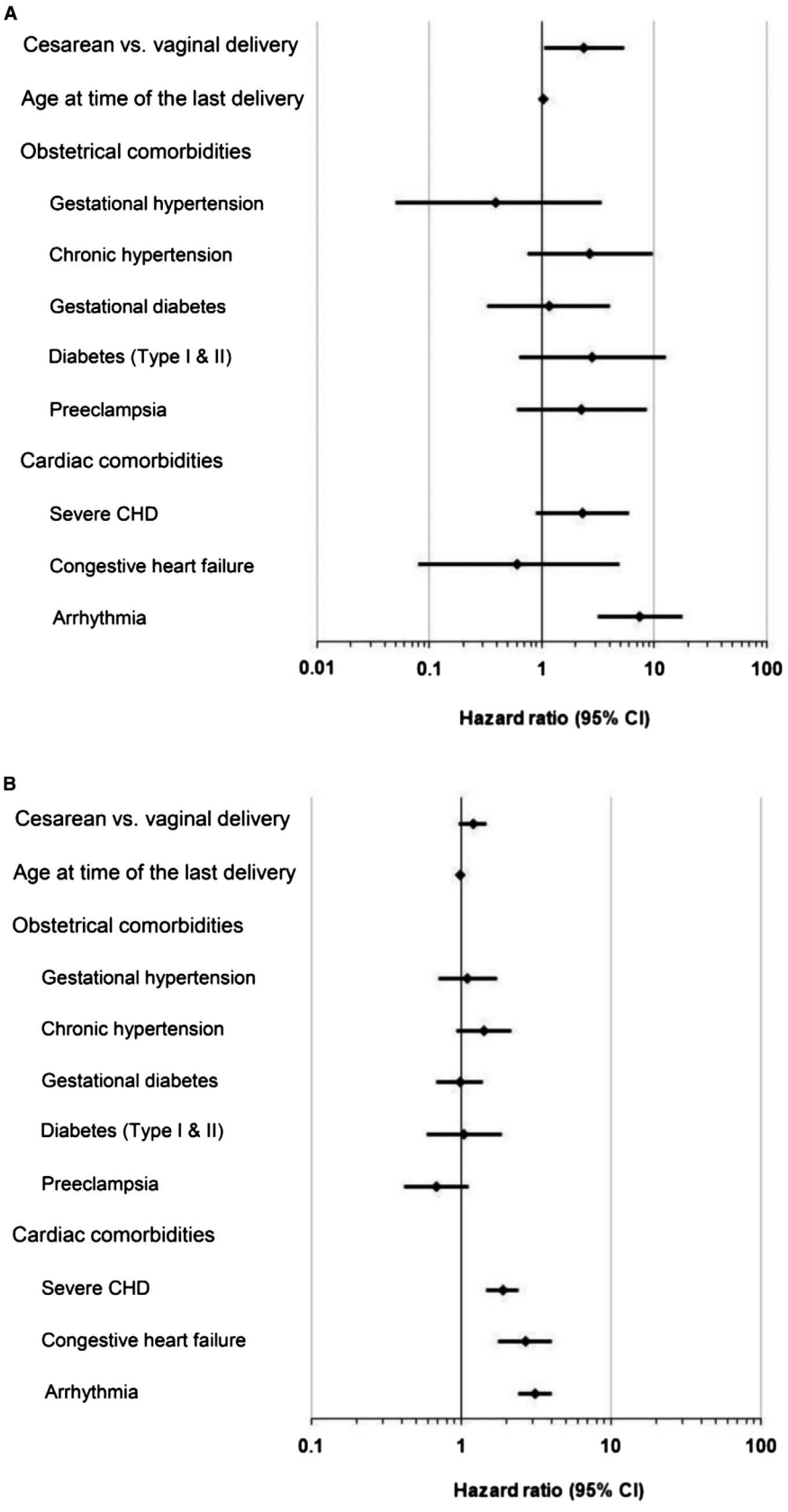

FIGURE 6 Predictors of cardiac hospitalization (A) and out-patient visit to a cardiologist (B) during the first year postpartum

greatly reduce the hospitalization burden on health care systems and the risk of complications for patients.

To our knowledge, this study was the first to present Canadian population-based trends of pregnancy rates and delivery outcomes among women of reproductive age with CHD over a period of 13 years. Indeed, several prior studies on pregnancy outcomes in women with CHD have included women already known to be pregnant, precluding estimation of pregnancy rates from the adult CHD population.[3,4,8-10,23,31] In addition, Quebec provides universal health care to its resident and more than 99% of women in the province are admitted to hospital for delivery.[32,33] Thus, outcomes described were highly representative of the underlying population. Limitations were also present. We did not have data beyond 2005, and pregnancy trends may have changed in recent years. While the number of uninsured women in Canada is not known, undocumented women in Quebec have previously been found to experience sub-standard perinatal care and increased peripartum morbidity.[34,35] In the United States, uninsured and state-insured women had more severe maternal morbidity events than commercially insured women.[36] Since we did not have data on uninsured women, the magnitude of adverse postpartum events may have been underestimated. In addition, results may not be generalizable to settings without universal health insurance. Indeed, in the United States, uninsured infants had a higher risk of mortality than those with private insurance.[37] Moreover, state-insured children had an increased risk of mortality and morbidity in their first year of life.[37,38] Therefore, universal insurance in Quebec may have led to better access to care and early childhood interventions, thereby improving adult CHD outcomes and resulting pregnancy rates. Finally, since indications for cesarean sections and hospitalizations were not reported, firm conclusions on the cause of increased use of operative delivery and hospitalizations could not be drawn.

In conclusion, women with CHD had increased pregnancy rates in the 13-year span of our study. They tended to have more cesarean deliveries than non-CHD controls, mostly driven by comorbidities such as gestational diabetes and hypertensive disorders of pregnancy. Cesarean sections increased health care utilization. Limiting their use in the future may help to reduce health care costs. Further research is required to determine how to integrate optimal preconception counseling for women with CHD, and how to implement continuous medical education initiatives in order to limit the use of operative deliveries in this patient population.

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CONFLICT OF INTEREST

None.

AUTHOR CONTRIBUTIONS

Conceptualized and designed the study: NB, IM, RII, JT, and AM

Data analysis: LG

Data interpretation, critical revision, and approval of the final manuscript: NB, IM, LG, RII, JT, and AM.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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