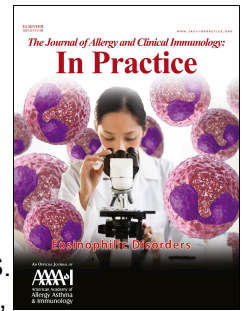


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Specialist Care in Individuals with Asthma Who Required Hospitalization: A Retrospective Population-Based Study

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Author's contributions

All co-authors were involved in the following: study conception and design, interpretation of the data, critically revising the manuscript for the accuracy and important intellectual content, and final approval of the version to be published.

Tetyana Kendzerska and Mohsen Sadatsafavi were additionally involved in the literature search, obtaining administrative data, analyses of data, and drafting of the manuscript.

Hamid Tavakoli and Elizabeth Kunkel were additionally involved in data analyses and drafting the method section.

Moussa Meteb was additionally involved in the literature search and drafting of the manuscript.

Guarantor Statement

Together, Tetyana Kendzerska and Mohsen Sadatsafavi had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. They affirm that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained. All authors had full access to statistical reports and tables.

Other contributions

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 author and not necessarily those of CIHI.

Data Availability & Sharing Statement

78 In Ontario, the dataset from this study is held securely in coded form at ICES. While data sharing
79 agreements prohibit ICES from making the dataset publicly available, access may be granted to
80 those who meet pre-specified criteria for confidential access, available at www.ices.on.ca/DAS.
81 The full dataset creation plan and underlying analytic code are available from the authors upon
82 request, understanding that the computer programs may rely upon coding templates or macros
83 that are unique to ICES and are therefore either inaccessible or may require modification.

Abstract: [289]

Background: Patients who are at risk of severe asthma exacerbations should receive specialist care. However, the care pattern for such patients in the ‘real world’ is not clear.

Objectives: To describe the pattern of care among individuals with asthma who required hospitalization, and to identify factors associated with receiving asthma specialist care.

Methods: This was a retrospective population-based study using health administrative data from two Canadian provinces. Individuals aged 14 to 45 years who were newly diagnosed with asthma between 2006-2016 and had at least one hospitalization for asthma at or within five years following their initial asthma diagnosis were included. First, we calculated frequencies of primary and specialist care around asthma diagnosis: one year before and two years after in a 6-month period. Next, among individuals diagnosed with asthma by a primary care physician, we used multivariable Cox regressions to identify factors associated with receiving specialist care.

Results: For 1,862 individuals included, we found that most individuals ($\geq 71\%$ per time period) were cared for by their primary care physicians one year prior and two years after the asthma diagnosis; the percentage of individuals seen at least once by a specialist for asthma and/or asthma-related respiratory conditions during the first six months since the diagnosis did not exceed 40%. Among 1,411/1,862 (76%) individuals who were under primary care before the asthma diagnosis, controlling for covariates, living in a rural area or a low-income neighbourhood were associated with less likelihood of receiving specialist care.

Conclusions: Despite recommendations, more than half of individuals with asthma who required hospitalization did not receive specialist care during the first two years since the diagnosis. Identified factors associated with receiving asthma specialist care suggested access is an important barrier to receiving the recommended care.

- 1. What is already known about this topic? Individuals who are at risk of severe asthma exacerbations should receive specialist care; however, the care pattern for such patients in the ‘real world’ is not clear.
- 2. What does this article add to our knowledge? We described the pattern of care among individuals with asthma who required hospitalization and identified factors associated with receiving asthma specialist care.
- 3. How does this study impact current management guidelines? Living in a rural area or a low-income neighbourhood were the strongest factors associated with a reduced likelihood of receiving specialist care suggesting access to care as an important barrier to receiving the recommended care.

Highlights Box

Keywords

Asthma, inpatient exacerbations, health care pattern, primary care, specialist care

112 **Abbreviations**

British Columbia	BC
Charlson Comorbidity Index	CCI
Chronic obstructive pulmonary disease	COPD
Confidence interval	CI
Emergency department	ED
Gastroesophageal reflux disease	GERD
Hazards ratio	HR
Formerly known as the Institute for Clinical Evaluative Sciences	ICES
Ontario	ON
Primary care practitioners	PCPs
Socioeconomic status	SES
Standard deviation	SD

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INTRODUCTION

Asthma, one of the most common chronic diseases, affects more than 300 million people worldwide (1). Globally, asthma imposes a significant strain on health-care resources and individuals' quality of life (2) and causes almost 250,000 people to die prematurely each year (3).

Acute intensification of asthma symptoms, known as flare-ups, asthma attacks, or exacerbations, is a hallmark of asthma. Severe exacerbations that require inpatient care are in particular watershed moments associated with significant morbidity and can be fatal (4-7). It is known that following contemporary asthma management recommendations should result in a reduced risk of exacerbations (8). Indeed, asthma is considered an “ambulatory care-sensitive condition,” indicating that with proper outpatient care, the risk of such severe exacerbations should greatly be reduced (9). As such, severe asthma exacerbations generally represent a preventable gap in care.

Specialists play an important role in the asthma care continuum. Usually, primary health-care providers initiate management of asthma, with certain cases referred for specialist management (10). Global Initiative for Asthma recommends considering a referral to a specialist if the patient needs frequent or urgent care, such as after a severe exacerbation that requires hospitalization or in case of repeated emergency department [ED] visits (10, 11). Some studies suggest that specialist care improves asthma patients' quality of life and satisfaction (12, 13), and reduced hospitalizations (10, 12) or ED visits (14, 15). On the other hand, for individuals with asthma, local, high-quality, and accessible primary care could be a solution to poor control (16, 17). Despite potential benefits of specialist care, gaps in the continuum of care and asthma management still exist (10, 18). For example, in the United Kingdom, 20% of asthma deaths

were attributable to the lack of referrals to specialists (19). In Ontario (Canada), acute asthma cases in the EDs had exceptionally low referral rates to specialists, with less than 3% of asthma patients being referred (20).

More research is needed to understand the continuum of care for individuals with uncontrolled asthma and its effect on adverse health outcomes and resource use. The *primary aim* of this study was to describe the pattern of care by specialty in the ‘real world’ setting before and after asthma diagnosis among individuals with asthma who, at some point during their course of asthma, experienced a severe exacerbation that required inpatient care. We further identified factors associated with receiving specialist care. Finally, as an exploratory objective, we described hospitalization and spirometry rates and health care costs associated with primary care only versus combined primary and specialist care.

METHODS

Study design

We conducted a retrospective population-based study using provincial health administrative data from 2006 to 2018 from two Canadian provinces, Ontario (ON) and British Columbia (BC). In 2020, ON's and BC's populations were 14.7 and 5.1 million, respectively (Statistics Canada, 2020).

The use of data in this project was authorized under section 45 of Ontario's Personal Health Information Protection Act, which does not require review by a Research Ethics Board. The University of British Columbia's Human Ethics Board approved the present study (H17-00938). All inferences, opinions, and conclusions drawn in this research are those of the authors and do not reflect the opinions or policies of the Data Steward(s).

Data Sources

Because both provinces have a publicly funded health care system, data for all legal residents are collected in centralized health administrative databases that contain individual-level information, including registration status and demographic characteristics, vital statistics, hospitalizations, outpatient physician services as well as information on characteristics of physicians and surgeons licenced to practice (21-25). Complete information on ED visits not requiring hospitalizations was not available in BC; thus, ED visits were not considered in the study. All databases were linkable at the individual level and have shown excellent reliability with a very low rate of missing or incorrect data (21, 26). A detailed description of databases used is available at: www.datadictionary.ices.on.ca/Applications/DataDictionary/ (ON) and <http://www.popdata.bc.ca/data> (BC). In ON, all databases were linked using unique encoded identifiers, held and analyzed at ICES (formerly known as the Institute for Clinical Evaluative Sciences). Details by province are provided in the **Data Supplement**.

Study population

Using the databases described above, we created a cohort of individuals aged 14 – 45 years who were newly diagnosed with asthma between 2006 and 2016, who upon diagnosis, or at some point after their diagnosis, required hospital admission for asthma (27) (**Figure 1**). First, to identify individuals with newly diagnosed asthma, we used a previously validated case definition consisting of one asthma hospitalization or two or more asthma-related ambulatory care visits within two years (28). To ensure the construction of an incidence cohort, we only included individuals who had no outpatient or inpatient asthma-related visits in the five years prior to the first asthma-related encounter. We further restricted our cohort to individuals hospitalized for asthma as the most responsible diagnosis on the day of or within five years of the initial date of

diagnosis. Individuals who did not have at least two years of follow-up after their first instance of asthma-related hospitalization were removed. This criterion was imposed to ensure sufficient follow-up time after the hospitalization to capture transition in care that might ensue after such an event. We limited our cohort to those diagnosed at age 45 or younger to prevent misclassification of chronic obstructive pulmonary disease (COPD) diagnoses as asthma. An entry date of 2006 was chosen to capture recent practice standards and because respirology as a separate specialty was identified in BC only since 2006.

For each patient, an ***index date*** was defined as the date of the initial diagnosis of asthma (i.e., the date of the first asthma-related encounter), marking the beginning of follow-up.

Cohort creation and time frames for different research aims are described in **Figure 1**.

Patterns of primary and specialist care (primary aim) around asthma diagnosis

In the Canadian medical system, *primary care practitioners* (PCPs) include family physicians and general practitioners, whereas all other physicians, including internists, are considered specialists who provide care upon referral. Utilizing physician characteristics from health administrative databases, we quantified, separately, the proportion of patients who had at least one encounter with (i) PCPs; (ii) relevant specialists (allergists/ immunologists, respirologists, pediatricians, and internal medicine specialists - combined and separately by specialty); and (iii) other specialist care physicians (not-asthma related). We studied these encounters from one year prior to two years after the index date, in 6-month periods. A 6-month period since the index date was chosen as the recommended time frame for regular asthma monitoring visits (29). All individuals in the population of interest had at least two years of follow-up. Given that a greater number of asthma-related primary care visits may have potential benefits on asthma-

exacerbations required inpatient visits (30), we also looked separately at a proportion of individuals with at least two primary care visits within six months.

Reasons to visit a physician were categorized as: (i) for asthma; (ii) for asthma or asthma-related respiratory conditions (see **Table 1** for definitions); and (iii) any cause.

Factors associated with receiving asthma specialist care (secondary aim)

This analysis was restricted to individuals initially diagnosed with asthma by a primary care physician and who were under primary care (for other than asthma respiratory conditions) before the asthma diagnosis. For this analysis, we retrospectively followed patients from their index date until March 31, 2018, death, or the last date of registration with the provincial health-care insurance plan, whichever was the earliest. The outcome for this aim was time from the date of the asthma diagnosis to a specialist visit. We considered several factors potentially associated with the outcome of interest. Sociodemographic factors (age, sex, socioeconomic status [SES], and rural/urban residence) were measured in the index year. Based on neighborhood (based on postal code in the year of diagnosis) income quintiles, SES was categorized into three levels: low (lowest two quintiles), middle (the third quintile), and high (the highest two quintiles) (31). This variable has been shown to correlate well with an individual- and household-level SES and has been previously used to investigate SES-related disparities in asthma outcomes (32, 33). To capture comorbidities in the 12 months prior to the index date, we calculated the Charlson Comorbidity Index (CCI) (34, 35) and identified hospitalizations for pneumonia, influenza, or bronchitis, conditions that may increase the likelihood of seeing a specialist (36). The CCI was calculated after excluding asthma from the summary score (35) and was categorized further into two levels: none (CCI score = 0), any (CCI score ≥ 1) comorbidity. In the last five years prior to the index date, we identified individuals with depression or anxiety (37), chronic rhinosinusitis

(38), atopic conditions (39), gastroesophageal reflux disease (GERD) (40), asthma-related respiratory conditions excluding asthma (41) (**Table 1**), and whether the patient underwent spirometry. Definitions of variables of interest were synchronized between two provinces and presented in the **Data Supplement**.

Health care outcomes following initial asthma diagnosis (exploratory aim)

For this analysis, similarly to the secondary aim, we retrospectively followed individuals from their index date until March 31, 2018, death, or the last date of registration with the provincial health-care insurance plan, whichever was the earliest. The following outcomes were considered of interest since the initial asthma diagnosis in individuals initially diagnosed with asthma by a primary care physician and who were under primary care for other than asthma respiratory conditions before the asthma diagnosis: (i) hospitalizations [and ED visits for ON only] for asthma or asthma-related conditions; (ii) all-cause hospitalizations [and ED visits for ON only]; (iii) spirometry, and (iv) costs.

We used cost-per-weighted-case costing methodology to identify inpatient and outpatient health care costs; inpatient costs included acute care hospitalizations, and outpatient costs included ED visits and outpatient physician visits (42). To synchronize the cost calculations between provinces given data availability, ED visits were excluded from the ON cost, and medications were excluded from the outpatient cost in BC. All costs were expressed in 2015 Canadian dollars; we inflated past costs using the healthcare-specific yearly consumer index reported by Statistics Canada.

Analysis

Descriptive statistics were used to characterize the study populations by specialty of care patients received prior to and after the initial asthma diagnosis. Descriptive statistics between the two

provinces were pooled by weighted-averaging province-specific figures, with weights being the cohort size within each province.

For our **primary research aim**, we described the percentage of individuals seen by primary and specialist care physicians one year prior and two years after the index date (per 6-month periods), separately by province.

For the **secondary aim**, we used multivariable Cox regression analysis to model the time from index date to the first asthma-related specialist visit. We included in our statistical model covariates described above: sociodemographic factors at the index date, CCI, hospitalizations for pneumonia, influenza, or bronchitis in the 12 months prior to the index date, and separate comorbidities and spirometry in the last five years prior to the index date. Hospitalization [ED visits in ON only] for asthma or asthma-related condition, all-cause hospitalizations, spirometry, and inpatient and outpatient health care costs entered the analysis as time-dependent covariates. The follow-up time was split into 6-month periods, and time-dependent covariates were derived for each period. We used a lagged definition of time-dependent covariates, such that variables were defined in the period immediately preceding the outcome-assessment period. Adjusted hazard ratios (HRs) and 95% confidence intervals (CIs) were pooled between the two provinces utilizing fixed-effect meta-analysis.

Finally, for the exploratory aim, we used descriptive statistics to understand the pattern of receiving spirometry, hospitalizations for asthma or other asthma-related respiratory conditions, or all-cause (rates) and cost by a specialist exposure since the index date by the end of the follow-up in 6-month periods.

All statistical analyses were performed using SAS Enterprise Guide 7.15 (SAS Institute Inc., Cary, NC).

RESULTS

Cohorts characteristics

The characteristics of individuals included in our study are shown in **Table 1**. The total number of individuals who met our inclusion criteria was 1,862 (1,350 from ON and 512 from BC) (**Figure 1**) with a mean age of 31 years. 64% were female; 14% were located in a rural area and 53% in an area with low SES. The most prevalent comorbid conditions in the previous five years were depression (31%), acute infection of tonsils and adenoids (11%), and GERD (12%). Characteristics by province are presented in the Data Supplement (**Table E1**).

Primary and specialist care pattern over time (primary aim)

For 1,862 individuals included in this analysis, the frequencies of primary and specialist care in both provinces one year prior and two years after the initial asthma diagnosis are presented in **Figure 2**. The percentage of patients and the number of visits by specialty are presented in the Data Supplement (**Tables E2-3**). Similar patterns were noted in both provinces over time. Specifically, in both provinces, most individuals ($\geq 71\%$ per time period) were cared for by their PCPs. More than 64% of those individuals were seen by PCPs twice or more every six months (**Figure 2; Tables E2-3**). In both provinces, the percentage of individuals seen at least once by a specialist for asthma and/or asthma-related respiratory conditions during the first six months since the index date did not exceed 40%; among different specialties, up to 30% of patients were seen by an internal medicine specialist, up to 23% by a respirologist, and up to 9% by a pediatrician or allergist/immunologist (**Tables E2-3**).

Factors associated with specialist care after the initial asthma diagnosis (secondary aim)

Prior to the initial asthma diagnosis (**index date**), 1,411/1,862 (76%) of individuals were seen only by PCPs (**Table 1**). The average follow-up period among such individuals was 86 months (SD: 34). Among those individuals, 553/1,411 (39%) were solely cared for by their PCP from the time of diagnosis through follow-up. The remainder (61%) were cared for by both PCPs and specialists. The median time from the asthma diagnosis to a specialist visit, the last date of registration with the provincial health-care insurance plan, death or the end of the follow-up period, whichever occurred first, ranged between 755 days (IQR: 59-2,673) and 776 days (4-2,055) across provinces. Descriptive characteristics of the cohort of interest by specialty are presented in **Table 1** (combined) and **Table E4** (by province).

After adjusting for covariates (**Table 2**), individuals who lived in a rural vs. urban area at the index date (HR of 0.58; 95% CI: 0.46-0.72) and those who lived in a low-income neighbourhood (HR of 0.86; 95% CI: 0.73-1.00) were less likely to receive specialist care.

Prior asthma-related respiratory conditions such as nasopharyngitis, rhinitis, acute upper respiratory tract infection, etc. (see details in Table 1), hospitalizations since the initial asthma diagnosis and receiving a spirometry test before or after initial asthma diagnosis were associated with a higher likelihood of being seen at least once by a specialist (**Table 2**). The estimates from the Cox regression models by province are presented in the **Data Supplement (Table E5)**.

Hospitalization, ED, spirometry rates, and costs associated with the type of care (exploratory aim)

All-cause and asthma-related hospitalizations and ED [for ON only] rates, spirometry rates, and costs since the index date and by the end of the follow-up are presented in **Figure 3 and the Data Supplement (Figures E1-2, Tables E6-8)**. Patterns of asthma or asthma-related hospitalizations were similar between provinces and regardless of being seen by a specialist with

a spike around the index date (reflecting the cohort definition), a steep decline within the next six months, and then a slow decline by the end of the follow-up (**Figure 3A**). Similar patterns were also noted for all-cause hospitalizations rates in both provinces (**Figure 3B**) and all-cause and asthma or asthma-related ED visits in ON (**Figure E1, Table E6**). Higher spirometry rates were noted among individuals seen by a specialist at least once compared to those who remained under the care of primary care physicians over time. The mean total cost patterns in follow-up were also similar between provinces with a higher cost, between \$4,000 and \$6,000 per 6-months among those seen by a specialist at least once within the first six months (**Figure E2, Table E8**).

DISCUSSION

In this large descriptive longitudinal population-based study, we showed that despite guidelines recommendations, among individuals aged between 14 and 45 years with newly diagnosed asthma who experienced asthma exacerbation requiring hospital admission, most individuals ($\geq 71\%$ per time period) were cared for by their primary care physicians one year prior and two years after the asthma diagnosis; the percentage of individuals seen at least once by a specialist for asthma and/or asthma-related respiratory conditions during the first six months since the diagnosis did not exceed 40%. Moreover, almost 40% did not receive specialist care for an average of about seven years since their initial asthma diagnosis. Further analyses showed that those who lived in a rural area or a low-income neighbourhood were less likely seen by a specialist for asthma and or asthma-related conditions controlling for potential confounders. Health professionals and policymakers can use this practical knowledge to optimize management and health outcomes.

It has been shown that regular clinical visits with PCPs may reduce the risk of asthma exacerbation requiring inpatient care, suggesting that accessible primary care could be a solution to poor asthma control (17). Primary care physicians are also better placed to coordinate the management of the range of comorbidities, especially chronic, contributing to severe asthma(43). Additionally, access to a community-based dietitian and clinical psychologist/mental health treatment plan is often more convenient for patients when provided nearer to home. Importantly, in our study, more than 70% of individuals with asthma that required hospitalizations remained under PCPs care during the first two years since the asthma diagnosis, with more than 60% of individuals seeing PCPs at least twice every six months. Despite a high rate of individuals being seen by PCPs in our study, less than 50% of individuals were seen by PCPs for asthma-related reasons at the end of the second year, which may affect the asthma care continuum as lower adherence was also reported in individuals with asthma who had received a prescription for asthma medication when visiting a physician for reasons other than asthma (44).

Several studies suggested that an asthma specialist follow-up may help prevent subsequent asthma hospitalizations more likely than a PCP follow-up (45). Although in our study, about 60% were cared for by both primary care physicians and specialists since the asthma diagnosis over an average of about seven years, the percentage of individuals seen at least once by a specialist for asthma-related reasons during the first six months since the index date did not exceed 40% and dropped to the lowest at 11% at the end of the second year. A steeper decline in a proportion of individuals seen by a specialist than a PCP may be explained by the fact that these patients saw a specialist in case of an emergency context, without a follow-up, confirming the need for better guidance for PCPs to assist in managing severe or uncontrolled asthma and

clear advice about when patients should be referred for a specialist review and importantly care coordination between primary care physicians and specialists (46).

Our findings are consistent with previous studies showing limited implementation of specialist referrals in clinical practice (10, 20, 46). For example, in a French survey of more than 1,000 individuals recruited through pharmacies found, similar to our study, more than 50% of individuals were cared for asthma by both primary and specialist care, and about 40% were under the care of primary care physicians only (47). Common listed barriers to a timely specialist review include an unclear reason for referral, travel distance/access to care, patient factors, and long waiting lists (43). Disparities in health care for rural individuals with asthma have been reported; limited access to care was explained by an increased travel distance and lack of providers, particularly specialists in a rural area; this may also explain a higher rate of asthma-related hospitalizations and mortality shown for rural residence compared to urban (48). Further, disparities in specialist care have been shown in individuals with lower family SES and education (49). This amplifies further because individuals with lower SES are more likely to suffer from asthma (50); in those with asthma, lower SES was associated with worse asthma control (51) and a higher risk for asthma-related emergency health service use (52). Finally, similarly to others, our study suggested that individuals with more asthma-related comorbidities, such as rhinosinusitis, are more likely to be seen by a specialist (36).

In the descriptive analysis, we have noticed comparable hospitalizations or ED visit rates for asthma and or asthma-related respiratory conditions by speciality with increased utilization of spirometry in individuals seen at least once by a specialist. However, our study was not designed for proper comparison. Further, individuals with more severe and poorly controlled asthma are usually more likely to have been referred to specialists (36) masking the ‘benefit’ of specialist

care in terms of subsequent hospitalizations or ED visits. Next, specialty training among specialists may also explain the difference in asthma-related outcomes (12, 53, 54). For example, while fewer hospitalizations were seen in individuals under the care of allergists, patients of respirologists were more likely to be hospitalized or have ED visits (12, 53), which was explained by a higher baseline asthma severity in individuals seen by a respirologist. We did not study the outcomes within specialty groups, but respirologists and internal medicine physicians were the specialists who saw most of the patients in our study. Finally, we restricted our population of interest to individuals with asthma who were hospitalized at some point, so if specialist care has resulted in better outcomes (e.g., not being hospitalized), we could not capture this. Future studies are needed to examine the outcome difference among primary care and specialist physicians on a population level in a real-world setting and identify the patient-related factors that might contribute to the outcomes' differences using guideline-defined tools (36). Notably, an interdisciplinary team approach involving individuals with asthma and their families, asthma educators, pharmacists, PCPs, and specialists, among others, is likely to have the greatest impact on asthma outcomes (55).

The strengths of our study are its real-world relevance, near-complete follow-up, and generalizability as we studied the entire population of two geographically well-defined jurisdictions.

Our study has several limitations. Misclassification bias and unmeasured confounding (e.g., lack of information on asthma severity) are common limitations of studies utilizing health administrative data. It may be aggravated by differences in practice and diagnostic coding between provinces. However, our cohorts of interest derived from two provinces had similar characterizes for most parameters; findings were also in similar patterns and consistent with

previous studies (10, 20, 46, 47), suggesting the robustness of our results. Finally, we were not able to identify allied health professionals involved in asthma care from health administrative data.

Conclusion

Despite recommendations, more than half of individuals with asthma who experienced at least one exacerbation required hospitalization did not receive specialist care during the first two years since the diagnosis and more than one-third over an average of about seven years since their initial asthma diagnosis. Living in a rural area and socioeconomic status were the strongest factors associated with a reduced likelihood of receiving specialist care, suggesting access is an important barrier to receiving the recommended care. Our findings support the necessity to improve uncontrolled asthma management and care coordination between primary care physicians and specialists.

Table 1. Characteristics of all individuals aged 14-45 years who were newly diagnosed with asthma between 2006 and 2016 and had at least one hospital admission for asthma within five years of their initial asthma diagnosis (*index date*) in two Canadian provinces (British Columbia and Ontario) combined#.

Cohort Characteristics		Total population of interest (<i>primary aim</i>)	Diagnosed with asthma by a primary care physician and under primary care for other respiratory conditions* before the asthma diagnosis (<i>secondary and exploratory aims</i>)		
			All	Seen by a specialist* at least once since the index date	Not seen by a specialist* since the index date
		N=1,862	N=1,411	N=858	N=553
Demographics					
Age, years, mean (SD)		31.1 (9.2)	31.5 (9.0)	31.8 (9.0)	31.0 (9.1)
Female, n (%)		1,196 (64.2)	892 (63.2)	537 (62.6)	355 (64.2)
Socioeconomic status, n (%) N missing = 5	Low (lowest 2 quintiles)	987 (53.2)	759 (53.9)	449 (52.5)	310 (56.3)
	Middle (the third quintile)	337 (18.1)	253 (18.0)	159 (18.6)	94 (17.1)
	High (the highest 2 quintiles)	533 (28.7)	395 (28.1)	248 (29.0)	147 (26.7)
Lived in rural (vs urban) area at the index year, n		255 (13.7)	213 (15.1)	96 (11.2)	117 (21.2)

(%)					
In the 12 months preceding the index date					
The Charlson comorbidity index (CCI), ≥ 1 , n (%)		33 (1.8)	18 (1.3)	—	—
Spirometry, n (%)		168 (9.0)	103 (7.3)	70 (8.2)	33 (6.0)
Cost in one year prior the index date, in CA\$**	Inpatients, mean (SD)	1,142.7 (6,760.4)	873.0 (4,154.9)	778.7 (4,356.8)	1,019.2 (3,823.0)
	Outpatients [No pharma/ ED visits], mean (SD)	1,005.8 (1,675.2)	882.8 (1,446.9)	884.5 (1,516.0)	880.0 (1,335.2)
Separate comorbidities in the last five years preceding index date, n (%)					
Depression/anxiety		584 (31.4)	421 (29.8)	252 (29.4)	169 (30.6)
Atopic conditions		638 (34.3)	403 (28.6)	259 (30.2)	144 (26.0)
Infection of tonsils and adenoids, acute		207 (11.1)	133 (9.4)	90 (10.5)	43 (7.8)
Infection of tonsils and adenoids, chronic		28 (1.5)	16 (1.1)	11 (1.3)	5 (0.9)
GERD		221 (11.9)	170 (12.0)	105 (12.2)	65 (11.8)
Asthma-related conditions* excluding asthma		1,496 (80.3)	1,081 (76.6)	672 (78.3)	409 (74.0)
Spirometry		252 (13.5)	148 (10.5)	93 (10.8)	55 (9.9)
Time-dependent covariates, annual rates in follow-up*** [by the end of the study for the descriptive purpose]					

Hospitalizations for asthma and/or Asthma-related conditions, mean (SD)	0.3 (0.4)	0.2 (0.3)	0.5 (1.4)	0.3 (0.4)
All-cause hospitalizations, mean (SD)	0.5 (0.7)	0.5 (0.6)	0.5 (0.6)	0.4 (0.4)
Spirometry, mean (SD)	1.5 (2.4)	1.3 (2.1)	1.9 (2.5)	0.4 (0.5)
Mortality, n (%)	31 (1.7)	27 (1.9)	—	—
Time from the index date to the first hospitalization with asthma as the main diagnosis, months, mean (SD)	8.8 (14.2)	8.6 (14.3)	10.1 (15.2)	6.4 (12.4)
Follow-up time to the end of study (death, end of follow-up or loss of insurance), months, mean (SD)	85.9 (33.8)	87.0 (33.4)	86.2 (33.4)	88.3 (33.3)

*Reason for the visit as asthma and asthma-related respiratory conditions: asthma, acute nasopharyngitis, acute upper respiratory tract infection, acute bronchitis or bronchiolitis, chronic pharyngitis/nasopharyngitis, allergic rhinitis, viral pneumonia, pneumococcal pneumonia, other bacterial pneumonia, bronchopneumonia, influenza, bronchitis – other, chronic bronchitis, emphysema, bronchiectasis, chronic airway obstruction.

** All costs were expressed in 2016 Canadian dollars; we inflated past costs using health care-specific yearly consumer index reported by Statistics Canada

***The number of events per year calculated by dividing the number of events by the number of years they were followed up.

#Hospitalizations for pneumonia or flu or bronchitis were not reported due to the number of individuals less than five in each province. The Charlson comorbidity index and mortality were not reported by the specialty due to the number of individuals less than five per subgroup.

Gastroesophageal reflux disease (GERD); Interquartile range (IQR); Standard deviation (SD).

Table 2. The relationship between characteristics of interest and being seen at least once by a relevant specialist since the index date with asthma and/or asthma-related respiratory conditions as a reason for the visit among individuals diagnosed with asthma by a primary care physician and who were under primary care for other respiratory conditions before the asthma diagnosis (N=1,411). Results are reported from multivariable Cox regressions. Estimates presented as pooled* hazard ratios (HRs) and 95% confidence intervals (CI).

Predictors/Risk factors		Pooled Adjusted HR (95% CI)
Demographics		
Age, years, per 5-year increase		1.02 (0.98-1.06)
Sex: Female vs. Male		0.94 (0.82-1.08)
SES	Low (lowest 2 quintiles) vs. High (the highest 2 quintiles)	0.86 (0.73-1.00)
	Middle (the third quintile) vs. High (the highest 2 quintiles)	1.00 (0.81-1.22)
Lived in rural vs. urban area at the index year		0.58 (0.46-0.72)
In the 12 months preceding the index date		
The Charlson Comorbidity Index, score: ≥ 1 vs. 0		0.60 (0.27-1.35)
Hospitalizations for pneumonia/influenza: Yes vs. No		0.55 (0.21-1.48)
Hospitalizations for acute bronchitis or bronchitis not specified as acute or chronic: Yes vs. No		0.85 (0.21-3.42)
Spirometry: Yes vs. No		1.31 (1.03-1.68)
In the last 5 years preceding index date		
Depression/anxiety: Yes vs. No		0.95 (0.82-1.10)
Chronic rhinosinusitis: Yes vs. No		1.06 (0.50-2.24)

Atopic conditions: Yes vs. No	1.12 (0.96-1.31)
Infection of tonsils and adenoids (Acute): Yes vs. No	1.13 (0.91-1.42)
Infection of tonsils and adenoids (Chronic): Yes vs. No	1.53 (0.84-2.78)
GERD: Yes vs. No	1.01 (0.80-1.26)
Asthma-related respiratory conditions excluding asthma: Yes vs. No	1.18 (1.00-1.38)
Spirometry: Yes vs. No	1.15 (0.94-1.42)
Time-dependent covariate# (since the index date)	
Hospitalizations for asthma and asthma-related conditions, Yes vs. No	1.46 (1.05-2.04)
All-cause hospitalizations, Yes vs. No	1.05 (0.86-1.27)
Spirometry, Yes vs. No	2.00 (1.60-2.51)

SES, socioeconomic status

*The estimates of the effect from two provinces were pooled using a fixed-effect meta-analysis.

#6-month period

Figure Legends:

Figure 1. Cohort creation diagram

Figure 2. Percentage of individuals who made ambulatory visits for any-cause or asthma or asthma-related respiratory conditions one year prior and two years after the initial asthma diagnosis date calculated for 6-month periods: primary care physicians and specialists: (A) Ontario; (B) British Columbia. PCPs – primary care physicians

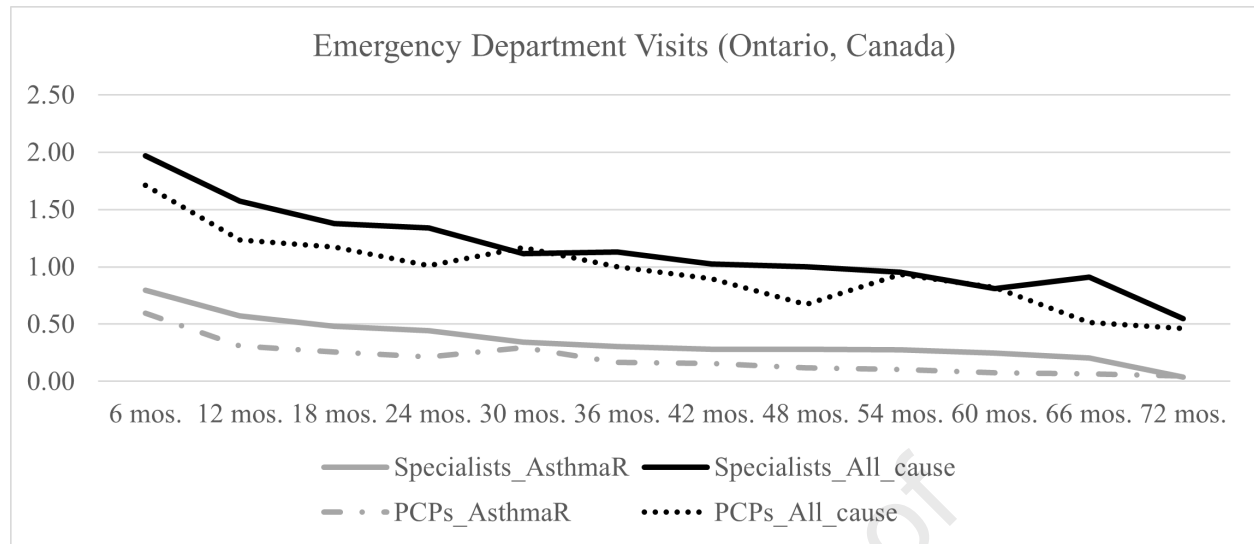
Figure 3. Hospitalization rates for asthma or asthma-related respiratory conditions (A), all-cause (B), and spirometry rates (C) since the asthma initial diagnosis: primary care physicians and specialists. Rates were calculated as the number of events/total number of people at risk in this period (6 months). Specialists: Individuals seen at least once by a specialist for asthma or asthma-related respiratory conditions in follow-up time; PCPs: Individuals who stayed with primary care physicians (PCPs) in the follow-up

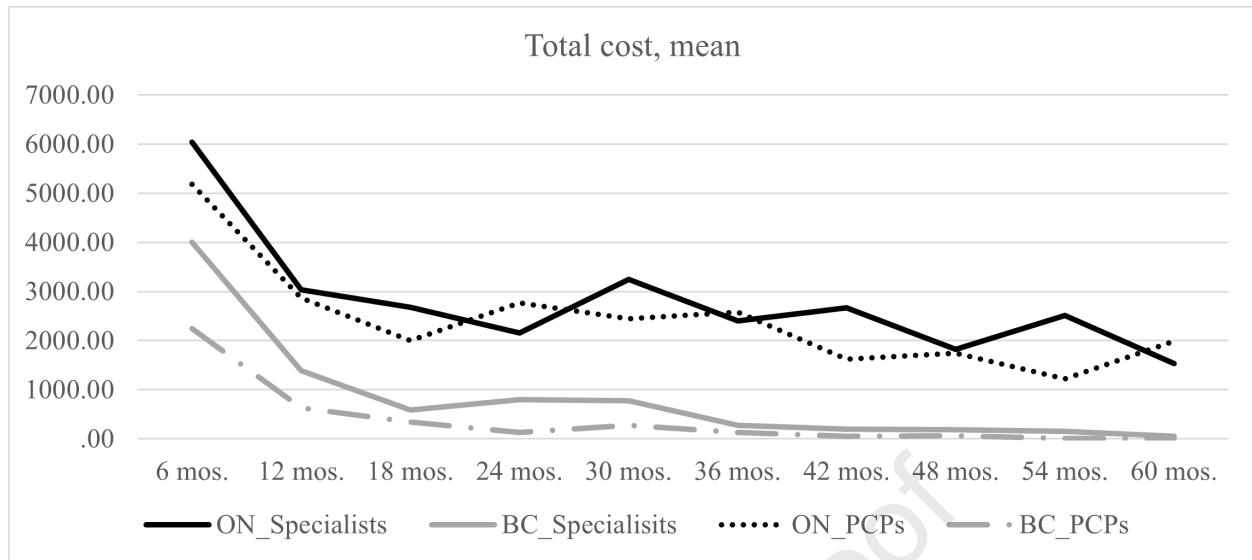
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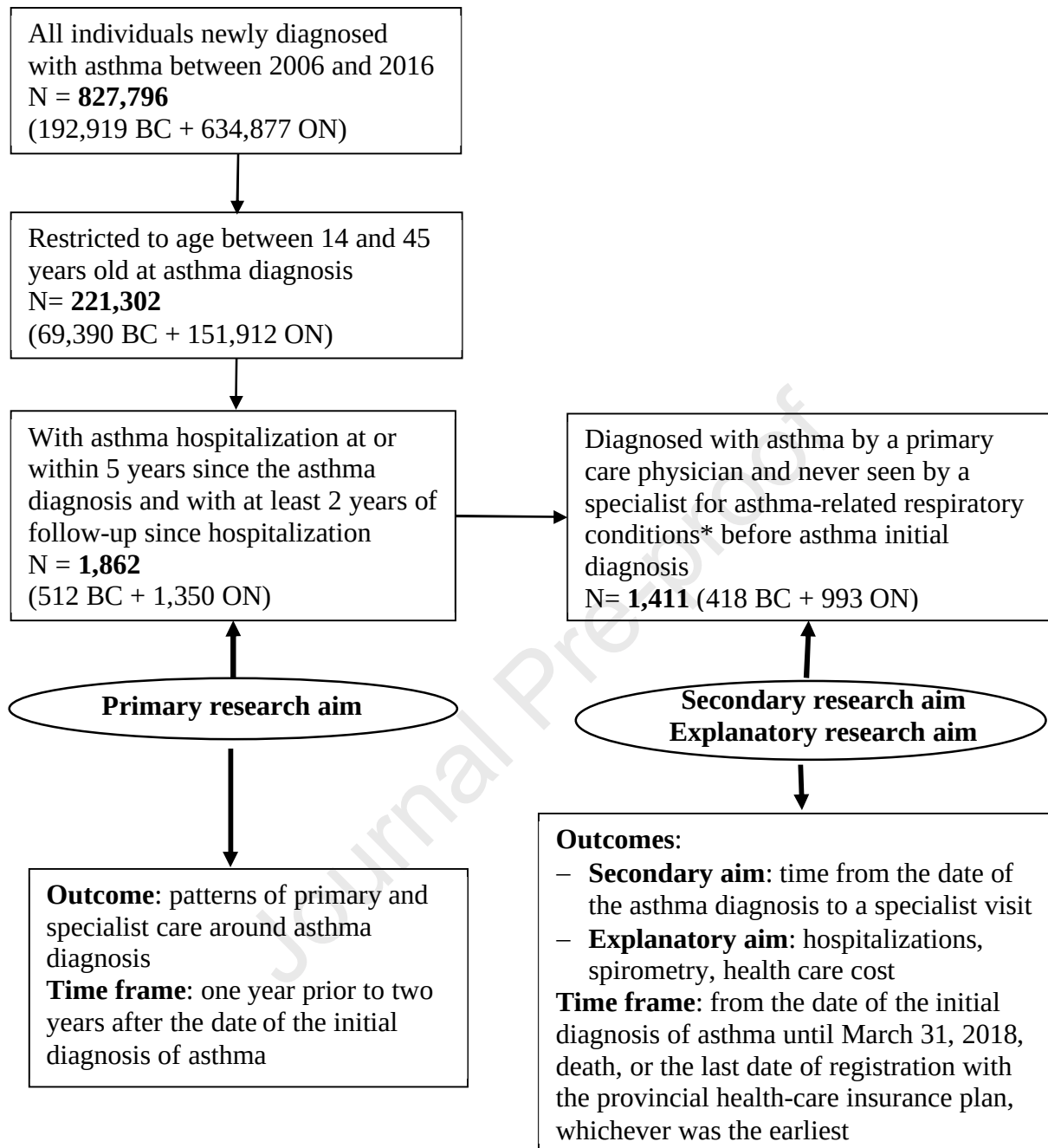
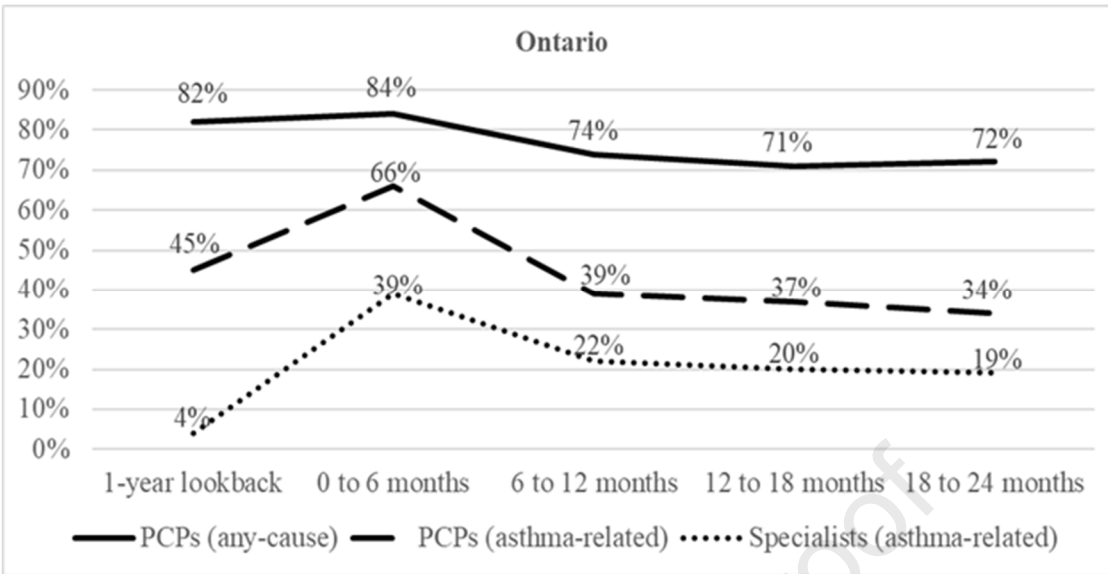


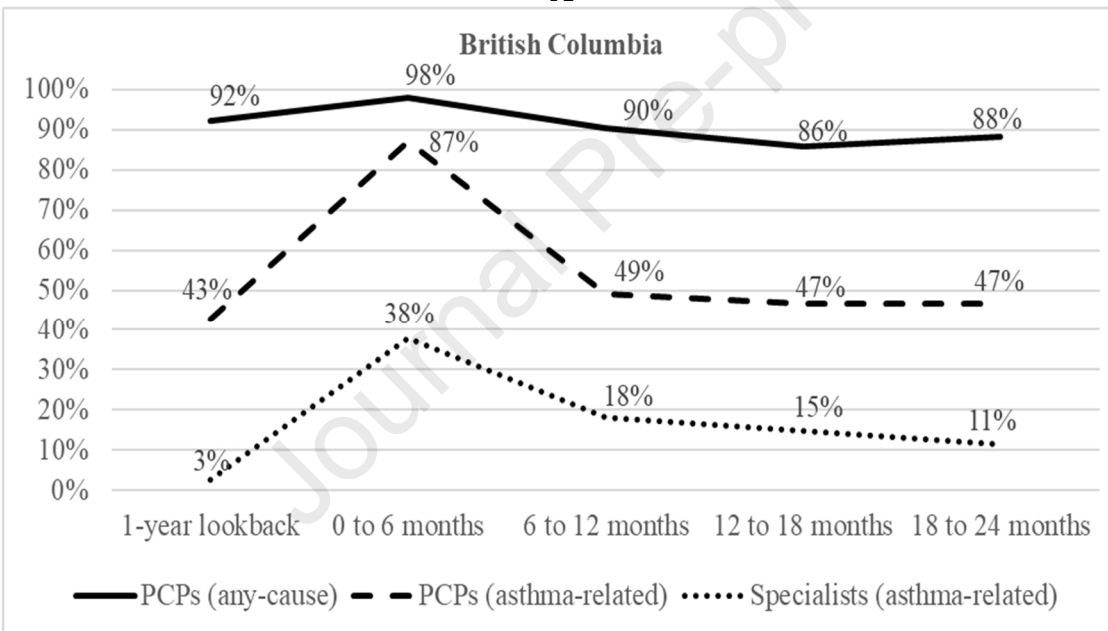
Figure 1. Cohort creation diagram

*Asthma and asthma-related reason for the visit: asthma, acute nasopharyngitis, acute upper respiratory tract infection, acute bronchitis or bronchiolitis, chronic pharyngitis/nasopharyngitis, allergic rhinitis, viral pneumonia, pneumococcal pneumonia, other bacterial pneumonia, bronchopneumonia, influenza, bronchitis – other, chronic bronchitis, emphysema, bronchiectasis, chronic airway obstruction

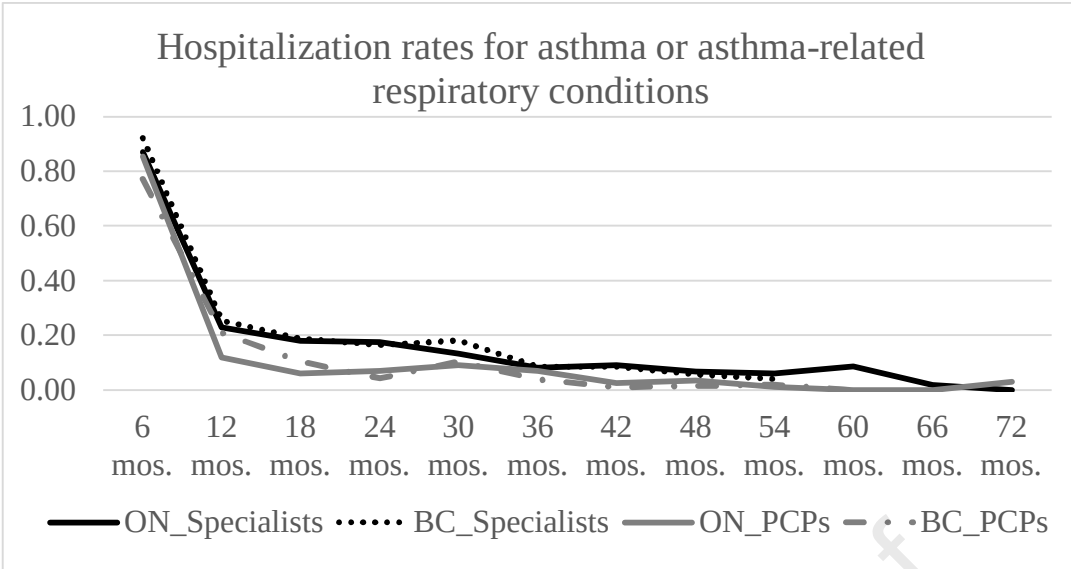
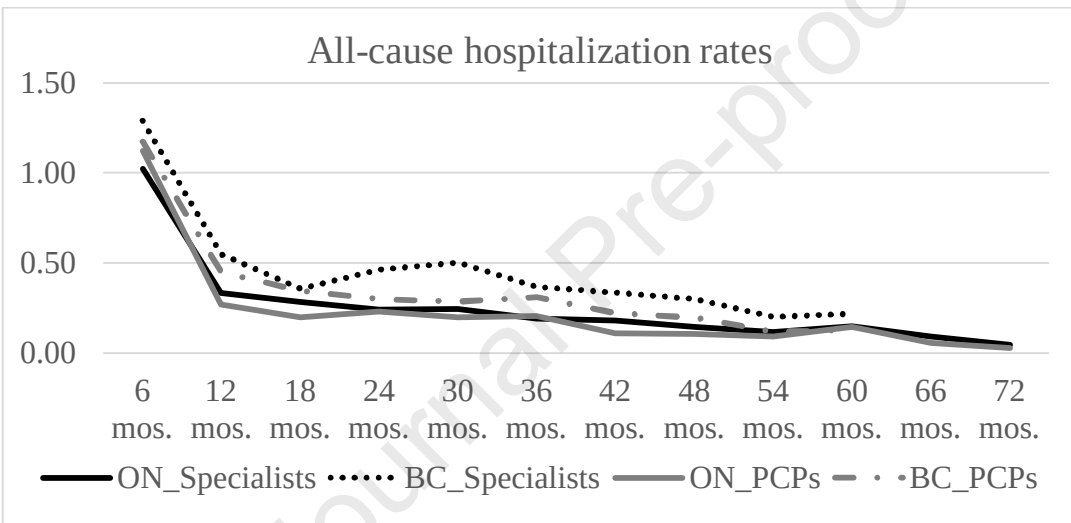
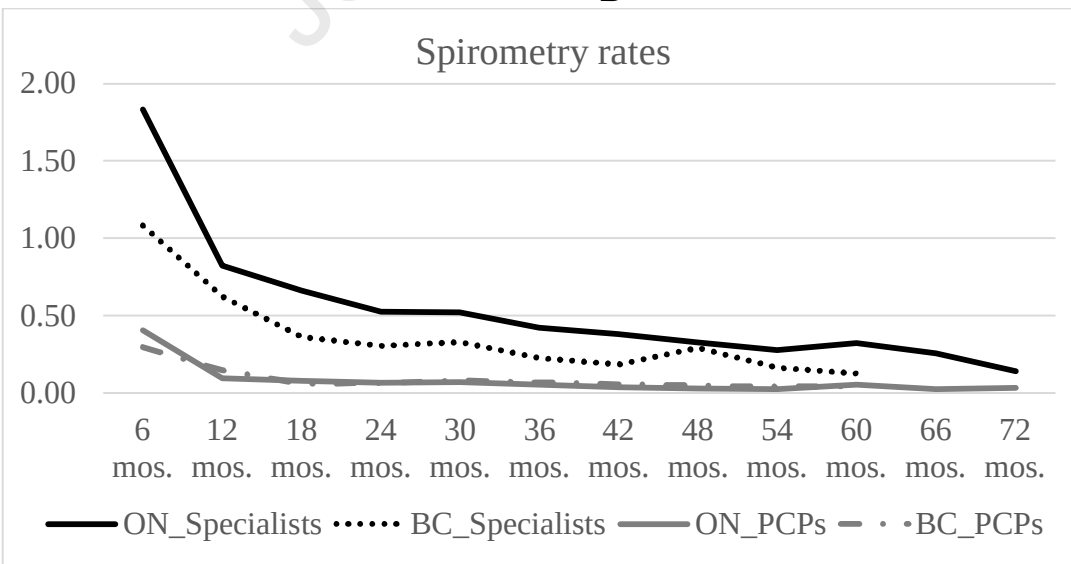
BC, British Columbia; ON, Ontario



A



B

**A****B****C**

Title: Specialist Care in Individuals with Asthma Who Required Hospitalization: A Retrospective Population-Based Study

Authors: Tetyana Kendzerska, Shawn D. Aaron, Moussa Meteb, Andrea S. Gershon, Teresa To, M. Diane Loughheed, Hamid Tavakoli, Wenjia Chen, Elizabeth Kunkel, Mohsen Sadatsafavi, for the Canadian Respiratory Research Network

Text E1. Description of data sources by province

Text E2. Details on variable definitions

Table E1. Characteristics of all individuals aged 14-45 years who were newly diagnosed with asthma between 2006 and 2016 and had at least one hospital admission for asthma within five years of their initial asthma diagnosis (index date) in two Canadian provinces (British Columbia and Ontario)

Table E2. Percentage and number of individuals who made ambulatory visits for any-cause or asthma or asthma-related respiratory conditions one year prior and two years after the initial asthma diagnosis date calculated for 6-month periods: primary care physicians and specialists (Ontario, Canada)

Table E3. Percentage and number of individuals who made ambulatory visits for any-cause or asthma or asthma-related respiratory conditions one year prior and two years after the initial asthma diagnosis date calculated for 6-month periods: primary care physicians and specialists (British Columbia, Canada)

Table E4. Characteristics by specialty of all individuals aged 14-45 years who were newly diagnosed with asthma between 2006 and 2016 and had at least one hospital admission for asthma within five years of their initial asthma diagnosis (index date) in two Canadian provinces (British Columbia and Ontario)

Table E5. The relationship between characteristics of interest and being seen at least once by a relevant specialist since the index date with asthma and/or asthma-related respiratory conditions as a reason for the visit among individuals diagnosed with asthma by a primary care physician and who were under primary care for other respiratory conditions before the asthma diagnosis.

Table E6. Hospitalization, emergency department and spirometry rates since the asthma initial diagnosis in Ontario (Canada): primary care physicians and specialists. Rates were calculated as the number of events/total number of people at risk in this period (6 months).

Table E7. Hospitalization, emergency department and spirometry rates since the asthma initial diagnosis in British Columbia (Canada): primary care physicians and specialists. Rates were calculated as the number of events/total number of people at risk in this period (6 months).

Table E8. Total cost (inpatient and outpatient) since the date of the initial asthma diagnosis.

Figure Legends

Figure E1. Emergency department (ED) visits rate in Ontario (Canada) for asthma or asthma-related respiratory conditions and all-cause the asthma initial diagnosis: primary care physicians and specialists. Rates were calculated as the number of events/total number of people at risk in this period (6 months). Specialists: Individuals seen at least once by a specialist for asthma or asthma-related respiratory conditions in follow-up time; PCPs: Individuals who stayed with primary care physicians (PCPs) in the follow-up

Figure E2. Total cost (inpatient and outpatient) since the date of the initial asthma diagnosis: primary care physicians and specialists. Specialists: Individuals seen at least once by a specialist for asthma or asthma-related respiratory conditions in follow-up time; PCPs: Individuals who stayed with primary care physicians (PCPs) in the follow-up.

References

Text E1. Description of data sources by province

(1) **Provincial health administrative databases of Ontario (ON).** Residents of ON have universal public health insurance covering all medically necessary services. ICES (formerly known as the Institute for Clinical Evaluative Sciences) houses high quality individual-level administrative databases on a wide variety of publicly funded services provided since 1991 (1). We used the following databases for this project: the Registered Persons Database, which includes demographic and death information; the Discharge Abstract Database, which includes diagnostic, procedural, and treatment information on hospital admissions; National Ambulatory Care Reporting System database, which contains diagnostic, procedural and treatment information on ED visits; the Ontario Health Insurance Plan database, which includes information on approved physician claims along with the diagnosis responsible for the claim, the service provided and the date of service; the ICES Physician Data Base, which contains information on characteristics of physicians and surgeons licenced to practice in Ontario. A detailed description of the ICES databases used is available at www.datadictionary.ices.on.ca/Applications/DataDictionary/. All databases were linked using unique encoded identifiers, held and analyzed at ICES.

(2) **Provincial health administrative databases of British Columbia (BC).** Similar to ON, because BC has a publicly funded health care system, data for all legal residents are collected in centralized health administrative databases that contain individual-level information, including registration status and demographic characteristics (2), vital statistics (3), hospitalizations (4), and outpatient physician services (5). In BC, we used the following databases for this project: the Discharge Abstract Database (please see description above); the Medical Services Plan, which contains information on all outpatient services dates, diagnoses, and costs (6); BC Vital Statistics, which contains information on death; demographic and census containing demographic information such as date of birth, sex, and socioeconomic status (income quintiles determined from the geographic neighbourhood). Complete information on ED visits not required hospitalizations was not available in BC; thus, not considered in the study. All data were linkable at the individual level and have shown excellent reliability with a very low rate of missing or incorrect data (7). A detailed description of the databases used is available at <http://www.popdata.bc.ca/data>.

Text E2. Details on variable definitions

Variables	Definitions
Incident asthma	A validated case definition of one or more asthma hospital discharges and/or two or more asthma ambulatory care visits within two years with no asthma claims within a minimum lookback window of five years to confirm incidence (8)
At the date of the initial asthma diagnosis (<i>index date</i>)	
Demographics: age, sex	from RPDB
Rural location	Defined using patient's postal code (9).
Neighbourhood Income Quintile	Ontario neighbourhoods are classified into one of the five approximately equal-sized income quintiles, ranked from poorest (Q1) to wealthiest (Q5) and these have been shown to be related to population health status and health care utilization (10). Each patient was assigned to the income quintile based on the patient's postal code at the time of baseline and Statistics Canada's Postal Code Conversion File (11, 12).
In the 12 months preceding the index date	
The Charlson comorbidity index	Charlson comorbidity index (13) was calculated excluding asthma from the score and categorized into 4 levels: none (CCI score = 0), low (score = 1), moderate (score = 2), and high (score ≥ 3)
Hospitalizations for pneumonia and influenza	from CIHI DAD Codes: ICD-10: J10 – J18; ICD-9: 480 – 487
Hospitalizations for acute bronchitis or bronchitis not specified as acute or chronic	from CIHI DAD Codes: ICD-10: J20, J22, J40; ICD-9: 466
Spirometry	from OHIP (ON): J301, J304, J307, J310, J324, J327
Cost (CA\$)	All costs were expressed in 2016 Canadian dollars to inflate past costs using health care-specific yearly consumer index reported by Statistics Canada – Total – Inpatients – Outpatients (with no pharmacotherapy-related cost)
In the last 5 years preceding the index date: both inpatients and outpatients visits	
Depression/anxiety	from CIHI DAD; OHIP; the physician fee-for-service claims; OMHRS Definition: 2 depression outpatient visits within a one-year window OR one inpatient visit (14) • From CIHI/DAD/ the physician fee-for-service claims: – ICD-10: F20.4, F31.3–F31.5, F32.x, F33.x, F34.1, F41.2, F43.2 – ICD-9: 296.2, 296.3, 296.5, 300.4, 309.x, 311 • OHIP: 311 or 300 • From the OMHRS: 296.2, 296.3, 296.5, 300.4, 309.0, 309.28, 311
Chronic rhinosinusitis (CRS)	From CIHI DAD; OHIP; the physician fee-for-service claims Definition: ≥ 2 claims for CRS within 2 years (15) • From CIHI/DAD: – ICD-9: 471.x, 473.x – ICD-10: J32.x, J33.x • OHIP: 473
Infection of tonsils and adenoids	from CIHI DAD; OHIP; the physician fee-for-service claims • Chronic tonsillitis – ICD-10: J35.0 – OHIP: 474 • Acute tonsillitis – ICD-10: J03

	– OHIP: 463
Atopic conditions (16)	from CIHI DAD; OHIP; the physician fee-for-service claims – ICD-10: L20.x; L24.x; L25.x; L27.x; J30.x – ICD-9: 477.x or 691.x or 692.x or 692.x – OHIP: 477, 691-693
GERD (17)	Conditions considered: heartburn, esophagitis, ulcer of the esophagus, esophageal stricture, gastro-esophageal reflux disease with and without esophagitis, esophageal obstruction from CIHI DAD; OHIP; the physician fee-for-service claims – ICD-10: R12, K20, K210, K219, K221, K222 – ICD-9: 787.1, 530.1, 530.2, 530.3 – OHIP: 530
Asthma-related respiratory conditions excluding asthma (18)	Conditions considered: acute nasopharyngitis, sinusitis, pharyngitis, laryngitis, tracheitis, croup, epiglottitis, upper respiratory tract infection, bronchitis or bronchiolitis; chronic pharyngitis/nasopharyngitis, sinusitis, laryngitis; allergic rhinitis; upper respiratory tract hypersensitivity reaction; viral, pneumococcal and other bacterial pneumonia; bronchopneumonia; influenza; bronchitis; emphysema; bronchiectasis; chronic airway obstruction from CIHI DAD; OHIP; the physician fee-for-service claims ICD-9: 460-462; 464-466; 472; 473; 476; 477; 478.8; 480-487; 490-492; 494; 496 ICD-10: J00-J02; J04-J06; J20; J21; J31; J32; J37; J30; J39.3; J10-J18; J40; J41; J42; J44; J43; J47; J44 OHIP: 460; 461; 464; 466; 473; 477; 480-487; 491; 492; 494; 496
Spirometry	from OHIP (ON): J301, J304, J307, J310, J324, J327
Time-dependent covariate: since the index date	
Hospitalizations for asthma	from CIHI DAD – ICD-10: J45 Asthma; J46 Status asthmaticus – ICD-9: 493 Asthma
Hospitalizations for asthma and/or asthma-related respiratory conditions	from CIHI DAD – See details above
All-cause hospitalizations	from CIHI DAD
ED visits for asthma	from CIHI NACRS (for ON only)
ED visits for asthma and/or asthma-related respiratory conditions	from CIHI NACRS (for ON only)
All-cause ED visits	from CIHI NACRS (for ON only)

CIHI DAD, Canadian Institute for Health Information Discharge Abstract Database (information on all acute care hospitalization in Canada); OHIP, Ontario Health Insurance Plan Physician Services Claims Database; SES, socioeconomic status; RPDB, Registered Persons Database

Table E1. Characteristics of all individuals aged 14-45 years who were newly diagnosed with asthma between 2006 and 2016 and had at least one hospital admission for asthma within five years of their initial asthma diagnosis (index date) in two Canadian provinces (British Columbia and Ontario)

			Total population of interest		
Cohort Characteristics			BC (N = 512)	ON (N = 1,350)	Total (N=1,862)
Demographics					
Age, years, mean (SD)			31.2 (8.8)	31.0 (9.3)	31.1 (9.2)
Female, n (%)			325 (63.5)	871 (64.5)	1,196 (64.2)
Socioeconomic status, n (%) N missing = 5	Low (lowest 2 quintiles)		277 (54.1)	710 (52.6)	987 (53.2)
	Middle (the third quintile)		90 (17.6)	247 (18.3)	337 (18.1)
	High (the highest 2 quintiles)		145 (28.3)	388 (28.7)	533 (28.7)
Lived in rural (vs urban) area at the index year, n (%)			68 (13.3)	187 (13.9)	255 (13.7)
Being seen by a specialist care physician who presumably delivered services for individuals with asthma and/or asthma-related diagnoses* as a reason for a visit any time before the index date, n (%)			94 (18.4)	357 (26.4)	451 (24.2)
In the 12 months preceding the index date					
The Charlson comorbidity index (CCI), ≥1, n (%)			11 (2.2)	22 (1.6)	33 (1.8)
Hospitalizations for pneumonia and influenza, n (%)			6 (1.2)	21 (1.6)	27 (1.5)
Spirometry, n (%)			61 (11.9)	107 (7.9)	168 (9.0)
Vaccinations, n (%)			Not available (NA)	123 (9.1)	—
Cost, in CA\$**	Inpatients	Mean (SD)	1,252.9 (4,653.8)	1,100.9 (7,404.2)	1,142.7 (6,760.4)
		Medium (IQR)	0 (0)	0 (0)	—
	Outpatients [No pharma/ ED visits]	Mean (SD)	902.6 (1,348.2)	1,045.0 (1,783.6)	1,005.8 (1,675.2)
		Medium (IQR)	427.4 (921.1)	424 (962)	—
Separate comorbidities in the last 5 years preceding index date, n (%)					
Depression/anxiety			195 (38.1)	389 (28.8)	584 (31.4)
Chronic rhinosinusitis (CRS)			16 (3.1)	19 (1.4)	35 (1.9)
Atopic conditions			124 (24.2)	514 (38.1)	638 (34.3)
Infection of tonsils and adenoids, acute			54 (10.6)	153 (11.3)	207 (11.1)
Infection of tonsils and adenoids, chronic			8 (1.6)	20 (1.5)	28 (1.5)
GERD			162 (31.6)	59 (4.4)	221 (11.9)
Asthma-related conditions* excluding asthma			403 (78.7)	1,093 (81.0)	1496 (80.3)
Spirometry			61 (11.9)	191 (14.1)	252 (13.5)
Vaccinations			NA	366 (27.1)	—
Time-dependent covariates, annual rates in follow-up*** [by the end of study for the descriptive purpose]					
Hospitalizations for asthma and/or asthma-related conditions, mean (SD)			0.3 (0.4)	0.3 (0.4)	0.3 (0.4)
ED visits for asthma and related conditions per year for follow-up, mean (SD)			NA	0.4 (1.3)	—

All-cause hospitalizations, mean (SD)	0.7 (0.8)	0.4 (0.6)	0.5 (0.7)
Spirometry, mean (SD)	0.4 (0.7)	1.9 (2.8)	1.5 (2.4)
Mortality, n (%)	6 (1.2)	25 (1.9)	31 (1.7)
Time from the index date to the first hospitalization with asthma as a main diagnosis, months, mean (SD)	10.6 (15.9)	8.1 (13.5)	8.8 (14.2)
Follow-up time to the end of study (death, end of follow-up or loss of insurance), months, mean (SD)	73.5 (29.1)	90.6 (35.4)	85.9 (33.8)

*Reason for the visit as asthma and asthma-related respiratory conditions: asthma, acute nasopharyngitis, acute upper respiratory tract infection, acute bronchitis or bronchiolitis, chronic pharyngitis/nasopharyngitis, allergic rhinitis, viral pneumonia, pneumococcal pneumonia, other bacterial pneumonia, bronchopneumonia, influenza, bronchitis – other, chronic bronchitis, emphysema, bronchiectasis, chronic airway obstruction.

** All costs were expressed in 2016 Canadian dollars; we inflated past costs using health care-specific yearly consumer index reported by Statistics Canada

***The number of events per year calculated by dividing the number of events by the number of years they were followed up.

#Hospitalizations for pneumonia or flu or bronchitis were not reported due to the number of individuals less than five in each province. The Charlson comorbidity index and mortality were not reported by the specialty due to the number of individuals less than five per subgroup.

Gastroesophageal reflux disease (GERD); Interquartile range (IQR); Standard deviation (SD).

Table E2. Percentage* and number of individuals who made ambulatory visits for any-cause or asthma or asthma-related respiratory conditions one year prior and two years after the initial asthma diagnosis date calculated for 6-month periods: primary care physicians and specialists (Ontario, Canada)

Physician specialty		1-Year Look-Back		0 to 6 months		6 to 12 months		12 to 18 months		18 to 24 months	
		No. of visits	% of patients	No. of visits	% of patients	No. of visits	% of patients	No. of visits	% of patients	No. of visits	% of patients
Primary care physicians	Asthma	0	0	1,360	54	626	26	528	23	477	20
	Asthma and/or asthma related#	1,289	45	2,034	66	1,132	39	1,012	37	913	34
	Any reason	6,827	82	5,188	84	4,585	74	4,512	71	4414	72
Regular primary care users (2+ visits)		—	74	—	74	—	80	—	67	—	64
Relevant specialist care**	Asthma	0	0	1,403	35	755	20	696	18	689	17
	Asthma and/or asthma related#	124	4	1,675	39	856	22	770	20	760	19
	Any reason	837	20	2,455	50	1,367	32	1,238	29	1210	28
Specialist care physicians who presumably delivered services for individuals with asthma*											
Respirologist/ Pulmonologist	Asthma	0	0	547	22	326	16	299	14	297	13
	Asthma and/or asthma related#	21	1	584	23	342	16	313	14	308	14
	Any reason	67	2	746	28	395	18	355	16	350	16
Internal medicine	Asthma	0	0	609	26	330	15	314	14	312	13
	Asthma and/or asthma related#	51	3	727	30	373	17	340	15	342	14
	Any reason	563	15	1212	40	730	26	669	23	663	22
Pediatrician	Asthma	0	0	149	7	46	2	34	2	30	2
	Asthma and/or asthma related#	33	2	197	9	62	3	50	3	43	2
	Any reason	178	6	305	11	141	5	125	4	115	4
Allergist/ Immunologist	Asthma	0	0	98	6	53	3	49	2	50	2
	Asthma and/or asthma related#	19	1	167	9	79	5	67	4	67	3
	Any reason	29	2	192	10	101	6	89	5	82	4
Other specialists (not-asthma related)	Asthma	0	0	14	1	14	1	15	1	12	1
	Asthma and/or asthma related#	46	2	66	3	63	3	87	3	80	3
	Any reason	2171	51	1426	38	1494	47	1439	49	1469	47

*Percentage was calculated as (the number of patients in each follow up period*100)/the total number of patients

** Respirologist, Internal medicine, Generalist, Pediatrician, Allergist/Immunologist

#asthma and asthma-related reason for visit: asthma, allergy injection, acute nasopharyngitis, acute upper respiratory tract infection, acute bronchitis or bronchiolitis, chronic pharyngitis/nasopharyngitis, allergic rhinitis, viral pneumonia, pneumococcal pneumonia, other bacterial pneumonia, bronchopneumonia, influenza, bronchitis – other, chronic bronchitis, emphysema, bronchiectasis, chronic airway obstruction

Table E3. Percentage* and number of individuals who made ambulatory visits for any-cause or asthma or asthma-related respiratory conditions one year prior and two years after the initial asthma diagnosis date calculated for 6-month periods: primary care physicians and specialists (British Columbia, Canada)

Physician specialty		1-Year Look-Back		0 to 6 months		6 to 12 months		12 to 18 months		18 to 24 months	
		No. of Visits	% of patients	No. of Visits	% of patients	No. of Visits	% of patients	No. of Visits	% of patients	No. of Visits	% of patients
Primary care physicians	Asthma	0	0	2,186	98	2,186	90	2,186	86	2,186	88
	Asthma and/or asthma related#	782	43	2,733	87	2,733	49	2,733	47	2,733	47
	Any reason	8,629	92	7,650	98	7,650	90	7,650	86	7,650	88
Regular primary care users (2+ visits)		449	88	485	95	485	82	485	80	485	80
Relevant specialist care**	Asthma	0	0	1,171	36	1,171	17	1,171	14	1,171	10
	Asthma and/or asthma related#	39	3	1,264	38	1,264	18	1,264	15	1,264	11
	Any reason	527	19	2,680	52	2,680	30	2,680	27	2,680	25
Specialist care physicians who presumably delivered services for individuals with asthma*											
Respirologist/ Pulmonologist	Asthma	0	0	666	22	666	10	666	10	666	8
	Asthma and/or asthma related#	8	1	703	23	703	11	703	11	703	8
	Any reason	116	4	1,541	32	1,541	19	1,541	18	1,541	15
Internal medicine	Asthma	0	0	311	16	311	6	311	4	311	3
	Asthma and/or asthma related#	17	1	364	18	364	7	364	5	364	4
	Any reason	325	13	796	30	796	17	796	12	796	12
Pediatrician	Asthma	0	0	96	3	96	1	96	1	96	0
	Asthma and/or asthma related#	3	0	96	3	96	1	96	1	96	0
	Any reason	47	4	197	5	197	3	197	2	197	2
Allergist/ Immunologist	Asthma	0	0	98	5	98	3	98	1	98	2
	Asthma and/or asthma related#	11	1	101	5	101	4	101	2	101	3
	Any reason	39	2	146	7	146	5	146	2	146	3
Other specialists (not-asthma related)	Asthma	0	0	183	11	183	3	183	3	183	2
	Asthma and/or asthma related#	12	1	202	13	202	5	202	4	202	3
	Any reason	2,337	48	1,736	48	1,736	44	1,736	38	1,736	43

*Percentage was calculated as (the number of patients in each follow up period*100)/the total number of patients

** Respirologist, Internal medicine, Generalist, Pediatrician, Allergist/Immunologist

#asthma and asthma-related reason for visit: asthma, allergy injection, acute nasopharyngitis, acute upper respiratory tract infection, acute bronchitis or bronchiolitis, chronic pharyngitis/nasopharyngitis, allergic rhinitis, viral pneumonia, pneumococcal pneumonia, other bacterial pneumonia, bronchopneumonia, influenza, bronchitis – other, chronic bronchitis, emphysema, bronchiectasis, chronic airway obstruction

Table E4. Characteristics by specialty of all individuals aged 14-45 years who were newly diagnosed with asthma between 2006 and 2016 and had at least one hospital admission for asthma within five years of their initial asthma diagnosis (index date) in two Canadian provinces (British Columbia and Ontario)

Cohort Characteristics			British Columbia				Ontario			
			Not seen by a specialist* prior the index date	Seen by a specialist* at least once since the index date	Not seen by a specialist* since the index date	p value#	Not seen by a specialist* prior the index date	Seen by a specialist* at least once since the index date	Not seen by a specialist* since the index date	p value #
			N=418	N=256	N=162		N=993	N=602	N=391	
Demographics at the index year (the date of the initial asthma diagnosis)										
Age, years, mean (SD)			31.2 (8.9)	31.1 (8.8)	31.3(9.1)	0.790	31.6 (9.1)	32.1 (9.1)	30.9 (9.1)	0.063
Female, n (%)			259 (61.9)	155 (60.5)	104 (64.2)	0.454	633 (63.7)	382 (63.5)	251 (64.2)	0.813
SES**, n (%)	Low (lowest 2 quintiles)		226 (54.1)	137 (53.5)	89 (54.9)	0.796	533 (53.7)	312 (51.8)	221 (56.5)	0.469
	Middle (the third quintile)		71 (16.9)	46 (17.9)	25 (15.4)		182 (18.3)	113 (18.8)	69 (17.6)	
	High (the highest 2 quintiles)		121 (28.9)	73 (28.5)	48 (29.6)		274 (27.6)	175 (29.1)	99 (25.3)	
Lived in rural area, n (%)			54 (12.9)	20 (7.8)	34 (20.9)	<.0001	159 (16.0)	76 (12.6)	83 (21.2)	<.001
In the 12 months preceding the index date										
The Charlson comorbidity index (CCI, aggregated (≥1), n (%))			7 (1.6)	<5	<5	0.577	11 (1.1)	<5	>5	0.004
Spirometry, n (%)			42 (10.1)	28 (10.9)	14 (8.6)	0.447	61 (6.1)	42 (7.0)	19 (4.9)	0.175
Vaccinations, n (%)			NA				81 (8.2)	52 (8.6)	29 (7.4)	0.492
Inappropriate prescription of rescue medication, n (%)			63 (15.1)	37 (14.4)	26 (16.1)	0.657	NA			
Cost in CA\$***	Inpatients	Mean (SD)	1,195.6 (4,875.8)	1,010.1 (4,231.9)	1,488.6 (5,750.5)	0.058	737.2 (3,810.8)	680.3 (4,408.9)	824.7 (2,640.0)	0.560
		Medium (IQR)	0 (0)	0 (0)	0 (0)		0 (0)	0 (0)	0 (0)	
	Outpatients [No pharma /ED]	Mean (SD)	887.5 (1397.6)	884.9 (1,488)	891.7 (1,245.9)	0.590	880.8 (1,467.1)	884.4 (1,527.7)	875.1 (1,370.5)	0.922
		Medium (IQR)	390.9 (906.6)	361.1 (906.1)	417.9 (904.7)		362 (834)	382 (800)	340 (888)	
Separate comorbidities in the last 5 years preceding index date, n (%)										
Depression/anxiety			158 (37.8)	93 (36.3)	65 (40.1)	0.436	263 (26.5)	159 (26.4)	104 (26.6)	0.948
Atopic conditions			86 (20.6)	57 (22.3)	29 (17.9)	0.282	317 (31.9)	202 (33.6)	115 (29.4)	0.171
Infection of tonsils/adenoids, acute			41 (9.8)	24 (9.4)	17 (10.5)	0.708	92 (9.3)	66 (11.0)	26 (6.6)	0.022

Cohort Characteristics			British Columbia				Ontario			
			Not seen by a specialist* prior the index date	Seen by a specialist* at least once since the index date	Not seen by a specialist* since the index date	p value#	Not seen by a specialist* prior the index date	Seen by a specialist* at least once since the index date	Not seen by a specialist* since the index date	p value #
			N=418	N=256	N=162		N=993	N=602	N=391	
Infection of tonsils/adenoids, chronic			10 (1.0)	5 (0.8)	5 (1.3)	0.489	6 (1.4)	6 (2.3)	0 (0)	0.050
GERD			124 (29.7)	81 (31.6)	43 (26.5)	0.266	46 (4.6)	24 (4.0)	22 (5.6)	0.230
Asthma-related conditions excluding asthma			313 (74.9)	199 (77.7)	114 (70.4)	0.090	768 (77.3)	473 (78.6)	295 (75.4)	0.251
Spirometry			42 (10.1)	28 (10.9)	14 (8.6)	0.447	106 (10.7)	65 (10.8)	41 (10.5)	0.877
Vaccinations			NA				237 (23.9)	158 (26.2)	79 (20.2)	0.029
Time-dependent co-variates, annual rates in follow-up [by the end of study for the descriptive purpose]										
Hospitalizations for asthma and/or asthma-related conditions, mean (SD)			0.3 (0.4)	0.4 (0.5)	0.2 (0.2)	0.050	0.2 (0.3)	0.5 (1.7)	0.3 (0.5)	0.015
All-cause hospitalizations, mean (SD)			0.6 (0.7)	0.7 (0.8)	0.5 (0.6)	0.539	0.4 (0.5)	0.4 (0.5)	0.3 (0.34)	0.105
Spirometry, mean (SD)			0.4 (0.7)	0.5 (0.8)	0.1 (0.3)	<.0001	1.7 (2.5)	2.5 (2.9)	0.5 (0.8)	<.001
ED visits for asthma and related conditions per year for follow-up, mean (SD)			NA				0.4 (1.4)	0.3 (0.4)	0.2 (0.2)	<.001
Mortality, n (%)			6 (1.4)	<5	<5	0.784	21 (2.1)	10 (1.7)	11 (2.8)	0.218
Time from the index date to the first hospitalization with asthma as a main diagnosis, months, mean (SD)			10.8 (16.1)	11.6 (16.8)	9.5 (14.9)	0.055	7.7 (13.4)	9.4 (14.4)	5.1 (11.2)	<.001
Time in days from the date of the index date to the date of the specialist visit or the end of the study, median (IQR) ****			775.5 (4-2,055)	72 (0-596)	2,291 (1,521-2,956)		755 (59-2,673)	98.5 (18-485)	1,802 (1,995-3,797)	
Follow-up time to the end of study, months, mean (SD)			74.1 (28.6)	74.16 (28.4)	73.9 (28.9)	0.926	92.4 (35.2)	91.3 (35.3)	94.2 (34.9)	0.196
Cost per year of follow-up	Inpatients	Mean (SD)	1,069.5 (3715.6)	1,364.1 (4713.8)	603.9 (457.7)	0.044	2,035.4 (4,839.7)	2,187.8 (5,163.3)	1,800.8 (4,290.1)	0.002
		Medium (IQR)	487.3 (540.6)	498.3 (679.9)	442.9 (395.5)		717 (1,282)	762 (1,275)	645 (1,213)	

Cohort Characteristics			British Columbia				Ontario			
			Not seen by a specialist* prior the index date	Seen by a specialist* at least once since the index date	Not seen by a specialist* since the index date	p value#	Not seen by a specialist* prior the index date	Seen by a specialist* at least once since the index date	Not seen by a specialist* since the index date	p value #
			N=418	N=256	N=162		N=993	N=602	N=391	
	Outpatients [No pharma /ED]	Mean (SD)	178.4 (447.5)	250.8 (557.3)	64 (72.9)	<.001	1,503.9 (1,761.01)	1,647.6 (1,824.5)	1,282.7 (1,636.3)	<.001
		Medium (IQR)	85.1 (146.8)	137.4 (198.2)	41.5 (66.5)		961 (1,334)	1,051 (1,393)	787 (1,286)	

*A specialist visit for asthma and/or asthma-related reasons: asthma, allergy injection, acute nasopharyngitis, acute upper respiratory tract infection, acute bronchitis or bronchiolitis, chronic pharyngitis/nasopharyngitis, allergic rhinitis, viral pneumonia, pneumococcal pneumonia, other bacterial pneumonia, bronchopneumonia, influenza, bronchitis – other, chronic bronchitis, emphysema, bronchiectasis, chronic airway obstruction

** May not sum up to 100% due to missing values

*** All costs were expressed in 2016 Canadian dollars; we inflated past costs using health care–specific yearly consumer index reported by Statistics Canada

***** For a patient seen by a specialist at least once, the follow up was censored by the date of specialist visit, and for the patients with no specialist visit the follow up continues to the end of the study (the last date of registration with the provincial health-care insurance plan, death or the end of the follow-up period, March 31, 2018, whichever occurred first)

p values for comparison of individuals who saw a specialist at least once for the asthma and/or asthma-related reasons and those who stayed with a primary care physician

No statistical difference in the comorbid chronic rhinosinusitis in the last 5 years, and hospitalization for pneumonia or flu or bronchitis in 12 months before index date in both provinces (p values >0.3; not reported due to number per cell <5 for some subgroups)

Emergency department (ED); Gastroesophageal reflux disease (GERD); Interquartile range (IQR); Standard deviation (SD).

Table E5. The relationship between characteristics of interest and being seen at least once by a relevant specialist since the index date with asthma and/or asthma-related respiratory conditions as a reason for the visit among individuals diagnosed with asthma by a primary care physician and who were under primary care for other respiratory conditions before the asthma diagnosis. Results are reported from multivariable Cox regressions. Estimates presented as pooled* hazard ratios (HRs) and 95% confidence intervals (CI).

Predictors/Risk factors		British Columbia		Ontario		Total
		Adjusted HR (95% CI)	p value	Adjusted HR (95% CI)	p value	Pooled Adjusted HR (95% CI)
Demographics at the index date (the initial asthma diagnosis)						
Age, years, per 5-year increase		0.99 (0.92-1.06)	0.728	1.03 (0.98-1.08)	0.222	1.02 (0.98-1.06)
Sex: Female vs. Male		0.90 (0.70-1.15)	0.401	0.96 (0.81-1.13)	0.621	0.94 (0.82-1.08)
Socioeconomic status	Low (lowest 2 quintiles) vs. High (the highest 2 quintiles)	0.92 (0.69-1.22)	0.545	0.83 (0.69-1.00)	0.056	0.86 (0.73-1.00)
	Middle (the third quintile) vs. High (the highest 2 quintiles)	1.06 (0.73-1.54)	0.750	0.97 (0.76-1.23)	0.781	1.00 (0.81-1.22)
Lived in rural vs. urban area at the index year		0.46 (0.29-0.73)	0.001	0.62 (0.49-0.80)	0.0002	0.58 (0.46-0.72)
In the 12 months preceding the index date						
The Charlson comorbidity index, score: ≥ 1 vs. 0		1.03 (0.38-2.76)	0.958	0.21 (0.05-0.84)	0.027	0.60 (0.27-1.35)
Hospitalizations for pneumonia/influenza: Yes vs. No		0.41 (0.06-2.91)	0.371	0.61 (0.20-1.91)	0.400	0.55 (0.21-1.48)
Hospitalizations for acute bronchitis or bronchitis not specified as acute or chronic: Yes vs. No		0.82 (0.12-5.87)	0.846	0.89 (0.12-6.31)	0.905	0.85 (0.21-3.42)
Spirometry: Yes vs. No		1.29 (0.87-1.92)	0.199	1.33 (0.97-1.81)	0.078	1.31 (1.03-1.68)
Vaccinations: Yes vs. No		NA		1.05 (0.79-1.40)	0.723	
In the last 5 years preceding the index date						
Depression/anxiety: Yes vs. No		0.91 (0.71-1.18)	0.485	0.97 (0.81-1.16)	0.708	0.95 (0.82-1.10)
Chronic rhinosinusitis: Yes vs. No		0.92 (0.41-2.07)	0.843	2.39 (0.34-16.94)	0.382	1.06 (0.50-2.24)
Atopic conditions: Yes vs. No		1.22 (0.91-1.64)	0.181	1.09 (0.92-1.30)	0.295	1.12 (0.96-1.31)
Infection of tonsils and adenoids (Acute): Yes vs. No		0.95 (0.62-1.46)	0.821	1.21 (0.93-1.57)	0.151	1.13 (0.91-1.42)
Infection of tonsils and adenoids (Chronic): Yes vs. No		2.91 (1.29-6.57)	0.010	0.72 (0.30-1.74)	0.464	1.53 (0.84-2.78)
GERD: Yes vs. No		1.13 (0.87-1.48)	0.356	0.77 (0.51-1.16)	0.215	1.01 (0.80-1.26)
Asthma-related conditions excluding asthma: Yes vs. No		1.24 (0.93-1.67)	0.146	1.15 (0.94-1.39)	0.173	1.18 (1.00-1.38)
Spirometry: Yes vs. No		1.29 (0.87-1.92)	0.199	1.08 (0.83-1.40)	0.562	1.15 (0.94-1.42)
Vaccinations: Yes vs. No		NA		1.18 (0.98-1.42)	0.074	
Time-dependent covariate						
Hospitalizations for asthma and asthma-related		1.51 (0.45-5.02)	0.503	1.46 (1.04-2.06)	0.030	1.46 (1.05-2.04)

conditions, Yes vs. No*					
ED visits for asthma and asthma-related conditions, Yes vs. No*	NA		1.31 (1.09-1.59)	0.005	
All-cause hospitalizations, Yes vs. No*	1.03 (0.74-1.43)	0.846	1.06 (0.83-1.35)	0.654	1.05 (0.86-1.27)
Spirometry, Yes vs. No*	1.17 (0.63-2.16)	0.622	2.18 (1.71-2.78)	<.0001	2.00 (1.60-2.51)

*6-month period

Not available (NA)

Emergency department (ED); Gastroesophageal reflux disease (GERD).

Table E6. Hospitalization, emergency department and spirometry rates since the asthma initial diagnosis in Ontario (Canada): primary care physicians and specialists. Rates were calculated as the number of events/total number of people at risk in this period (6 months).

Mos	Seen at least once by a specialist for asthma or asthma-related respiratory conditions* since the initial asthma diagnosis					Not seen by a specialist* since the index date				
	Hospitalizations		ED visits		Spirometry	Hospitalizations		ED visits		Spirometry
	Asthma or asthma-related condition*	All-cause	Asthma or asthma-related condition*	All-cause		Asthma or asthma-related condition*	All-cause	Asthma or asthma-related condition*	All-cause	
0-6	0.87	1.02	0.79	1.97	1.83	0.85	1.12	0.59	1.71	0.41
6-12	0.23	0.33	0.57	1.57	0.82	0.12	0.27	0.31	1.23	0.09
12-18	0.18	0.28	0.48	1.38	0.66	0.06	0.20	0.26	1.17	0.08
18-24	0.17	0.24	0.44	1.34	0.52	0.07	0.23	0.21	1.01	0.06
24-30	0.13	0.25	0.34	1.11	0.52	0.09	0.20	0.29	1.17	0.07
30-36	0.08	0.19	0.30	1.13	0.42	0.07	0.21	0.17	1.00	0.05
36-42	0.09	0.18	0.28	1.02	0.38	0.03	0.11	0.16	0.90	0.04
42-48	0.07	0.15	0.28	1.00	0.33	0.03	0.11	0.12	0.67	0.03
48-54	0.06	0.12	0.28	0.95	0.28	0.01	0.09	0.10	0.93	0.02
54-60	0.09	0.15	0.25	0.81	0.32	0.00	0.14	0.08	0.82	0.05
60-66	0.02	0.09	0.21	0.91	0.25	0.00	0.06	0.06	0.52	0.02
66-72	0.00	0.05	0.04	0.55	0.14	0.03	0.03	0.04	0.46	0.03

*A specialist visit for asthma and/or asthma-related reasons: asthma, allergy injection, acute nasopharyngitis, acute upper respiratory tract infection, acute bronchitis or bronchiolitis, chronic pharyngitis/nasopharyngitis, allergic rhinitis, viral pneumonia, pneumococcal pneumonia, other bacterial pneumonia, bronchopneumonia, influenza, bronchitis – other, chronic bronchitis, emphysema, bronchiectasis, chronic airway obstruction

Table E7. Hospitalization, emergency department and spirometry rates since the asthma initial diagnosis in British Columbia (Canada): primary care physicians and specialists. Rates were calculated as the number of events/total number of people at risk in this period (6 months).

Mos	Seen at least once by a specialist for asthma or asthma-related respiratory conditions* since the initial asthma diagnosis			Not seen by a specialist* since the index date		
	Hospitalizations		Spirometry	Hospitalizations		Spirometry
	Asthma or asthma-related condition*	All-cause		Asthma or asthma-related condition*	All-cause	
0-6	0.92	1.29	1.08	0.77	1.17	0.30
6-12	0.25	0.55	0.62	0.21	0.45	0.15
12-18	0.19	0.36	0.36	0.10	0.35	0.06
18-24	0.17	0.47	0.30	0.04	0.30	0.06
24-30	0.18	0.50	0.33	0.10	0.29	0.08
30-36	0.09	0.37	0.23	0.04	0.31	0.07
36-42	0.08	0.34	0.18	0.01	0.22	0.06
42-48	0.06	0.30	0.29	0.02	0.20	0.05
48-54	0.04	0.20	0.16	0.02	0.12	0.04
54-60	<5 number of events	0.22	0.13	0.00	0.13	0.04

*A specialist visit for asthma and/or asthma-related reasons: asthma, allergy injection, acute nasopharyngitis, acute upper respiratory tract infection, acute bronchitis or bronchiolitis, chronic pharyngitis/nasopharyngitis, allergic rhinitis, viral pneumonia, pneumococcal pneumonia, other bacterial pneumonia, bronchopneumonia, influenza, bronchitis – other, chronic bronchitis, emphysema, bronchiectasis, chronic airway obstruction

Table E8. Total cost (inpatient and outpatient)* since the date of the initial asthma diagnosis.

Months	Seen at least once by a specialist for asthma or asthma-related respiratory conditions* since the initial asthma diagnosis		Not seen by a specialist* since the index date	
	Total cost, mean (SD)		Total cost, mean (SD)	
	Ontario	British Columbia	Ontario	British Columbia
0-6	6037.03 (9892.07)	1895.03 (5526.93)	5182.66 (8940.78)	2380.35 (6471.47)
6-12	3037.16 (6639.62)	4000.72 (9137.46)	2871.86 (14648.55)	2242.37(1626.44)
12-18	2682.27 (5170.12)	1385.95 (5945.14)	1994.69 (6523.03)	625.98 (1679.84)
18-24	2151.66 (4691.21)	586.61 (1643.43)	2765.72 (9370.68)	336.99 (1016.05)
24-30	3245.92 (15163.23)	794.44 (3462.75)	2443.83 (7894.31)	135.40 (625.24)
30-36	2403.28 (7197.36)	773.38 (3164.30)	2573.93 (8420.76)	275.85 (863.52)
36-42	2662.37 (9747.13)	277.78 (1107.44)	1626.53 (6355.42)	126.44 (634.23)
42-48	1822.66 (4652.99)	198.21 (911.62)	1745.23 (8189.77)	54.23 (308.93)
48-54	2512.63 (14236.87)	190.10 (768.26)	1217.07 (3868.49)	60.61 (357.79)
54-60	1534.24 (3354.14)	154.68 (723.42)	1993.43 (7370.34)	10.07 (27.68)
60-66	1246.37 (2674.96)	52.16 (111.41)	817.96 (2462.02)	13.33 (50.78)
66-72	770.00 (1851.53)		458.45 (1476.66)	

All costs were expressed in 2016 Canadian dollars; we inflated past costs using health care-specific yearly consumer index reported by Statistics Canada

*to synchronize costs across provinces, the cost of pharmacotherapy was extracted from calculations in British Columbia as this information was not available in Ontario; the cost of emergency department visits was extracted from calculations in Ontario as this information is not available in British Columbia.

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