

Impact of an Interdisciplinary Asthma Care Network on Emergency Department Visits and Hospitalizations

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Background: Current national and international asthma clinical practice guidelines emphasize care continuity and adherence to guideline-based care delivered through interdisciplinary teams. However, the efficacy of such teams in reducing urgent asthma-related care has not yet been assessed.

Objective: To measure the impact of an interdisciplinary asthma care network (ACN) on health services utilization.

Methods: We identified a retrospective cohort of individuals with confirmed or suspected asthma who received specialized interdisciplinary asthma care in Southeastern Ontario, Canada between 2009–2018. Individuals were matched (on age, sex, and year of asthma diagnosis) to controls with suspected asthma who were not enrolled in the ACN. Asthma-related emergency department (ED) and inpatient visits were compared via zero inflated Poisson regression, stratified between pediatric and adults.

Results: 1248 ACN patients were matched to 3629 non-ACN controls. Asthma-related ED visits were reduced for 21% of ACN patients versus 6.7% of non-ACN participants. Similarly, hospitalizations were reduced for 10.7% of ACN participants post-index visit compared to 1.4% of non-ACN participants (both $P < 0.001$). Despite higher pre-enrolment health service utilization, ACN adults no longer had higher health service use compared to non-ACN, after enrolment in the network (Risk Ratio: 1.3 (0.9–1.88)). Pediatric ACN patients continued to have higher health service use compared to non-ACN participants post-enrolment (Risk Ratio 1.72 (1.30–2.26)).

Conclusion: Enrolment in a guideline-based interdisciplinary ACN reduces acute, unplanned asthma-related health service utilization, particularly in adults. Despite higher pre-enrolment health service utilization, adults enrolled in guideline-based interdisciplinary asthma care no longer had higher service use following enrolment.

Keywords: asthma, guideline-based care, health service utilization

Introduction

Asthma is a chronic respiratory disease affecting millions globally.¹ Asthma accounts for approximately 80% of chronic respiratory disease in Canada.² The burden of asthma continues to grow, adding strains to the healthcare system.² Acute exacerbations of asthma result in increased health care costs and worse health outcomes compared to stable, well managed asthma, making asthma control an important target for patient management.^{3,4} Numerous national and international asthma guidelines^{1,5-8} have been published with the goal of achieving harmonization of diagnosis and treatment by increasing adherence to evidence-based management strategies to improve asthma control.⁸⁻¹⁰ These recommendations include close follow-up with a primary care provider or specialist following an exacerbation requiring an Emergency Department (ED) visit or inpatient hospitalization, along with educational strategies for patient symptom recognition and appropriate management.⁹

A clear emphasis is placed on minimizing gaps in care, particularly around acute exacerbations. Previous studies have demonstrated the efficacy of multidisciplinary asthma care delivery models on improving health outcomes in individuals with asthma in varying healthcare settings.^{11,12} These networks emphasize integration between phases of care and adherence to most recent regional guidelines for diagnosis, treatment, and monitoring of asthma.^{1,8,9,13,14} However, studies in Ontario have identified that referrals to asthma specialists are exceptionally low following an ED visit.¹⁵ Access to specialist care may be an issue, as Kendzerska et al demonstrated that more than half of individuals who had been hospitalized for asthma in Ontario, Canada did not receive care from a specialist within two years of their diagnosis.¹⁶ Specialist care provision was also reported in less than 50% of over 54,000 patients with severe asthma in the USA.¹⁷ Thus, primary care physicians often manage these patients on their own, missing interdisciplinary strategies that are increasingly becoming necessary to reduce emergency health care utilization rates and improve symptom control.¹⁶

To improve adherence to asthma management guidelines, a regional network of inter-disciplinary clinics focused on guideline-based asthma care, an Asthma Care Network (ACN), was created in Southeastern Ontario in 2009. The goal of the ACN is to bridge the gap between guideline-based therapy and current practice while collecting objective data to provide patient-centred care, knowledge translation, and evaluation of the ACN in terms of healthcare utilization and other patient outcomes such as symptom control. The Kingston Health Sciences Centre Asthma Program's ACN includes several adult and pediatric asthma clinics staffed by respirologists and/or a nurse practitioner, an Asthma Education Centre, and outreach asthma education delivered in seven Primary Care Asthma Program locations in the network. Providers in the ACN facilitate patient and family education, monitoring of asthma via objective measures, creation of action plans, and facilitation of follow-up after an acute encounter or exacerbation. Since its inception, there has not been an evaluation of the effectiveness of the ACN on asthma-related health care utilization.

The aims of this study were to: 1) determine the effect of an interdisciplinary tertiary ACN on health services utilization in patients enrolled in the ACN compared to non-enrolled controls; and 2) to identify factors associated with greater or lesser improvement in health service utilization to identify areas for quality improvement within the ACN.

Methods

Study Design and Setting

We conducted a retrospective observational matched cohort study using linked administrative health data held at ICES (formerly the Institute for Clinical Evaluative Sciences) in Ontario, Canada. The study was approved by the Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board (Approval #6025257).

Data Sources

The Asthma Management and Outcomes Monitoring System (AMOMS) is a point of care asthma electronic clinical management system used by providers in the ACN.¹⁸ It is integrated into the local hospital's electronic medical record and collects information on demographics, comorbidities, environmental exposures, symptoms, treatment, spirometry, and local health service use. Information was extracted only for individuals who provided express approval for their personal health information data to be used in research and quality improvement.

ICES is an independent, non-profit research institute whose legal status under Ontario's health information privacy law allows it to collect and analyze health care and demographic data, without consent, for health system evaluation and improvement. The data holdings housed at ICES comprise all inpatient admission records, outpatient surgical procedure records, emergency department records, outpatient visits, billings under the Ontario Health Insurance Plan (OHIP), and asthma diagnoses within the province, among other data holdings. These datasets were linked using unique encoded identifiers and analyzed at ICES.

Study Population

Inclusion Criteria

Patients with confirmed or suspected asthma were identified in AMOMS who were seen by a provider within the ACN between January 1st, 2009, and December 31st, 2018. Confirmed asthma cases were defined via spirometry (FEV_1/FVC below the lower limit of normal and either a positive pre-post bronchodilator response of $\geq 12\%$, diurnal variation, or a $\geq 15\%$ decrease in FEV_1 post-exercise, non-specific bronchial provocation testing, or peak expiratory flow variability $\geq 20\%$), whereas suspected asthma was based on the specialists' opinion in the absence of objective testing. Patients of legal age, or parent/guardian consent in those less than 18 years of age must have provided consent for inclusion of their data in research. Participants were excluded if they were missing data for any of the independent variables.

Individuals were assigned an index date corresponding to their first visit in the ACN. Notably, individuals may have received specialist care prior to this index date outside of the ACN. Data on patients who had provided consent (or parent/guardian consent in the case of pediatric patients) for use of their personal health information for research were extracted from AMOMS and linked to Ontario's administrative databases at ICES. Health Card Number, a unique 10-digit permanent identification number assigned to eligible Ontario residents to receive insured health services, was used to perform a deterministic linkage to identify subjects in the Registered Persons Database (RPDB) which then facilitated linkage with databases containing information on health service utilization (HSU; Figure 1).

In the ICES data, a control group of individuals with asthma (non-ACN) was identified using a validated administrative case definition, where an individual was considered to have asthma if they had one hospital admission with an asthma diagnosis (an International Classification of Diseases (ICD)-10 code of J45 or J46) or two Ontario Health Insurance Plan (OHIP) claims with a physician-assigned asthma diagnosis within two years from the index date.¹⁹ These individuals must have resided within the Southeast Local Health Integration Network (SELHIN; now referred to as Southeast area of Home and Community Care Services) during the study period, but must not have received care within the ACN.

Health Service Utilization

Acute health service utilization for asthma, defined as ED visits and hospitalizations, was identified for 12 months prior and 24 months following the index visit in the ACN as the primary outcome. Non-urgent ambulatory care visits, comorbidities (as defined by aggregate diagnosis groups; ADGs), specialist visits, and use of diagnostic tests (spirometry billing codes) were also identified as secondary outcomes or covariates. ADGs are pre-specified, validated diagnostic clusters of ICD codes shown to predict morbidity and mortality in a general ambulatory population cohort.^{20,21} Patients

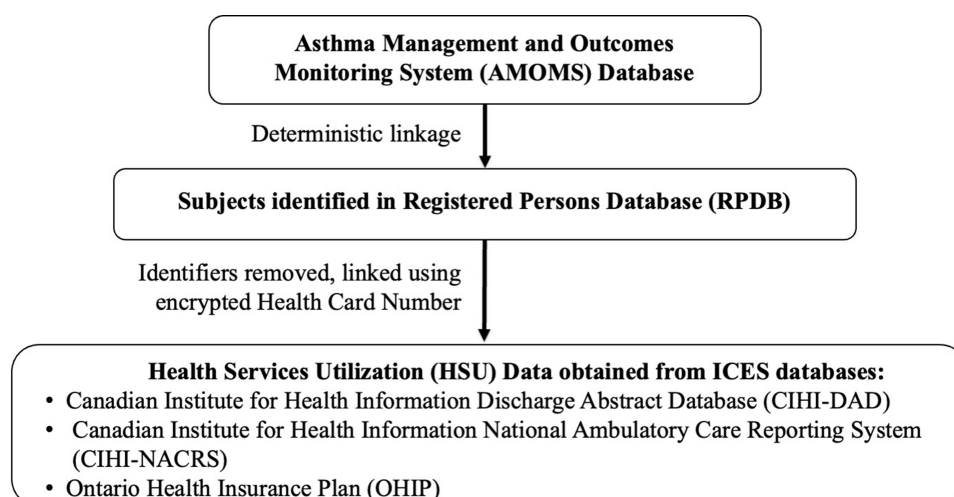


Figure 1 Data Sources and linkage. The ACN cohort was identified in the AMOMS database and linked to data holdings at ICES on health service utilization.

Abbreviations: AMOMS, Asthma Management and Outcomes Monitoring System; RPDB, Registered Persons Database; HSU, Health Service Utilization; ICES, Institute for Clinical and Evaluative Sciences.

with no data on ED visits or hospitalizations were assumed to not have used healthcare services within the observation period.

Analysis

The non-ACN group was matched to ACN patients on age (year of birth), sex, and year of asthma diagnosis at a 3:1 ratio. These characteristics were chosen as age, sex, and asthma duration are associated with severity of symptoms, health service use, and phenotype of asthma. The index date was defined as the first encounter with an ACN provider for those in the ACN with the same date assigned to matched non-ACN participants. Continuous variables were compared using the dependent *t*-test (parametric) and Kruskal–Wallis test (non-parametric). Categorical variables were compared using the Chi-squared test for homogeneity. All health care utilization data for both groups were taken from ICES health administrative databases and stratified by pediatric (< 18 years of age) and adult (≥ 18 years of age) participants. Zero inflated Poisson (ZIP) regression was used to assess the rate of ED visits and/or hospitalizations between ACN and non-ACN participants. A count of individuals who had a reduction in HSU post-index visit was also calculated by comparing ED visits and inpatient hospitalizations pre and post index visit to provide a percentage of individuals in each subgroup who saw a reduction in HSU. The ZIP model was chosen to account for the excess number of zero counts (individuals with no visits) within the dataset and overdispersion commonly observed in healthcare utilization data. Given the small number of ED visits and hospitalizations in the two years following the index visit, these were analyzed together. The ZIP model consists of two components: 1) A Poisson count model estimating the incidence rate ratio (IRR) of visits among individuals at risk of experiencing events; 2) A logistic model estimating the probability of having an excess zero (ie, individuals not at risk). We report adjusted risk ratios (IRRs) with 95% confidence intervals (CIs) derived from the count portion of the ZIP model. Covariates included in the model were number of asthma-related ED visits in the year prior to the index visit as a proxy for asthma severity in the absence of symptom burden and information on prescribed therapy in ICES data, as well as the number of major and minor comorbidities (as defined by ADGs which may confound the association between enrolment in the ACN and post-visit HSU).²¹ All analyses were conducted using SAS 9.4 (SAS Institute Inc., Cary, North Carolina, USA) and statistical significance was defined as a two-sided *p*-value < 0.05.

Results

A total of 4923 visits were identified in the ACN from January 1st, 2009 to December 31st, 2018 by 2375 unique patients. The linkage between AMOMS-ICES was highly successful with 98.4% (*n*=2336) of ACN patients successfully linked to ICES databases for health service utilization. Participants were excluded if they resided outside of the SELHIN, were not eligible for OHIP during the observation period, or had missing data for any of the independent variables, leaving a final sample size of 1248 ACN patients with 3629 matched non-ACN patients (Figure 2).

A total of 17.8% (*n*=222) of ACN participants had an asthma-associated ED visit in the two years following the index visit, while 6.1% (*n*=221) of non-ACN individuals with asthma had asthma associated ED visits within the same timeframe (Supplementary Table 1). On average, individuals in the ACN had more asthma-related healthcare utilization than non-ACN individuals (Table 1; Unstratified results found in Supplementary Table 2). For inpatient hospitalizations, 3.0% (*n*=38) of those in the ACN had a hospitalization, while 0.8% (*n*=28) in the non-ACN group had a hospitalization within two years post index visit. Asthma-related ED visits were reduced for 16.6% (95% CI: 12.4%–20.7%) of those in the ACN versus 2.6% (95% CI: 0.0%–5.0%) in the non-ACN group post-index visit. Similarly, hospitalizations were reduced for 10.2% (95% CI: 8.6–11.8%) of ACN participants post-index visit compared to 0.3% (95% CI 0.0%–1.2%) of non-ACN patients (both *p*<0.001). Post-index visit, 90.4% (*n*=4408) of the study population did not have ED visits or inpatient hospitalizations within the observation period.

Regression Analysis

In unadjusted analyses, both adult and pediatric patients in the ACN were more likely to have post-index ED visits and inpatient hospitalizations compared to non-ACN controls (Rate Ratio (RR): 1.62 (95% CI 1.14–2.31) for adults, 2.03 (95% CI 1.55–2.66) for pediatrics). After adjustment for major and minor comorbidities (as defined by ADGs) and asthma ED visits in the year prior to index, adult individuals in the ACN were no longer more likely to have more post-

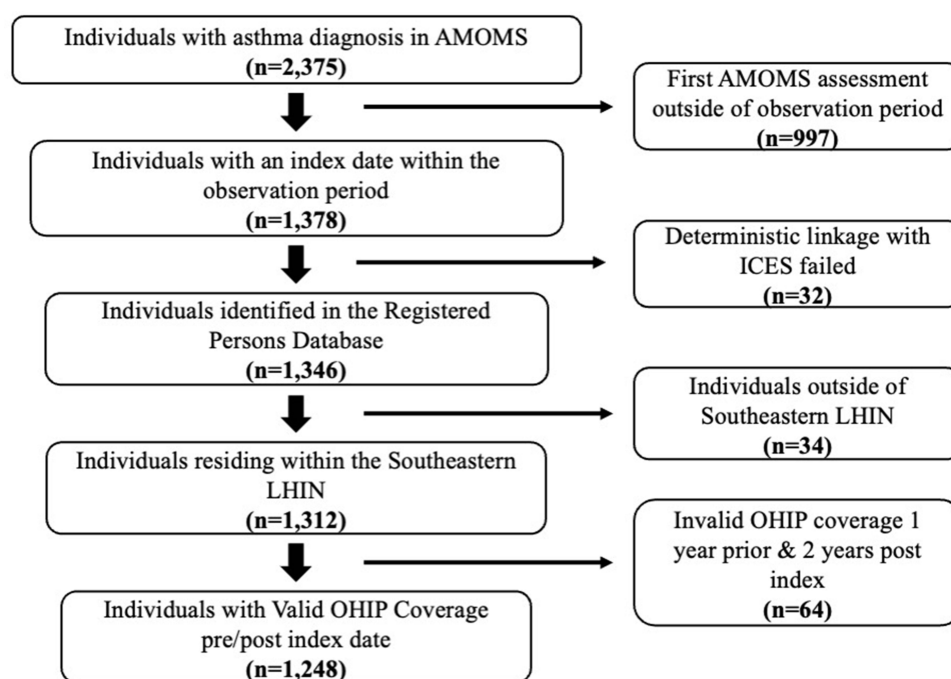


Figure 2 Cohort derivation and study population exclusions.

Abbreviations: AMOMS, Asthma Management and Outcomes Monitoring System; ICES, Institute for Clinical and Evaluative Sciences; OHIP, Ontario Health Insurance Plan; LHIN, Local Health Integration Network.

index visit asthma encounters compared to non-ACN controls, however, for pediatric patients the association persisted (Table 2; Logistic component found in [Supplementary Table 3](#)). Individuals with more asthma ED visits in the year prior to index date and those with major comorbidities were similarly more likely to have asthma health service utilization (HSU) post index date.

Discussion

Individuals enrolled in a specialized interdisciplinary asthma care model in Southeastern Ontario had higher HSU compared to those who were not enrolled; however, despite their overall increased asthma HSU, individuals with asthma enrolled in the ACN no longer had increased HSU compared to non-ACN patients following their first ACN visit. Pediatric patients enrolled in the ACN continued to have increased visits post-index compared to non-ACN controls, however, the relationship was attenuated after controlling for comorbidities and pre-index date HSU.

This study adds to a growing body of literature demonstrating that providing specialized interdisciplinary asthma care and follow-up reduces the number of acute, unplanned health care visits.^{11,12,22–24} Despite individuals enrolled in the ACN having had higher visits pre-enrollment (indicative of more severe and/or less well controlled asthma), there was a greater improvement between pre- and post-index date HSU in the ACN versus the non-ACN group. While the increased asthma severity in the ACN may indicate confounding by indication, after controlling for comorbidities and pre-index HSU, those who received care within the ACN no longer showed a relative increase in visits compared to non-ACN controls. These differences suggest that despite their increased severity, specialized asthma care helps to reduce asthma-related HSU.

There are several potential explanations for why adults enrolled in the ACN show a reduction in their HSU after their first visit. The overarching principle of the ACN is to align asthma care with evidence-based guidelines by providing individuals with close follow-up and optimal maintenance of asthma, including asthma education and the provision of written action plans. In a recent systematic review, asthma education was associated with a 31% reduction in the risk of ED visits compared to non-ACN controls, and 54% reduction in hospitalizations.²⁵ It is possible that this relationship was not seen in the pediatric population given that younger individuals are more likely to have their first presentation and

Table 1 Demographic Characteristics of the Study Population

	Pediatrics (<18 Years) N= 1978		Adults (≥18 Years) N=2899	
	ACN Patients (n=498)	Non-ACN Asthma Controls (n=1480)	ACN Patients (n=750)	Non-ACN Asthma Controls (n=2149)
Female	210 (42.17%)	620 (41.89%)	503 (67.07%)	1459 (67.89%)
Age at Index Visit (years), mean ± SD	7.26 ± 4.70	7.20 ± 4.68	50.42 ± 16.75	50.21 ± 16.74
Objective Diagnosis (yes)	97 (19.48%)	88 (5.95%)	414 (55.20%)	287 (13.36%)
Minor ADGs				
0-4	167 (33.53%)	693 (46.82%)	151 (20.13%)	764 (35.55%)
5-6	134 (26.91%)	358 (24.19%)	185 (24.67%)	534 (24.85%)
7-8	98 (19.68%)	239 (16.15%)	179 (23.87%)	400 (18.61%)
9+	99 (19.88%)	190 (12.84%)	235 (31.33%)	451 (20.99%)
Major ADGs				
0	253 (50.80%)	887 (59.93%)	204 (27.20%)	836 (38.90%)
1	158 (31.73%)	413 (27.91%)	274 (36.53%)	697 (32.43%)
>1	87 (17.47%)	180 (12.16%)	272 (36.27%)	616 (28.66%)
Health Care Use in 1 year prior to index visit				
Asthma office visits (visits/year)	1.80 ± 1.94	0.82 ± 1.31	1.83 ± 1.82	0.50 ± 1.31
Asthma ED visits (visits/year)	0.47 ± 0.92	0.10 ± 0.40	0.25 ± 0.71	0.04 ± 0.21
Asthma inpatient hospitalizations (visits/year)	0.22 ± 0.50	0.02 ± 0.13	0.08 ± 0.32	0.00 ± 0.06
Asthma ICU visits (visits/year)	0.07 ± 0.27	0.00 ± 0.05	0.02 ± 0.16	0.00 ± 0.04

Notes: Bold indicates statistically significant ($p < 0.05$) difference between ACN vs non-ACN controls (within stratified subgroup) via unpaired t-test for continuous variables and Fisher's exact tests for categorical variables.

Abbreviations: CAN, Asthma Care Network; SD, Standard Deviation; ADGs, Aggregate Diagnosis Groups; ED, Emergency Department; ICU, Intensive Care Unit.

diagnosis of asthma coincide with their index visit, and visits beyond their initial ACN encounter may be required to optimize management. Given the stepwise approach to asthma treatment based on control criteria, individuals with their first presentation of asthma would have multiple encounters to advance therapy and ultimately achieve optimal control. Furthermore, pediatric patients overall had more acute HSU compared to adults suggesting either more severe disease, increased exposure to infectious and/or environmental triggers, or poorer overall asthma control. Furthermore, there were differences in the delivery of the ACN between adults and pediatrics during the observation period, where adult patients referred from the ED were prioritized soon after discharge in the asthma specific clinics, with more clinic time allotted to adult-specific clinics which may have introduced administrative delays in routine follow-up care after acute HSU for pediatrics. Further optimization of care can be achieved by complementing the existing care model in the ACN with novel digital and AI-based educational tools which have been proven efficacious in the context of asthma care.^{26,27}

Our study is the first to examine the impact of specialized asthma care on HSU in southern Ontario. The AMOMS dataset is a rich source of data with information on asthma confirmation, severity, control, and treatment which can be utilized in future studies to explore what factors specifically contribute to reductions in HSU. Additionally, we utilized a comprehensive database through Ontario provincial health insurance which captures all asthma-associated visits in Ontario.

There are some limitations to our work. First, our definition of asthma utilized billing codes to define our non-ACN control group. While previous studies have identified good sensitivity of 83.8% (95% CI 77.1–89.1% and a moderate specificity of 76.5% (95% CI 71.8–80.8%)) it is possible that associations are underestimated due to misclassification.¹⁹ Second, inpatient hospitalizations and ED visits were analyzed together given that few individuals had documented asthma-related inpatient hospitalizations. It is possible that the factors which lead to ED visits and inpatient hospitalizations are distinct. To minimize the impact of the large number of individuals without visits, we used a zero inflated Poisson model. Future work can examine a longer observation period following the ACN to allow for modelling of ED

Table 2 Rate Ratios of Post-Index Visit Asthma-Related HSU (ED Visits & Inpatient Hospitalizations; Count Component)

	Adults (Age ≥18 years)		Pediatric (Age <18 years)	
	Unadjusted	Adjusted	Unadjusted	Adjusted
Exposure to ACN	1.62 (1.14–2.31)	1.3 (0.90–1.88)	2.03 (1.55–2.66)	1.72 (1.30–2.26)
Minor ADGs (2 years preceding index)				
0–4	Reference			
≥5	1.08 (0.67–1.76)	0.71 (0.44–1.15)	1.26 (0.93–1.72)	1.08 (0.78–1.50)
Major ADGs (2 years preceding index)				
0	Reference			
>0	2.23 (1.35–3.69)	2.4 (1.43–4.02)	1.53 (1.17–1.99)	1.36 (1.01–1.82)
Asthma ED Visits in 1 year prior to index				
0 Visits	Reference			
> 0 Visits	1.61 (1.15–2.25)	1.38 (0.97–1.96)	1.98 (1.55–2.53)	1.69 (1.32–2.18)

Notes: Values are Rate Ratios (95% CI). Bold indicates statistically significant, $p < 0.05$.

Abbreviations: CAN, Asthma Care Network; ADGs, Aggregate Diagnosis Groups.

visit rates separately from inpatient hospitalizations. Additionally, we utilized the number of visits prior to index date as a proxy for asthma severity, which may not reflect disease severity per se, but rather asthma control and/or availability of health care services. Lastly, our dataset is from 2018, which pre-dates the introduction of many biologic therapies for asthma and may not fully reflect recent advances in asthma care. It will be pertinent in future studies to examine objective markers of asthma severity; such as pulmonary function test results, symptom severity and frequency, and/or the patient's treatment regimen. While these variables were available in AMOMS, they are not routinely collected in provincial data sources. Alternatively, an analysis which uses individuals as their own control pre-post visit and compares those in the ACN vs not enrolled in the ACN may provide a more robust estimate of the impact of the ACN while controlling for individual level factors and any residual confounding which may be present due to the non-randomized nature of the current study.

Ultimately, enrolment in a specialized asthma care model has a demonstrable positive impact with a significant reduction in acute HSU related to asthma, providing further evidence of the importance of interdisciplinary specialist care to achieve asthma control. These results support the conclusion that sustained, guideline-based follow-up after acute exacerbations leads to demonstrable improvements in asthma outcomes. The ACN model used in Southeastern Ontario can be utilized in other jurisdictions to help reduce the growing burden of asthma-related HSU and improve patient outcomes. This can be easily implemented within existing models of care for asthma. Future work should investigate patient and process of care factors associated with improvement in HSU, as well as novel artificial intelligence and technology-based models to further optimize care delivery, adherence, and patient outcomes.

Abbreviations

ED, Emergency Department; HSU, Health Service Utilization; ACN, Asthma Care Network; AMOMS, Asthma Management and Outcomes Monitoring System; ICES, Institute for Clinical Evaluative Sciences; RPDB, Registered Persons Database; ADG, Aggregate Diagnosis Group; ICD, International Classification of Diseases; OHIP, Ontario Health Insurance Plan.

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Disclosure

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