ERJ Express. Published on March 8, 2018 as doi: 10.1183/13993003.00209-2018

EUROPEAN RESPIRATORY *journal*

FLAGSHIP SCIENTIFIC JOURNAL OF ERS

Early View

Original article

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Please cite this article as: To T, Feldman LY, Zhu J, *et al*. Asthma Health Services Utilization Before, During, and After Pregnancy: A Population-Based Cohort Study. *Eur Respir J* 2018; in press (https://doi.org/10.1183/13993003.00209-2018).

Asthma Health Services Utilization Before, During, and After Pregnancy: A Population-Based Cohort Study

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Take-home message: Women in Ontario, Canada have increased hospitalizations and reduced primary care visits for asthma during pregnancy.

Abstract

During pregnancy, women with asthma may be at higher risk of exacerbation. The objective of this study was to determine whether women with asthma in Ontario, Canada have increased health services utilization (HSU) during pregnancy.

Rates of asthma-specific, asthma-related and non-pregnancy-related HSU were calculated in a population-based cohort of pregnant women with asthma. Poisson regression with repeated measures was used to determine adjusted rate ratios and 95% confidence intervals of HSU during and one year after pregnancy, compared to the year before pregnancy.

The cohort consisted of 103,976 women. Compared to the year prior to pregnancy, hospitalization rates per 100 person-months during pregnancy increased 30% for asthma (0.016 to 0.020), 24% for asthma-related conditions (0.012 to 0.015) and decreased 37% for non-pregnancy-related conditions (0.24 to 0.15). Emergency department visits for asthma and asthma-related conditions did not significantly increase during pregnancy. During pregnancy, physician office visits decreased 19% for asthma (2.20 to 1.79), 10% for asthma-related conditions (9.44 to 8.47) and increased 77% for non-pregnancy-related conditions (5.64 to 9.82).

Hospitalizations for asthma and asthma-related conditions increased during pregnancy, demonstrating that the overall increase in non-pregnancy-related physician office visits may not meet the primary care needs of pregnant women with asthma.

Introduction

Several prospective studies of asthmatic pregnant women have demonstrated that, during pregnancy, asthma tends to improve in one third of women, stay the same in one third and worsen in one third [1, 2].

The prognosis of asthma during pregnancy has been shown to be affected by provider and patient factors. An Australian survey demonstrated that many general practitioners involved in the primary care of pregnant women, despite reporting a good knowledge of asthma, decreased patients' asthma medications during pregnancy even when asthma was well-controlled by current therapy [3]. Healthcare providers in North America have been shown to delay or reduce prescription of systemic corticosteroids to pregnant women during asthma exacerbations treated in acute care settings, compared to non-pregnant women [4-7]. Many pregnant women themselves have been reported to reduce or discontinue asthma controller medications during pregnancy, due to concern about the effect of asthma medications on the fetus [8, 9]. Other factors that may affect the prognosis of asthma during pregnancy include women's pre-pregnancy severity of asthma, viral infections, allergic rhinitis and smoking [2, 10-13].

Deviation from asthma guidelines during pregnancy may place pregnant women at higher risk of asthma exacerbations, thus leading to avoidable maternal and possibly fetal morbidity, and an increased burden on the health care system. A systematic review of 33 published studies did not find any conclusive links between preventive asthma medications and adverse pregnancy outcomes [14]. The authors of the study recommended that healthcare providers follow asthma guidelines produced by professional organizations such as the Global Initiative for Asthma (GINA), which emphasizes the importance of actively treating asthma during pregnancy and not stepping down medications even if asthma is well-controlled [15]. Further, it has been demonstrated that the use of asthma medications below levels recommended by GINA is associated with more severe asthma during pregnancy [13].

In order to understand the unique health care needs of pregnant women with asthma and the impact that these needs have on the health care system, it is important to describe the patterns and risk factors of health care utilization of this vulnerable population. The objective of this study was to determine whether women in Ontario, Canada with asthma have increased health services utilization during pregnancy, compared to before and after pregnancy and to identify individual as well as community level risk factors for increased health services utilization.

Methods

Study design

In this population-based cohort study, pregnant women with asthma living in Ontario, Canada were followed using health administrative databases to determine health services utilization (HSU) for asthma, asthma-related conditions and non-pregnancy-related conditions. HSU was evaluated at three time points: in the year before pregnancy, during pregnancy and in the first year post-delivery.

Approval to conduct this study was obtained from the Institute for Clinical Evaluative Sciences (ICES) and the Research Ethics Board at the Hospital for Sick Children, Toronto, Canada.

Study population

The study population consisted of pregnant women with pre-existing asthma aged ≥19 years living in Ontario, Canada. Women with asthma were identified from the Ontario Asthma Surveillance Information System (OASIS; http://lab.research.sickkids.ca/oasis/), which includes all individuals covered by Ontario's universal healthcare system who meet the following definition of asthma: ≥one hospitalization for asthma or ≥two outpatient claims for asthma in two consecutive years [16].Women were included if they delivered between April 1, 2005 and March 31, 2015 and if their pregnancy had gestational age between 37 and 42 weeks (inclusive) and did not result in termination, stillbirth or multiple births. Women were further excluded if, during their study period (i.e., within the year prior to and first year post-delivery), they had another delivery or had incomplete health insurance coverage or data. Fewer than six women had congestive heart failure; in order to protect individual identities, they were removed during the initial screening process.

If women had more than one delivery during the study period, only the first delivery that met inclusion/exclusion criteria was used in this study.

Data sources

All study data were captured in six large, population-based health administrative databases housed at ICES (Appendix eTable 1). Individuals in the study cohort were linked across these databases using their encrypted, unique health card number, given to every Ontario resident covered by Ontario's universal healthcare system.

Exposure and outcome measures

Exposure

The three exposure times we investigated were: the year prior to pregnancy, during pregnancy and the first year post-delivery. These dates are calculated using the mother's gestation weeks at delivery and the newborn's date of birth, as recorded in health administrative databases.

Outcomes

Asthma HSU was captured using the diagnostic code 493 (International Classification of Disease (ICD)-9) or J45/J46 (ICD-10) (Appendix eTable 2).

Asthma-related conditions HSU was captured using diagnostic codes for: acute respiratory infections, pneumonia, influenza, chronic obstructive pulmonary disease (COPD), atopic dermatitis, gastro-esophageal reflux disorder, heartburn and allergic contact dermatitis (Appendix eTable 2).

Non-pregnancy-related HSU was captured using any diagnostic code *except* for the following ICD chapter headings: complications of pregnancy, childbirth and the puerperium and certain conditions originating in the perinatal period (Appendix eTable 2). Non-pregnancy-related conditions therefore also included asthma and asthma-related conditions.

Three forms of HSU were captured for each group of conditions: hospitalizations, emergency department (ED) visits and physician office visits. For hospitalizations and ED visits, only primary

diagnostic codes were considered. For physician office visits, only one diagnosis code is available and is used per patient visit.

Statistical analysis

Counts of HSU were tabulated for the three time periods of the study, and rates per 100 person-months were calculated. This approach ensures that rates can be compared between the three time periods, which vary in duration from approximately nine to 12 months.

Poisson regression with repeated measures using Generalized Estimating Equations (GEE) was used to generate rate ratios (RR) and 95% confidence intervals (CI) for the effect of each period of pregnancy on HSU (reference period: the year prior to pregnancy). Separate models were run for the three groups of conditions (asthma, asthma-related conditions and non-pregnancy-related conditions) and each type of HSU. HSU was modelled as rates, using the number of days in each time period as an offset. To examine if HSU differed by maternal age at delivery, duration of maternal asthma, material deprivation, rural/urban residence and the presence of certain comorbidities, these variables were included as covariates in multivariable regressions. The duration of maternal asthma was calculated as the number of years since each woman was first included in OASIS. Material deprivation, a measure of socioeconomic status (SES), was measured using the Ontario Marginalization Index [17]. The following comorbidities were considered at each of the three exposure periods: diabetes, cardiovascular disease, COPD and cancer (defined in Appendix eTable 3).

Results

Descriptive data

The study cohort consisted of 103,976 pregnant women with asthma with one singleton delivery each (Figure 1). Pregnant women with asthma were on average aged 28.9 years at delivery (standard deviation (SD)=5.5) (Table 1). They were first included in OASIS when they were an average age of 16.4 years (SD=8.2) and had an average duration of asthma of 12.5 years (SD=5.5). 22.8% of the women were in the highest quintile of material deprivation (most deprived), whereas 23.0% were in the lowest quintile, and 11.2% lived in rural areas. The most common comorbidity was cardiovascular disease (8.7% in the year prior to pregnancy) followed by diabetes (1.7%).

Rates of HSU

Compared to the year prior to pregnancy, hospitalizations for asthma and asthma-related conditions increased during pregnancy, after which they dropped markedly in the first year post-delivery (Figure 2). ED visits for asthma and asthma-related conditions were stable during pregnancy, after which they also dropped markedly in the first year post-delivery. In contrast, acute care visits (hospitalizations and ED visits) decreased during pregnancy for non-pregnancy-related conditions, after which hospitalizations rebounded to pre-pregnancy levels and ED visits continued to decrease. Physician office visits for asthma and asthma-related conditions decreased during pregnancy and in the first year post-delivery, whereas they increased during pregnancy for non-pregnancy-related conditions (Figure 2).

Rates further broken down by trimester of pregnancy are shown in Appendix eFigure 1. While hospitalizations increased steadily across all trimesters of pregnancy for asthma, they were only increased in the second and third trimesters for asthma-related conditions. ED visits for asthma and asthma-related conditions were highest in the second trimester, and ED visits for non-pregnancy-related conditions peaked in the first trimester. The increase in physician office visits for non-pregnancy-related conditions during pregnancy was most pronounced in the third trimester.

Multivariable analysis

Figure 3 displays RR and 95%CI for HSU during pregnancy and in the first year post-delivery (reference period: the year prior to pregnancy). Covariate effects are also displayed.

Hospitalizations

Multiple regression analyses could not be conducted for asthma or asthma-related hospitalizations, due to too few outcomes occurring for these conditions. Compared to the year prior to pregnancy, hospitalizations for non-pregnancy-related conditions decreased 37% during pregnancy (RR 0.63, 95%CI 0.59–0.68), rebounding to baseline levels in the first year post-delivery (RR 0.99, 95%CI 0.94–1.05).

ED visits

Compared to the year prior to pregnancy, ED visits increased 6% for asthma and remained the same for asthma-related conditions during pregnancy (RR 1.06, 95%CI 1.00–1.12; RR 0.99, 95%CI 0.96–1.03, respectively) then decreased by approximately 40% in the first year post-delivery (RR 0.53, 95%CI 0.49–0.57; RR 0.67, 95%CI 0.65–0.70, respectively). ED visits for non-pregnancy-related conditions decreased 8% during pregnancy and 27% in the first year post-delivery (RR 0.92, 95%CI 0.91–0.94; RR 0.74, 95%CI 0.72–0.74, respectively).

Physician office visits

Compared to the year prior to pregnancy, physician office visits decreased 19% for asthma and 10% for asthma-related conditions during pregnancy (RR 0.81, 95%CI 0.79–0.83; RR 0.90, 95%CI 0.88–0.91, respectively) and 28% and 11% in the first year post-delivery (RR 0.72, 95%CI 0.71–0.74; RR 0.89, 95%CI 0.88–0.90, respectively). Physician office visits for non-pregnancy-related conditions increased 74% during pregnancy (RR 1.74, 95%CI 1.72–1.75) and nearly returned to baseline levels in the first year post-delivery (RR 1.02, 95%CI 1.01–1.03).

Covariate effects

Increased material deprivation was generally associated with increased HSU. Compared to being in the lowest quintile of material deprivation (least deprived), being in the highest quintile was associated with double the ED visits and 22% more physician office visits for asthma (RR 1.95, 95%CI 1.74–2.20; RR 1.22, 95%CI 1.16–1.29, respectively). Similarly, being in the highest quintile of material deprivation was associated with a 41% higher hospitalization rate and a 73% higher ED visit rate for non-pregnancy-related conditions (RR 1.41, 95%CI 1.28–1.55; RR 1.73, 95%CI 1.67–1.80, respectively), but was not as strongly associated with physician office visits (RR 1.02, 95%CI 1.00–1.03).

Women in rural areas experienced a higher rate of hospitalizations and ED visits and a lower rate of physician office visits, compared to women in urban areas. For example, women in rural areas experienced an 85% higher ED visit rate and 32% lower physician office visit rate for asthma (RR 1.85, 95%CI 1.68–2.04; RR 0.68, 95%CI 0.64–0.73, respectively).

Comorbidities were generally associated with increased HSU. COPD was the comorbidity associated with some of the greatest increases in HSU, including ED visits for asthma, asthma-related conditions and non-pregnancy-related conditions (RR 3.87, 95%CI 2.08–7.17; RR 2.39, 95%CI 1.51–3.76; RR 2.05, 95%CI 1.63–2.57, respectively). Diabetes was associated with the greatest increases in physician office visits for non-pregnancy-related conditions (RR 1.50, 95%CI 1.46–1.54).

Discussion

Our study used a population-based cohort of pregnant women with asthma to compare patterns of HSU before, during and after pregnancy. We reported a significant increase in hospitalizations during pregnancy for asthma and asthma-related conditions. We also found that physician office visits for non-pregnancy-related conditions were increased during pregnancy, whereas physician office visits for asthma and asthma-related conditions decreased. Higher levels of material deprivation, rural residence and the presence of comorbidities were associated with higher rates of HSU among pregnant women with asthma. The increase in hospitalizations for asthma and asthma-related conditions during pregnancy suggests a role for asthma-focused primary care during pregnancy.

Interpretation of findings in broader context of existing literature

Kim et al. examined asthma HSU in 3,357 pregnant and 50,355 non-pregnant women using the Korean National Health Insurance claim database [18]. They examined patterns of HSU in the year prior to pregnancy, during pregnancy and in the first and second years after delivery. Crude rates of asthma HSU were higher in the study by Kim et al. than in our study, likely because their inclusion criteria included prior asthma HSU and asthma-related medications or tests during the study period; therefore, their cohort would have been more likely to have “active” disease than the women in our study. However, the overall patterns of HSU were very similar to our study. As in our study, they showed that hospitalizations for asthma increased during pregnancy, whereas outpatient visits were significantly lower. In contrast to our findings, Kim et al. showed that ED visits declined during pregnancy and in the first year post-delivery. However, increases in hospitalizations and decreases in the number of ED visits for asthma during pregnancy were not statistically significant in their study, in which only a small number of acute care visits were seen.

The observed peak in ED visits for asthma during the second trimester of pregnancy is consistent with prospective cohort studies that have found asthma exacerbations to be most frequent between

gestational weeks 17 and 24 [19, 20]. In our study, hospitalizations for asthma, which accounted for a minority (about 10%) of acute care visits for asthma, peaked in the third trimester of pregnancy. This is consistent with the study by Kim et al. [18] and may reflect an increased tendency toward hospitalization among pregnant women with asthma presenting to the ED in the third trimester with respiratory complaints.

The association between material deprivation and health services utilization observed in our study is consistent with both Canadian and international literature. In Canada, low SES has previously been reported to be associated with increased healthcare utilization for asthma and other chronic health conditions, as well as generally higher healthcare utilization [21-26]. Some of this association may be explained by differing health needs across levels of SES [27]. International studies have also supported an association between lower SES and increased asthma health services utilization [28, 29].

In Ontario, Canada, there is a low availability of primary care physician services in some rural areas—particularly in Northern areas of the province; this is likely the reason that physician office visits are generally lower for women with rural residence, while hospitalizations and ED visits are higher [30].

The increase in hospitalizations for asthma and asthma-related conditions during pregnancy could be explained by a well-documented decrease in adherence to asthma medications during pregnancy. Enriquez et al. analyzed prescriptions filled by over 8,000 pregnant women with asthma who were enrolled in Tennessee Medicaid between 1995 and 2001 [9]. Although their use of health administrative data did not allow them to comment on reasons for the patterns they observed, Enriquez et al. demonstrated that pregnant women filled 22.9% fewer prescriptions for inhaled corticosteroids (ICS), 13.2% fewer prescriptions for short-acting beta-agonists and 54.3% fewer prescriptions for rescue oral corticosteroids from 5 to 13 weeks after the last menstrual period. Using health administrative databases to analyze 4,920 pregnancies among women with asthma in Québec, Canada, Blais et al. found that 48.5% of pregnancies were from women who discontinued or reduced their ICS use during pregnancy

[31]. Interestingly, Blais et al. found that women who discontinued ICS experienced fewer asthma exacerbations, while women who increased their use of ICS experienced more, likely reflecting residual confounding by asthma severity.

Strengths and limitations

Strengths of this study include the use of large, population-based databases covering the entire province of Ontario. The linkage of these large, population-based databases allowed us to assemble a longitudinal cohort to observe HSU before, during and after pregnancy for over 10 years. The use of prospectively-collected, population-based data reduces the risk of recall and selection bias and increases the generalizability of our results.

Limitations of this study include a lack of clinical variables, making it impossible for us to control for or stratify analyses by pre-pregnancy asthma severity. However, in our cohort study, women assessed for outcomes during pregnancy were the same women assessed for outcomes during the pre-pregnancy period. Therefore, the increase in acute care visits for asthma and asthma-related conditions seen during pregnancy cannot be due to a greater proportion of people with severe asthma being present in the study during this time period. The inclusion of live, singleton births between 37 and 42 weeks gestation resulted in the exclusion of preterm births, which are associated with asthma exacerbation [32]. Therefore, the magnitude of the association between pregnancy and acute asthma HSU is likely greater than that reported in our study. The use of health administrative data does not allow us to determine whether patterns of HSU changed due to disease worsening, or due to a change in health behaviours such as greater concern for pregnant women's health. However, we observed a decrease in acute care visits for non-pregnancy-related conditions, suggesting that the increase in hospitalizations we observed for asthma and asthma-related conditions was not merely a signal of overall changed health behaviours. Lastly, the lack of prescription data for those under age 65 in Ontario makes us unable to examine medication prescriptions as potential mechanisms underlying the association between periods of pregnancy and HSU.

Conclusions

We conducted a population-based study of pregnant women with asthma and found an increase in hospitalizations and a decrease in physician office visits during pregnancy for asthma and asthma-related conditions, suggesting less preventative and more reactive treatment. The observed increase in physician office visits for non-pregnancy-related conditions during pregnancy does not appear to meet the need for asthma-focused primary care during pregnancy. Since avoidance of hospitalizations for asthma is highly important during pregnancy, these findings point to a possible need for more preventive, focused physician office visits to ensure asthma is under control.

Funding

The Ontario Asthma Surveillance Information System (OASIS) is funded by the Ontario Ministry of Health and Long-term Care (MOHLTC). Data are provided by the Institute for Clinical Evaluative Sciences (ICES), which is funded by an annual grant from the MOHLTC. The opinions, results and conclusions reported in this paper are those of the authors and are independent from the funding sources. No endorsement by ICES or the Ontario MOHLTC is intended or should be inferred. Parts of this material are based on data and information compiled and provided by the Canadian Institute for Health Information (CIHI). However, the analyses, conclusions, opinions and statements expressed herein are those of the authors, and not necessarily those of CIHI. The authors have no other relevant sources of funding to declare.

A.S.G. holds a New Investigator Career Award from the Canadian Institutes of Health Research (CIHR) and is the recipient of a Physician Services Incorporated (PSI) Foundation Fellowship for Translational Health Research.

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Table 1. Characteristics of pregnant women with asthma who delivered between April 1, 2005 and March 31, 2014 (N=103,976)

Characteristic	Number	Percent (%)*
Mother's age at discharge of the delivery (Mean ± SD)	28.9 ± 5.5	
Duration of asthma in years (Mean ± SD)	12.5 ± 5.5	
Mother's age when first captured in provincial asthma surveillance system (Mean ± SD)	16.4 ± 8.2	
Mother's gestation weeks at delivery (Mean ± SD)	39.2 ± 1.2	
Death		
Yes	241	0.2
Deprivation quintile		
1 (least deprived)	23,611	23.0
2	18,552	18.1
3	18,609	18.1
4	18,428	18.0
5 (most deprived)	23,392	22.8
Rurality		
Urban	92,274	88.8
Rural	11,674	11.2
Comorbidities†		
Cardiovascular disease		
Year prior to pregnancy	9,021	8.7
During pregnancy	9,709	9.3
Year post delivery	10,508	10.1
Diabetes		
Year prior to pregnancy	1,778	1.7
During pregnancy	2,032	2.0
Year post delivery	2,331	2.2
Cancer		
Year prior to pregnancy	540	0.5
During pregnancy	595	0.6
Year post delivery	621	0.6
COPD		
Year prior to pregnancy	206	0.2
During pregnancy	308	0.3
Year post delivery	373	0.4

*Percentages are adjusted for missingness.

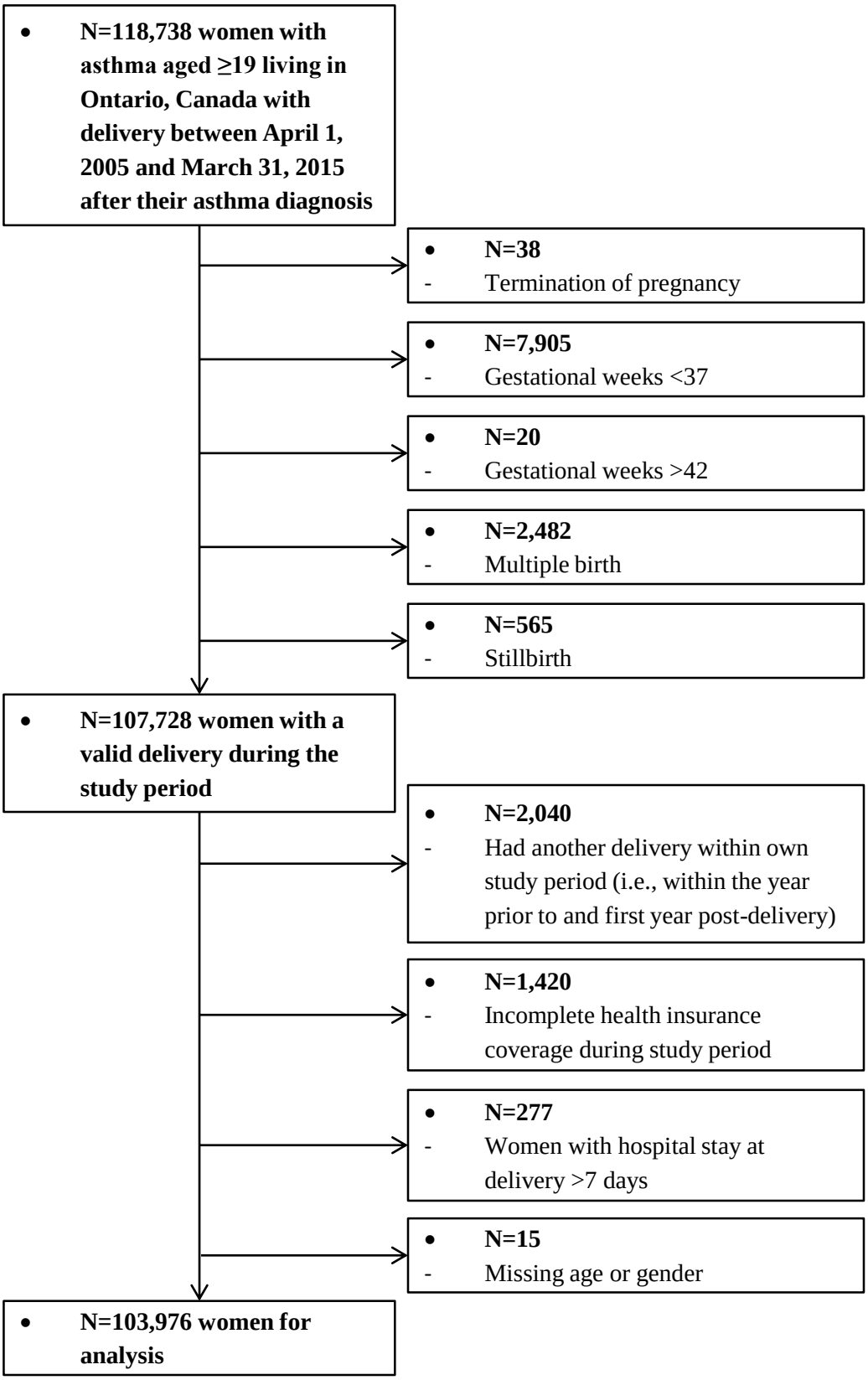
†Comorbidities were tabulated at the beginning of each time period of pregnancy. Categories are not mutually exclusive.

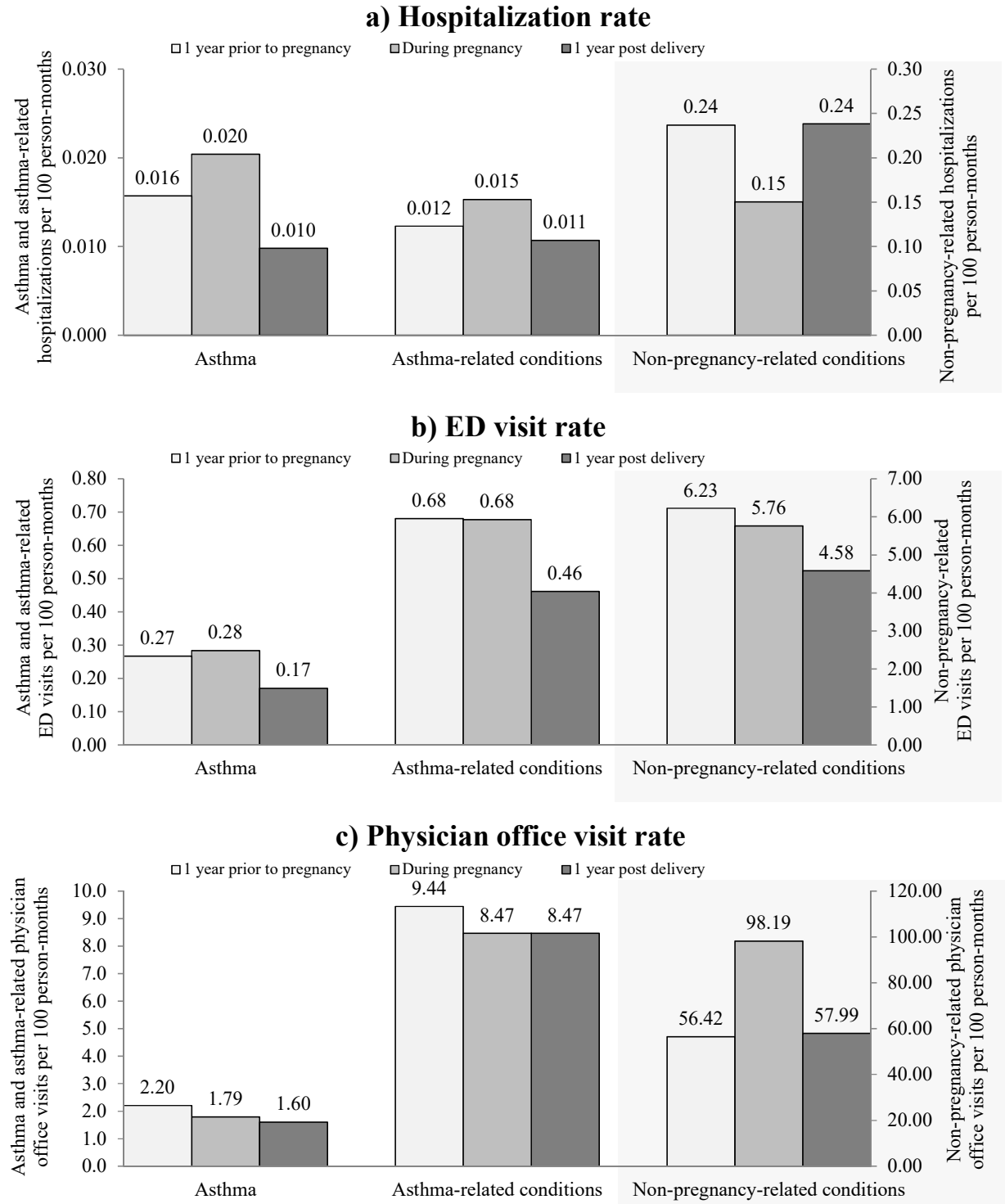
Figure legends

Figure 1. Flow diagram of the assembly of the study cohort.

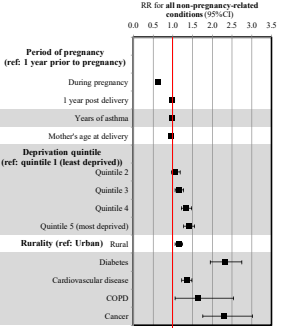
Figure 2. Rates per 100 person-months of follow-up for a) hospitalizations, b) ED visits and c) physician office visits for asthma, asthma-related conditions and non-pregnancy-related conditions during the three time periods in this study.

Figure 3. Rate ratios (RR) and 95% confidence intervals (CI) from Poisson regression with repeated measures describing exposure and covariate effects on a) hospitalizations, b) ED visits and c) physician office visits for asthma, asthma-related conditions and non-pregnancy-related conditions. Multiple regression analyses could not be conducted for asthma or asthma-related hospitalizations, due to too few outcomes occurring for these conditions.

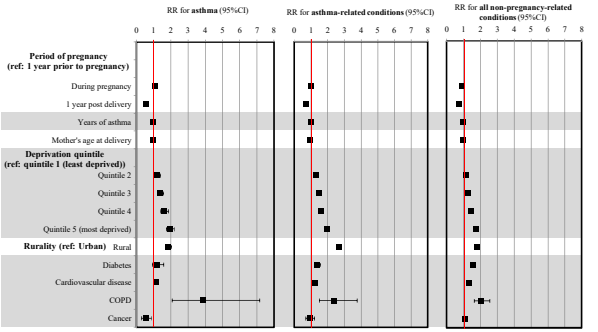

N=118,738 women with asthma aged ≥19 living in Ontario, Canada with delivery between April 1, 2005 and March 31, 2015 after their asthma diagnosis
N=38
- Termination of pregnancy
N=7,905
- Gestational weeks <37
N=20
- Gestational weeks >42
N=2,482
- Multiple birth
N=565
- Stillbirth
N=107,728 women with a valid delivery during the study period
N=2,040
- Had another delivery within own study period (i.e., within the year prior to and first year post-delivery)
N=1,420
- Incomplete health insurance coverage during study period
N=277
- Women with hospital stay at delivery >7 days
N=15
- Missing age or gender
N=103,976 women for analysis


a) Hospitalization rate
1 year prior to pregnancy
During pregnancy
1 year post delivery
Asthma and asthma-related hospitalizations per 100 person-months
Non-pregnancy-related hospitalizations per 100 person-months
0.016
0.020
0.010
0.012
0.015
0.011
0.24
0.15
0.24
Asthma
Asthma-related conditions
Non-pregnancy-related conditions
b) ED visit rate
1 year prior to pregnancy
During pregnancy
1 year post delivery
Asthma and asthma-related ED visits per 100 person-months
Non-pregnancy-related ED visits per 100 person-months
0.27
0.28
0.17
0.68
0.68
0.46
6.23
5.76
4.58
Asthma
Asthma-related conditions
Non-pregnancy-related conditions
c) Physician office visit rate
1 year prior to pregnancy
During pregnancy
1 year post delivery
Asthma and asthma-related physician office visits per 100 person-months
Non-pregnancy-related physician office visits per 100 person-months
2.20
1.79
1.60
9.44
8.47
8.47
56.42
98.19
57.99
Asthma
Asthma-related conditions
Non-pregnancy-related conditions

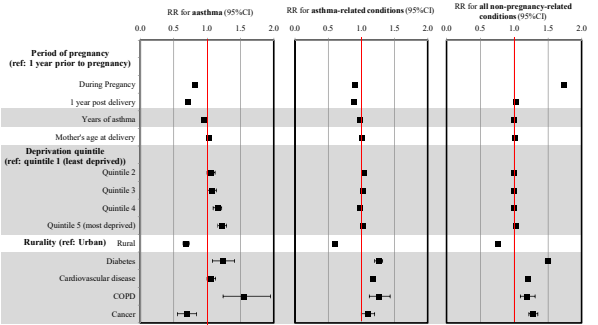
a) Hospitalizations



b) ED visits



c) Physician office visits



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Appendix eTable 1. Ontario health administrative data sources

Source	Description
Ontario Asthma Surveillance Information System (OASIS)	Surveillance system longitudinally monitoring over 2 million individuals with asthma in Ontario that have been captured according to a validated health administrative definition of asthma. This definition has shown 84% sensitivity and 76% specificity in adults compared to a clinical reference standard [1].
Mother and Baby Database (MOMBABY)	Record of all hospital deliveries in Ontario that captures maternal and newborn characteristics.
Ontario Health Insurance Plan Database (OHIP)	Contains information on all fee-for-service billings for physician services as well as emergency department visits in Ontario, including diagnosis.
Canadian Institute for Health Information's Discharge Abstract Database (CIHI-DAD)	Records administrative, clinical and demographic information on hospital discharges, including diagnosis codes.
The National Ambulatory Care Reporting System (NACRS)	Contains data for all visits to hospital-based emergency departments.
The Ontario Registered Persons Database (RPDB)	Captures information on sex, date of birth and residence postal code.

*These databases are housed at the Institute for Clinical Evaluative Sciences (https://datadictionary.ices.on.ca/Applications/DataDictionary/Default.aspx). They were linked on an individual level using an encrypted unique health card number given to all Ontario residents.

1. Gershon AS, Wang C, Guan J, Vasilevska-Ristovska J, Cicutto L, To T. Identifying patients with physician-diagnosed asthma in health administrative databases. Canadian Respiratory Journal 2009: 16(6): 183-188.

Appendix eTable 2. International classification of disease (ICD-9 and ICD-10) codes of asthma, asthma-related conditions and non-pregnancy-related conditions

Conditions	OHIP	ICD-9	ICD-10
Asthma	**Asthma, Allergic Bronchitis** 493	**Asthma** 493	**Asthma** J45 **Status asthmaticus** J46
Asthma-related conditions	**Acute respiratory infections** 460–462, 464–466 **COPD and allied conditions** 491, 492, 496 **Other diseases of the upper respiratory tract** 473, 477 **Pneumonia and influenza** 486,487 **Atopic dermatitis and related conditions** 691 **Symptoms involving respiratory system and other chest symptoms** 786 **Gastro-esophageal reflux disorder** 530 **Heartburn** 787	**Acute respiratory infections** 460, 461, 466 **COPD and allied conditions** 490–492, 496 **Other diseases of the upper respiratory tract** 471–473, 476, 477, 478.8 **Pneumonia and influenza** 480–487 **Atopic dermatitis and related conditions** 691.8 **Symptoms involving respiratory system and other chest symptoms** 786 **Other diseases of lung or respiratory system** 519.8, 519.9, 487.9, 518.81, 518.83, 518.84, 518.89 **Gastro-esophageal reflux disorder** 530.81 **Heartburn** 787	**Acute respiratory infections** J00–J02, J04–J06, J30, J20 **COPD and allied conditions** J40, J22, J40–J44 **Other diseases of the upper respiratory tract** J33, J31, J37, J30, J39.3 **Pneumonia and influenza** J10–J18 **Atopic dermatitis and related conditions** L20 **Symptoms involving respiratory system and other chest symptoms** R05, R06, R09.2, R09.3, R09.8 **Other diseases of lung or respiratory system** J39.8, J39.9, J96.0, J96.1, J96.9, J98.4, J98.8, J98.9 **Gastro-esophageal reflux disorder** K21 **Heartburn** R12 **Allergic contact dermatitis** L23
Non-pregnancy-related conditions *Conditions excluded include: normal labour,*	***All except:*** **Complications of pregnancy, childbirth, and the puerperium** 632–677	***All except:*** **Complications of pregnancy, childbirth, and the puerperium** 630–679	***All except:*** **Complications of pregnancy, childbirth, and the puerperium** O00–O99

obstructed pregnancy, pregnancy with abortive outcomes and caesarian delivery. *All other conditions are included, such as asthma, diabetes, cardiovascular disease and well visits to primary care.*	**Certain conditions originating in the perinatal period** 762–779	**Certain conditions originating in the perinatal period** 760–779 **Persons encountering health services in circumstances related to reproduction** V20–V29	**Certain conditions originating in the perinatal period** P00–P96 **Persons encountering health services in circumstances related to reproduction** Z30–Z39

Note: Asthma and asthma-related conditions are mutually exclusive. Non-pregnancy-related conditions include asthma and asthma-related conditions.

OHIP=Ontario Health Insurance Plan

ICD=International Classification of Disease

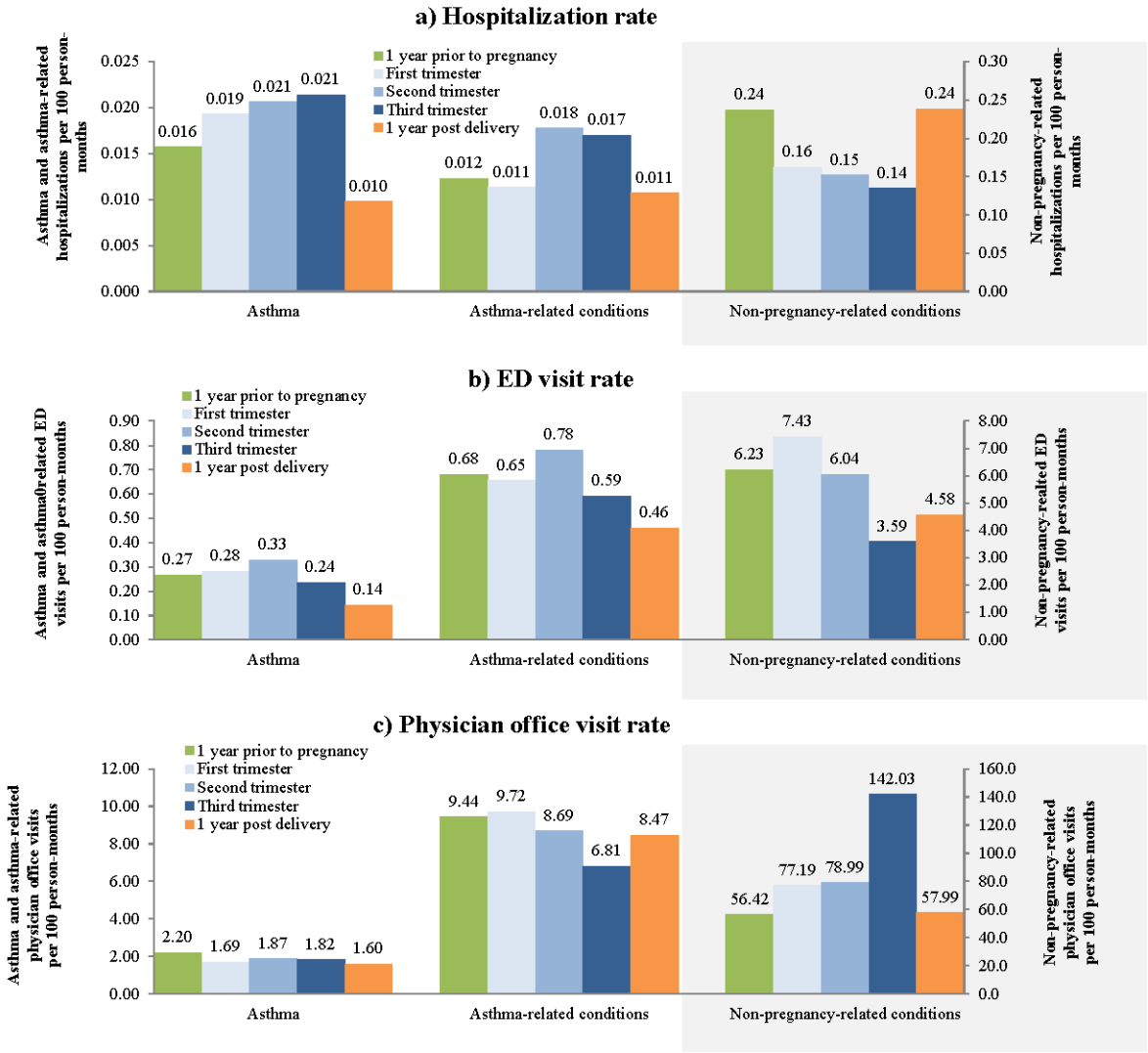
COPD=Chronic Obstructive Pulmonary Disease

Appendix eTable 3. International classification of disease (ICD-9 and ICD-10) codes of chronic diseases comorbidities

Conditions	ICD-9	ICD-10	Algorithm
Diabetes	250	E10, E11, E13, E14	≥2 OHIP claims with diagnostic code 250 or ≥1 OHIP claim with fee code Q040, K029 or K030 or ≥1 CIHI admission within 2 years.
Cardiovascular disease:			
Acute myocardial infarction	410	I21	Patients with a most responsible diagnosis of listed ICD codes in the CIHI-DAD, CIHI-SDS database
Angina	413	I20	Patients with a most responsible diagnosis of listed ICD codes in the CIHI-DAD, CIHI-SDS database, NACRS and OHIP claims.
Hypertension	401, 402, 403, 404, 405	I10, I11, I12, I13, I15	Patients with ≥1 hospital admission with a hypertension diagnosis, or ≥1 OHIP claim with a hypertension diagnosis followed within two years by either ≥1 OHIP claim or ≥1 hospital admission with a hypertension diagnosis.
Ischemic heart disease	411, 414	I24, I251, I258, I259	Patients with a most responsible diagnosis of any of listed ICD codes in the CIHI-DAD, CIHI-SDS database, NACRS and OHIP claims.
Stroke	433, 434, 435, 436	G45, G46, I63, I64	Patients with a most responsible diagnosis of any of listed stroke ICD codes in the CIHI-DAD, CIHI-SDS database, NACRS and OHIP claims.
Cancer	140-239	C00-D29	Patients in the Ontario Cancer Registry (OCR) who had any of listed ICD codes indicated as primary cancer. Note: The OCR is a computerized database of information on all adult Ontario residents who have been newly diagnosed with cancer ("incidence") or who have died of cancer ("mortality"). All new cases of cancer are registered, except non-melanoma skin cancer.
Chronic obstructive pulmonary disease (COPD)	491, 492, 496	J41, J42, J43, J44	*Ages 35 and above:* Individuals with ≥1 COPD diagnosis in OHIP or CIHI-SDS or CIHI-DAD databases.

CIHI-DAD=Discharge abstract data collected by the Canadian Institute for Health Information
CIHI-SDS=Same day surgery data collected by the Canadian Institute for Health Information
NACRS=National Ambulatory Care Reporting System
OHIP=Ontario Health Insurance Plan
ICD=International Classification of Disease

Appendix eFigure 1. Rates per 100 person-months of follow-up for a) hospitalizations, b) ED visits and c) physician office visits for asthma, asthma-related conditions and all non-pregnancy-related causes during the year prior to pregnancy, each of the three trimesters of pregnancy, and the first year post delivery.



Trimesters of pregnancy are defined as follows: weeks one through 13 for the first trimester, weeks 14 through 26 for the second trimester and week 27 and above for the third trimester.