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Caesarean section and health care utilization and costs in the offspring: a retrospective cohort study

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Abbreviations

AGA appropriate for gestational age
BMI body mass index
CI confidence interval
CS Caesarean section
ICD International Classification of Diseases
IRR incidence rate ratio
LGA large for gestational age
NSAPD Nova Scotia Atlee Perinatal Database
OR odds ratio
SD standard deviation
SGA small for gestational age

ABSTRACT

Objective: To examine the association between Caesarean section (CS) and health care utilization and costs in offspring from birth until age 7 years.

Methods: A retrospective cohort study of singleton term births in the Canadian province of Nova Scotia between 2003 and 2007 followed until age seven years was conducted using data from the Nova Scotia Atlee Perinatal Database and administrative health data. The main exposure was mode of delivery (CS vs. vaginal birth (VB)); the outcome was health care utilization and costs during the first seven years of life. Associations were modeled using multiple regression adjusting for maternal pre-pregnancy weight and socio-demographic factors.

Results: 32,464 births were included in the analysis. Compared to VB children, children born by CS had more physician visits (incidence rate ratio [IRR] 1.06, 95% confidence interval [CI] 1.05-1.08) and longer hospital stays (IRR 1.12, 95% CI 1.03-1.21) and were more likely to be high utilizers of physician visits (odds ratio 1.23, 95% CI 1.10-1.37). Physician and hospital costs were $775 higher for children born by CS compared to VB.

Conclusion: CS compared to VB is associated with small but statistically significant increases in health care utilization and costs in during the first seven years of life.

INTRODUCTION

The rates of Caesarean section (CS) have been increasing over the past decades with rates as high as 50% in some countries (1, 2). Approximately half of all countries have rates of CS above the World Health Organization's estimation of the 15% that are needed as life-saving for the infant (3, 4). About 10% of births are pre-labour elective CS (5), planned in advance at the mother's request due to cultural, psychosocial, or economic factors (6, 7). Compared to mothers with a vaginal birth, the odds of severe maternal outcomes such as admission to the intensive care unit, blood transfusion, hysterectomy, or death are almost six times higher for women receiving antepartum CS without medical indication and over 15 times higher for women receiving an intrapartum CS without medical indication (5). Additionally, the procedure increases a woman's risk for post-surgical bleeding, damage to other organs, surgical site infection, and longer-term outcomes such as complications in future pregnancies (8–10).

The association between CS and childhood health is increasingly being recognized. Following CS, the infant's digestive tract is colonized by bacteria that may negatively influence the development of the immune system and energy harvesting in the gut (11). A number of conditions have been reported to be more common in children born via CS compared to vaginal birth, including obesity (12), asthma (13, 14), food allergies (15, 16), inflammatory bowel disease (17), and type I diabetes (18). While a number of studies have shown higher health care utilization (19, 20) and costs (21) in the first months after birth with CS compared to vaginal birth, no information is available on the association between CS and long-term offspring health care utilization and costs. We therefore examined the association of CS with health care utilization and costs in a large retrospective cohort of children born in Nova Scotia, Canada from birth until age seven years.

METHODS

Study design and setting

This study is a retrospective cohort study of singleton term infants without major congenital anomalies born to mothers residing in the Canadian province of Nova Scotia between 2003 and 2007 who were followed using provincial administrative health data. At the time of the data abstraction for this project, administrative data was available until 2014; therefore, all children had seven years of follow-up. Data for the current study came from the Nova Scotia Atlee Perinatal Database (NSAPD) with linkage to administrative health databases for the health care utilization and cost data. In Canada, essential health services for all residents are paid for by a single-payer universal health care system in each province. Exclusion criteria were missing or implausible (birth weight z-score > |5|) birth weight, less than seven years of follow-up, preterm (< 37 weeks) birth, and missing information on mode of delivery or health care use. Infants born post-term were included in the study sample.

The study was approved by the IWK Health Centre Research Ethics Board (File # 1015756), the Joint Data Access Committee of the Reproductive Care Program of Nova Scotia, and the Health Data Nova Scotia Data Access Committee.

Data sources

The NSAPD records information on all pregnancies and births to mothers resident in Nova Scotia. Health records personnel obtained and recorded information from standard data collection forms filed in hospital charts for use in the NSAPD. Information includes demographics, diagnoses, morbidity, and mortality data for both mother and infant for each pregnancy as well as routine demographic variables, medical conditions, reproductive history, delivery events, and neonatal outcomes from each delivery record. Data in the NSAPD are regularly checked, edited, abstracted, and validated to ensure quality

and validity (22). The administrative health databases used were the Medical Services Insurance Physician Billings database, the Canadian Institute of Health Information Hospital Discharge Abstract Database, and the Insured Patient Registry. The Physician Billings Database was administered by Medavie Blue Cross in Nova Scotia and contains records of each insured health service performed by a physician and paid for by the Nova Scotia provincial health system. Each record contains the date, up to three diagnoses in International Classification of Diseases (ICD) 9 format, procedure codes, and the cost of the service. The Hospital Discharge Abstract Database contains information on admissions, separations, and day surgeries, including demographic information, diagnostic codes (ICD-10CA), procedure codes, and specialty services received. The Insured Patient Registry contains information about each beneficiary of Nova Scotia health care services and was used to identify individuals who left the province or died before they were seven years of age. Since prescription drugs are not universally covered under the Nova Scotia health care plan, drug cost information was not available for this study.

The NSAPD was linked to administrative health data using the provincial health card number, a unique identifier that is associated with individuals from birth over their lifetime.

Outcomes

The primary outcome was health care utilization during the first seven years of life, determined as the number of physician visits, number of hospital stays, number of hospital days, physician costs, hospital costs, high utilizer of physician services (> 95th percentile for the number of visits, corresponding to ≥ 90 visits), and high utilizer of hospital services (> 95th percentile of hospital days, corresponding to ≥ 6 days). The delivery admission was excluded from the analysis. Secondary outcomes were the number of physician visits in each ICD-9 chapter of the primary diagnosis for each visit.

Exposure

The main exposure was mode of delivery (CS or vaginal birth). In a secondary analysis, CS was grouped into CS before the second stage of labour (cervix dilated < 10cm) and CS performed during the second stage of labour (cervix dilated to 10cm).

Confounding variables

Confounding variables were identified using a directed acyclic graph (Figure 1) and included maternal pre-pregnancy weight status (not overweight or obese [< 25 kg/m^2], overweight [25 to < 30 kg/m^2], obese [≥ 30 kg/m^2]); parity (1, 2, or ≥ 3); maternal age; area of residence (urban or rural, based on the Canadian postal code); area-level income quintile derived from Census of Canada information (23); and birth weight for gestational age and sex categorized based on a Canadian reference population (24) as small (SGA, < 10^{th} percentile for gestational age and sex), large (LGA, > 90^{th} percentile for gestational age and sex), or appropriate (AGA, 10^{th} to 90^{th} percentile) for gestational age.

Statistical analysis

Descriptive statistics were summarized by mode of delivery. Generalized linear models were used to investigate the association between mode of delivery and health care utilization. The models were adjusted for parity, maternal age, area of residence, area-level income, maternal pre-pregnancy weight, and birth weight for gestational age category. The association between mode of delivery and the number of physician visits was estimated using negative binomial regression. The relationship between mode of delivery and the number of hospital stays and days, respectively, was examined using a two-part hurdle model (logistic regression to model having ever stayed in a hospital, and zero-truncated

negative binomial regression to model the rates of hospital stays and days, respectively). Results for these models are reported as incidence rate ratios. A generalized linear model with a gamma distribution and a log link function was used to model the association between the mode of delivery and physician costs, while hospital costs were modeled with a two-part hurdle model (logistic regression followed by gamma model). We were unable to directly determine the hospital costs from our data as Canadian hospitals do not operate on a fee for service basis. We therefore estimated the cost per hospital day as C$1221 from the average cost of a hospital stay of C$6107 and average length of stay of 5 days in Nova Scotia in 2014-2015 (25). Results from the cost models are presented as multiplicative changes in the expected costs (cost ratios). Logistic regression was used to examine the relationship between mode of delivery and high utilizer status. Multiple imputation (n = 20) with chained equations was executed (10 iterations) to impute missing values of the model covariates (26). Physician costs were adjusted to 2014 Canadian Dollars using the Canadian Consumer Price Index for health care services (27). The incremental impact of CS compared to vaginal birth over the first seven years of life for the outcomes was estimated from the corresponding regression models. To explore how the association between CS and health care utilization changes over age, the IRRs for physician visits and hospital admissions were estimated monthly up to seven years. Estimates were fit with a smoothed, adjusted generalized additive model and plotted by mode of delivery. Lastly, we calculated the rates of physician visits and hospital admissions over the first seven years of life by mode of delivery for ICD chapter-based disease groups.

RESULTS

A total of 42,050 children were born to mothers resident in Nova Scotia between January 1, 2003 and December 31, 2007, of which 39,369 had non-missing and plausible (birth weight z-score < |5|) birth

weight and gestational age information and could be linked with administrative health data. We removed children with less than seven years of follow-up (n = 4290) due to death or migration out of the province or who were born preterm (< 37 weeks, n = 2609) or were missing information on mode of delivery or health care use (n = 6), leaving 32,464 children born to 27,293 mothers in the analysis sample.

Twenty-seven percent of children in the sample were born by CS. The sociodemographic and clinical characteristics of the women by mode of delivery are shown in Table 1. Compared to women who had a vaginal birth, women with CS had higher pre-pregnancy weight and were more likely to have LGA offspring. Women who had a CS were also older, more likely to live in an urban area, and less likely to smoke.

Table 2 presents the results for the association between CS and offspring health care utilization. Children born by CS had significantly more physician visits, hospital admissions, hospital days, and physician costs, and were more likely to be a high utilizer of physician visits and hospital days than children born vaginally. The magnitude of the associations, however, and the corresponding incremental impact was fairly small. The adjusted difference in physician costs during the first seven years of life between children born by CS compared to children born vaginally was C$159 (95% confidence interval [CI] 118, 201) or 9% relative difference; the corresponding estimate for hospital costs was C$616 (95% CI -341, 1704) or 8% relative difference.

When the exposure was further grouped into CS before and during the second stage of labour (Table 3; online), point estimates of associations relative to vaginal birth were slightly higher with CS before the second stage of labour than during the second stage of labour, but the adjusted differences between the two CS groups were only significant for the number of hospital days ($P = 0.033$), respectively.

Figure 2 (online) shows the difference in the rate of physician visits and hospital admissions over age

for children born by CS compared to children born vaginally; the IRR for physician visits slowly decreased from birth to age 7, while the IRR for hospital admissions increased over the same period. The average number of physician visits for CS-born children relative to vaginally born children by ICD chapter are shown in Figure 3. The rate ratios of physician visits for CS-born children compared to children born vaginally were highest for diagnoses from the ICD chapters Newborn/Perinatal (1.48), Endocrine and metabolic disorders (1.38), Cardiovascular disorders (1.34), and Blood disorders (1.32).

DISCUSSION

The present study has expanded on previous work on the relationship between mode of delivery and long-term health by investigating the association between CS and health care utilization in childhood. Earlier studies have examined the immediate costs of CS birth in the postnatal period and generally found higher costs for mothers following CS compared to vaginal birth (21, 28). Our study is the first to compare offspring health care costs associated with CS and vaginal birth beyond the first months of life. We found a modest increase in the use and costs of health services among children born via CS compared to vaginal birth during the first seven years of life. The higher number of physician visits and hospital stays translate into an estimated excess cost of C$775 (corresponding to approximately 8% higher health care costs) per child born by CS during the first seven years of life. However, the actual cost difference may be larger than this estimate for two reasons. Firstly, costs for prescription drugs are not universally covered under the Nova Scotia health care plan and were therefore not captured. An Australian study on childhood health outcomes following CS found an odds ratio of 1.26 (95% CI 1.01, 1.56) for use of prescription medication in 6-7-year-old children born by CS compared to those born vaginally (29). Secondly, indirect health care costs, such as lost earnings when a parent has to care for a sick child, could also not be considered.

Previous studies found higher risks for chronic conditions such as asthma, obesity, type 1 diabetes, allergic disorders, and celiac disease among children born by CS than those born vaginally (12, 16, 18, 30), although some of these diseases may be present in the mothers as well and may make them more likely to have a CS. Our findings of longer hospital stays and a higher risk of being a high utilizer of physician visits and hospital days also suggest that children born by CS may be more likely to suffer from chronic conditions in childhood; high utilizers in our sample accounted for 13% of physician visits and 64% of hospital days in the first seven years of life. By way of comparison, a recent Canadian study that examined high utilizers found that children (0-17 years) who were above the 95th and 99th percentile of health care costs incurred 59% and 38% of total expenditures, respectively. The most common diagnoses in these high utilizers were preterm birth, cancer, and mental health disorders (31). The difference in the rate of hospital admissions among children born by CS compared to those born vaginally increased over the first seven years of life from about 1.14 to 1.28 (Figure 2). This observation may be explained by the fact that the conditions associated with birth by CS only manifest themselves beyond the first years of life. However, the increase should be interpreted with caution given the fairly wide confidence intervals and the fact that the IRR for physician visits showed the opposite trend during the same period. For privacy reasons, we did not have access to individual ICD codes for each provider contact, and thus we were unable to determine which specific conditions contributed to the differences in health care use. The ICD chapters from which diagnoses were more frequently coded in CS-born children compared to children born vaginally were Newborn/Perinatal (48% higher), Endocrine and metabolic disorders (38% higher), Cardiovascular disorders (34%), and Blood disorders (32%). In the absence of specific ICD codes, we can only speculate that the first two

may reflect follow-up care for perinatal complications that had led to CS, and childhood obesity (12) or diabetes (18), respectively.

Alterations in the composition of the microbiota in children born by CS are hypothesized to be responsible for the higher risk of immune-related conditions and obesity compared to children born vaginally (11). Our finding of significantly higher health care use and costs in the CS group are in keeping with this hypothesis, although we also could not exclude the possibility that infants who need to be delivered by CS because their mothers do not tolerate labour and also later need more health care. When comparing the group of children born by CS before the second stage of labour with those born during the second stage of labour, we also found that the former group had increased, albeit non-significantly, health care utilization. This finding could also be explained with the microbiome hypothesis as children born before the second stage of labour are overall less likely overall to be exposed to the maternal vaginal flora than children born during the second stage of labour. However, a Scottish record linkage study in 321,287 term infants found no difference in adverse childhood outcomes between children born via planned CS compared to unscheduled CS, except for a higher risk of type 1 diabetes mellitus (adjusted hazard ratio 1.35) (32).

Confounding by maternal pre-pregnancy maternal weight status constitutes a major threat to the validity of associations between CS and childhood health outcomes. Women who are obese are more likely to undergo CS (33) and are also more likely to have children who develop obesity and other health problems later in life (34). In the present study, the association between CS and health care utilization did not change substantially after adjustment for maternal pre-pregnancy weight status. We cannot exclude residual confounding by indication for CS and by maternal morbidity. We did not

adjust our models for breast-feeding as part of the effect of CS on child health is probably mediated by breast-feeding. A recent study on CS and offspring obesity suggested an interaction between mode of delivery and maternal weight status, with the strongest effect seen in offspring of mothers with obesity who underwent CS (35). We found no evidence of multiplicative interaction between CS and maternal weight status (data not shown). There is also the possibility that women who give birth by CS have other characteristics that are associated with the mode of delivery and health care use in their offspring that are unrelated to the microbiome; e.g., they may be more likely to have chronic health or other conditions including anxiety, which may make them more open to intervention during their birth and potentially also more likely to seek medical care for their offspring. A sibling analysis that compares offspring of the same mother with one born vaginally and the other via CS would be able to account for these shared confounders, but may introduce bias due to non-shared confounders such as birth order or indication for CS (36).

The strengths of the current study are the use of a large population-based cohort in a single payer universal health care system and the ability to adjust for a range of confounders. Our findings are limited by attrition due to non-linkage and loss to follow-up. Non-linkage due to discrepant or missing health card numbers most likely resulted in missingness at random; comparison of the characteristics of children that were included in the study with those who did not have the full seven years of follow-up showed a lower prevalence of maternal obesity in the excluded observations (14.2% vs. 19.9%). We did not have information on antenatal or perinatal administration of antibiotics to the mother, which may have influenced the child's microbiota. Lastly, due to the nature of the Canadian health care system, which does not reimburse hospitals on a fee-for-service basis, we had to estimate the cost of a hospital day from the average cost and length of stay, which ignored potential differences in resource

use between children born by CS and children born vaginally as a result of disease severity and complexity.

CONCLUSIONS

Compared to vaginal birth, CS is associated with small but statistically significant increases in the use of physician and hospital services during the first seven years of life for an estimated excess cost of CS of $775. Reduction of CS rates may potentially result in lower health care utilization and costs in the offspring. More studies are needed to confirm these findings in other populations.

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FIGURES

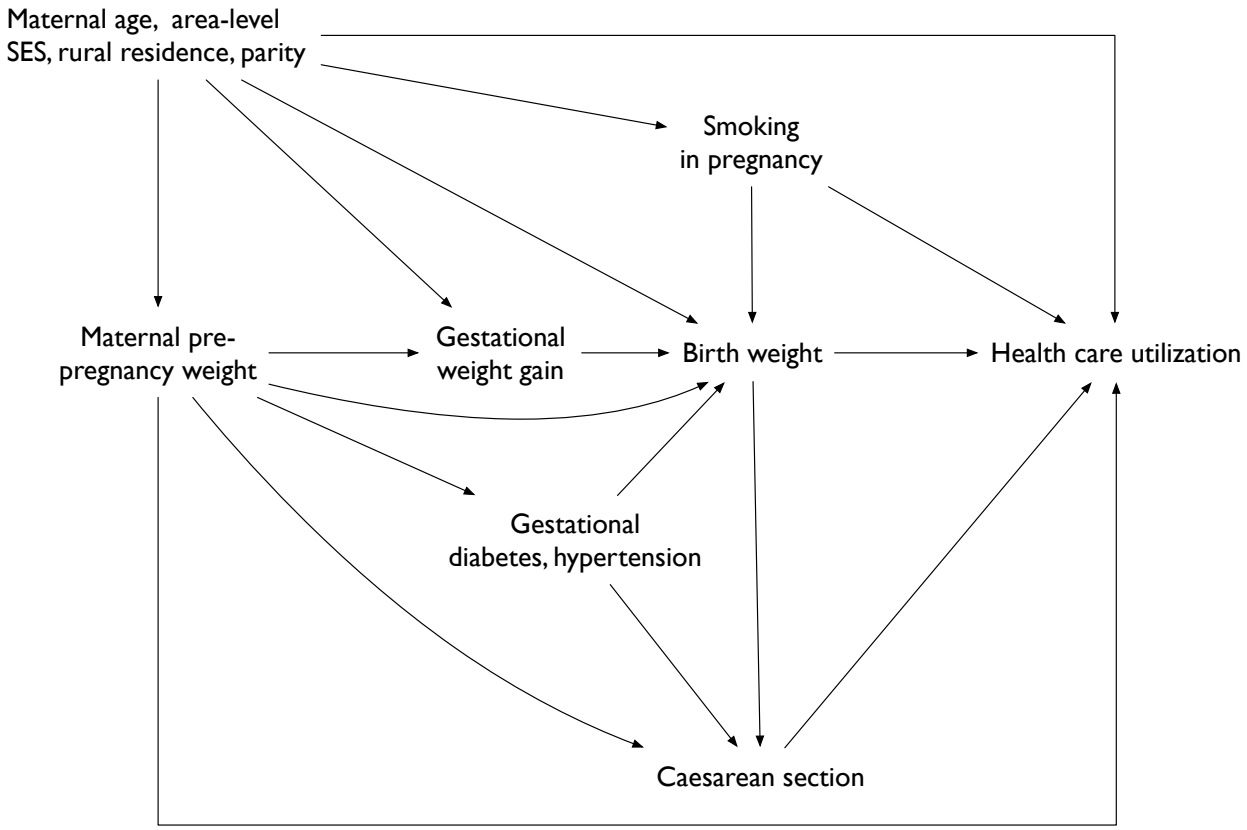

Figure 1: Directed acyclic graph representing the effect of Caesarean section on offspring health care utilization.

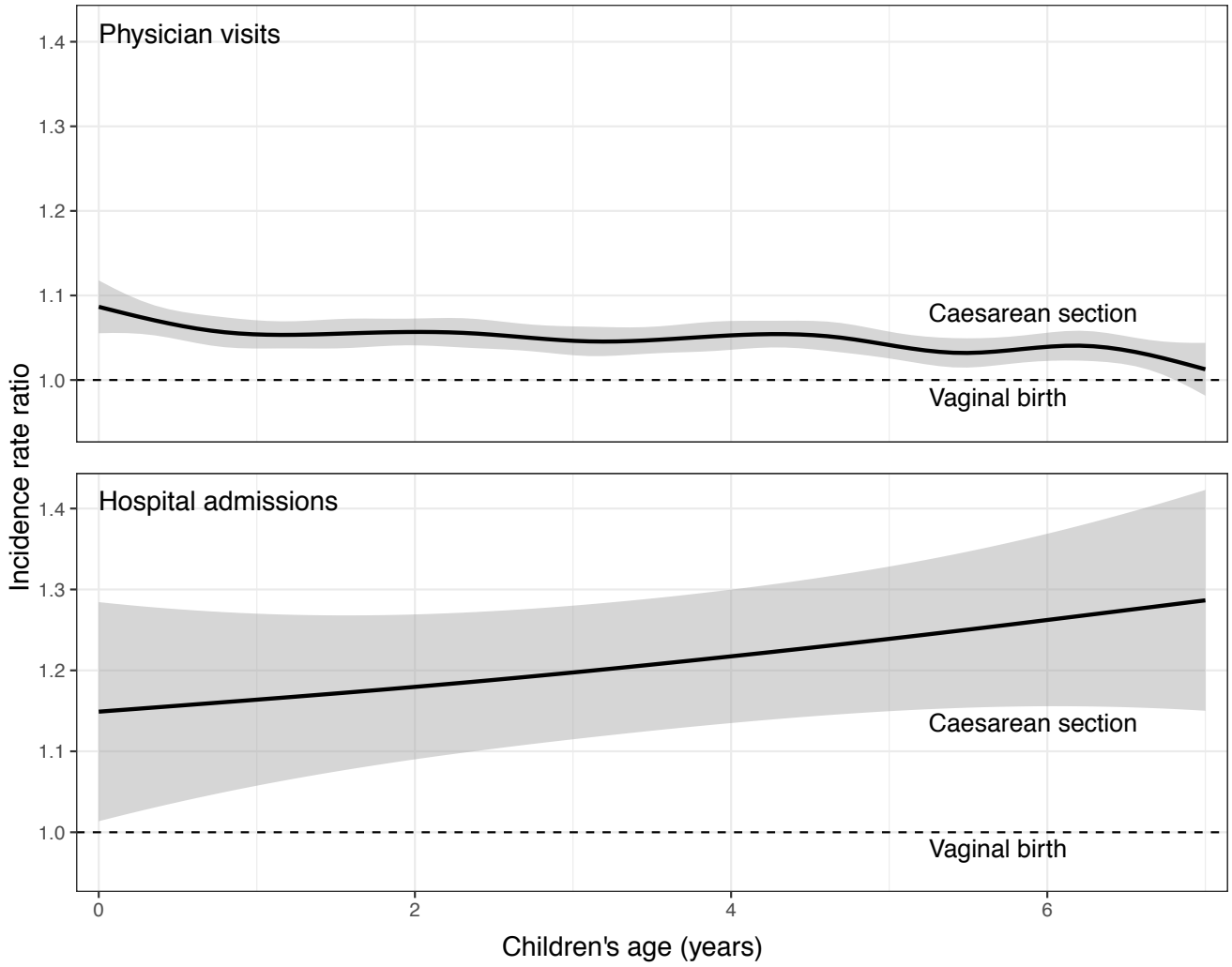

Figure 2: Smoothed incidence rate ratios with 95% confidence intervals of offspring physician visits (top) and hospital admissions (bottom) over the first 18 years of life for Caesarean section relative to vaginal delivery.

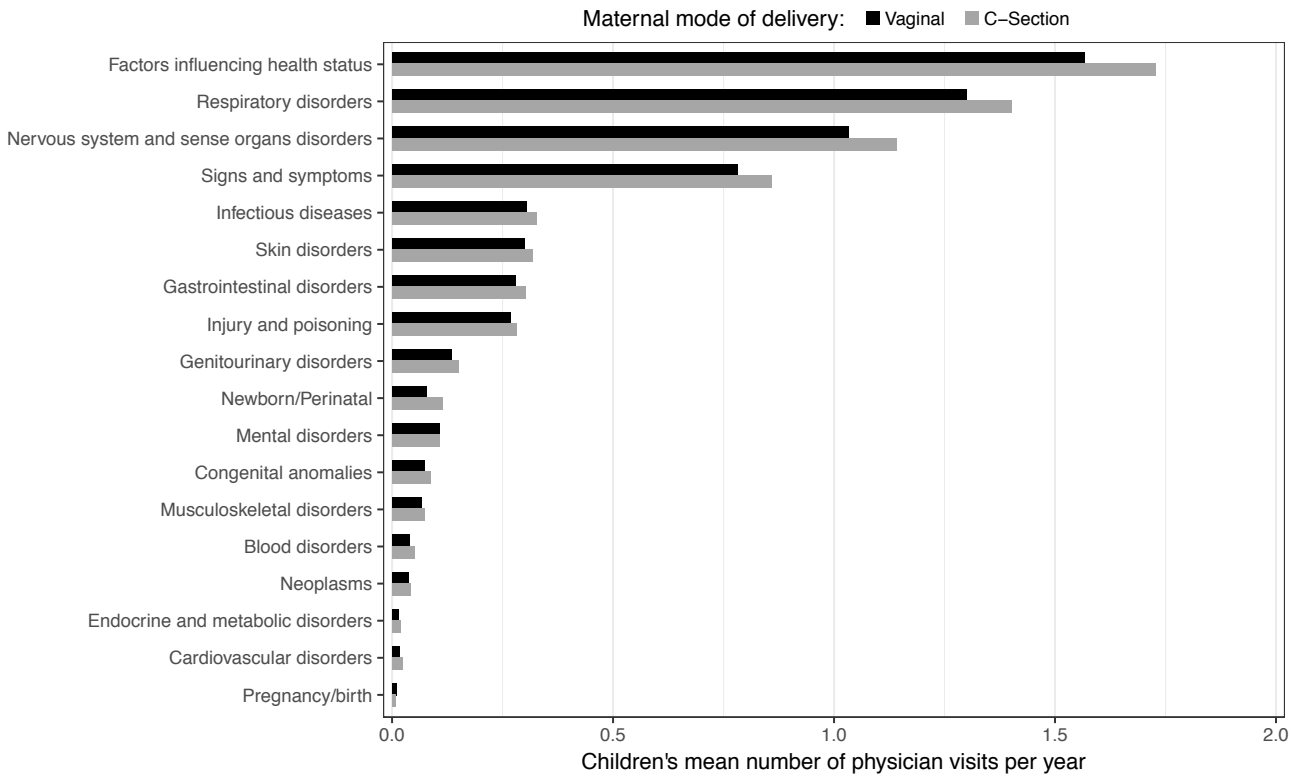

Figure 3: Children's mean number of physician visits per year over the first 7 years of life, by ICD chapter and mode of delivery.