# Using decision support for population tracking of adherence to recommended asthma guidelines

| | |
|---|---|
| Journal: | *BMJ Open* |
| Manuscript ID: | bmjopen-2013-003759 |
| Article Type: | Research |
| Date Submitted by the Author: | 07-Aug-2013 |
| Complete List of Authors: | Ahmed, Sara; McGill University, Faculty of Medicine<br>Tamblyn, Robyn; McGill University, Faculty of Medicine<br>Winslade, Nancy; McGill University, Faculty of Medicine |
| Primary Subject Heading: | Health informatics |
| Secondary Subject Heading: | Health informatics, Medical management |
| Keywords: | Asthma < THORACIC MEDICINE, Health informatics < BIOTECHNOLOGY & BIOINFORMATICS, EPIDEMIOLOGY |
| | |

## Article Summary

1) Article Focus –

- The objective of this study was to evaluate the discrepancy between actual asthma treatments prescribed by primary care physicians compared to those recommended by evidence-based guidelines using a decision support tool linked to a provincial health administrative database.

2) Key Messages - up to three bullet points outlining the key messages and significance of the study.

- Decision support systems that define evidence-based guidelines, linked to an administrative database, can be used to identify individuals with uncontrolled asthma or prescriptions that deviate from recommended treatment at a population level.
- When connected to the point of care, discrepancies between decision support and actual care can provide an opportunity for physicians to intervene early.
- The methods and approach from the current study can be used to evaluate adherence to evidence-based guidelines and indicators of disease management for other patient populations, at a population level if administrative databases are available or at the point of care if linked to an electronic health record.

3) Strengths and Limitations

- The availability of a provincial administrative database and decision support system allowed us to assess guideline adherence, and to identify sub-groups of individuals at risk of poor outcomes.
- The administrative database only includes individuals who are provincially insured and therefore discrepancies could not be examined for individuals with private insurance.

- The proportion of individuals with poor asthma control may have been underestimated as control status was evaluated over a 3-month period.

# Using decision support for population tracking of adherence to recommended asthma guidelines

**Sara Ahmed [1,3,4], Robyn Tamblyn [2,3], Nancy Winslade [2,3]**

[1]Faculty of Medicine, School of Physical and Occupational Therapy, McGill University
3654 Prom. Sir William Osler, Montreal, QC, H3G 1Y5, Canada

[2]Faculty of Medicine, Clinical and Health Informatics, McGill University
1140 Pine avenue west, Montreal, QC, H3A 1A3, Canada

[3] McGill University Health Center, Clinical Epidemiology

[4] Centre de Recherche Interdisciplinaire en Réadaptation du Montréal Métropolitain

**Corresponding author**

Sara Ahmed
Faculty of Medicine, McGill University
3654 Prom. Sir William Osler, Montreal, QC, H3G 1Y5, Canada
E-mail: sara.ahmed@mcgill.ca

**Word Count:** 3092
**Figures:** 2
**Tables**: 3

**Keywords**: Asthma, clinical practice guidelines, disease management, decision support, administrative database

**What is the key question?** What is the discrepancy between actual asthma treatments individuals' receive as recorded in the provincial administrative database as compared to those recommended by evidence-based guidelines as defined within an asthma decision support system.

**What is the bottom line; and why read on?** Decision support systems that define evidence-based guidelines, linked to an administrative database, can be used to identify individuals with uncontrolled asthma or prescriptions that deviate from recommended treatment at a population level.

**Why read on?** The methods and approach from the current study can provide an opportunity for physicians to intervene early and can be used to evaluate adherence to evidence-based guidelines and indicators of disease management for other patient populations.

**Abstract**

Background: Decision support systems linked to administrative databases provide a unique opportunity to monitor adherence to guidelines and target disease management strategies to patients not receiving guideline-based therapy. Objective: The objective of this study was to evaluate the discrepancy between actual asthma treatments prescribed by primary care physicians compared to those recommended by evidence-based guidelines using a decision support tool linked to a provincial health administrative database. Methods: The drug and medical services information of individuals with asthma were identified from the provincial health database and were pushed through an asthma decision support system. Recommendations aimed at optimizing asthma treatment were generated on two index dates, September 15 2007 (index date 1) and March 15 2008 (index date 2)

Results: 16, 803 individuals with asthma and provincial health insurance were identified on index date 1, and 18, 103 on index date 2. The distribution of recommendation categories were similar on both index dates. 94% were classified as well controlled and 7% as not well controlled. Among individuals well controlled, the largest proportion of individuals were in the *maintain treatment* category (50.6%), followed by *maintain/decrease treatment* (28.2%), and *decrease treatment* (2.7%). Almost all individuals not well controlled had the recommendation to *increase treatment* (88%) with a small proportion in the *refer* category (1%). Conclusions: The ADSS was able to identify sub-groups of patients from an administrative database that could benefit from a medication review and possible change. Discussion: Decision support systems linked to an administrative database can be used to identify individuals with uncontrolled asthma or prescriptions that deviate from recommended treatment. When connected to the point of care, this can provide an opportunity for physicians to intervene early.

## Introduction

Asthma poses a significant burden on healthcare resources and costs, [1] and results in reduced individual functioning and quality of life. [2, 3] Over the past 10 years there have been tremendous improvements in the scientific understanding of asthma and its treatment, and these findings have been made available to clinicians through the development of clinical practice guidelines. Despite achieving such sentinel milestones in asthma care, over 50% [4, 5] of individuals remain poorly controlled in the U.S. and Canada, with similar estimates worldwide. [6] This has translated into $306 million per year in direct costs for providing health management for approximately 2.2 million Canadians diagnosed with asthma. With appropriate disease management over $135 million in costs and reductions in physical and mental health can be prevented. [7]

Healthcare organizations worldwide have been charged with improving asthma outcomes over the next 2-3 years, with the aim of reducing hospitalizations and deaths related to asthma. [8] Several barriers for optimal management result in poor outcomes for asthma, [9] including clinician-related (non-adherence to guidelines), patient-related (non-adherence to treatment), and treatment- related barriers (cost, complexity of treatment). In moving towards improving clinical outcomes potentially modifiable barriers must be identified and targeted through appropriate interventions. A mechanism is needed to identify problematic asthma management so that gaps in care and barriers can be further evaluated and managed.

One potentially modifiable barrier is the gap between optimal versus actual asthma management as reflected by the lack of adoption of guidelines by clinicians or non-adherence of patients to recommended care. [10, 11] Much of the costs of asthma care are related to poor disease control

due to under-use of effective prophylactic therapies, and inadequate monitoring of disease control. At a population level there are few mechanisms available for tracking disease-management indicators for asthma to evaluate the current application of guidelines. Several studies have evaluated divergence from asthma guidelines, [12, 13] but have not been able to accurately estimate non-adherence to guidelines among a representative sample of individuals. Evaluations of adherence have mostly relied on chart reviews and clinician or patient reports which are difficult to complete for a large number of patients across several healthcare settings. [14-16]

Decision support systems are designed to facilitate uptake of evidence- based guidelines with the expectation that adherence to such guidelines will improve health outcomes. [17] Typically, decision support systems are used at the point of care. Such systems, however, may also have an alternate benefit of allowing population monitoring of adherence to disease management guidelines when the decision support algorithms are linked to administrative databases. By pushing through administrative health data including diagnoses, healthcare utilization and medication information, algorithms can be used to generate recommendations for optimizing treatment. In turn, patterns of under-optimization of treatment can be identified to monitor adherence to guidelines and target specific physician and patient sub-groups with disease management interventions.

The implementation of an asthma decision support system linked to provincial health insurance information represents a novel approach and facilitates the evaluation of the gap between recommended and actual treatment. We have developed a new methodology for assessing the quality of asthma management and asthma control in the population. Using evidence based decision-support systems developed to guide physicians using computerized physician order entry and electronic medical record systems, we developed a program for sequentially entering, assessing

and extracting individual and summarized population level quality monitoring and control status indicators. Using population level administrative data for over 16,000 asthma patients, we then used this program to evaluate asthma status and quality of adherence to national guidelines in a Quebec population on two randomly selected days in the spring and fall. This information is needed for asthma management, and can be used for identifying opportunities to target interventions and improve asthma outcomes.

In this study we examined the discrepancy between actual asthma treatments as recorded in the provincial administrative database compared to those recommended by evidence-based guidelines as defined in the asthma decision support system on two index dates.

## METHODS

### Study population

The drug and medical services information of patients cared for by primary care physicians (PCP) participating in the Medical Office of the 21st Century(MOXXI) study [18] in a large metropolitan area was used to evaluate adherence to asthma treatment guidelines. PCPs were identified by professional association master lists and contacted by letter and telephone to determine their interest in participating in the MOXXI project. Patients of these physicians were identified from the Quebec provincial health data base (RAMQ) medical service claims, physician, and beneficiary files. McGill University IRB approval was obtained for this study and PCPs who accepted provided consent for the research team to receive patient anonymised administrative data.

All patients with an ICD 9 code for asthma, with no prior diagnosis for COPD, and who were $\geq 5$ years old were identified from RAMQ based on algorithms validated in prior research. [19] For the

purposes of this study, only patients with full drug coverage by RAMQ were included to ensure that all drugs dispensed were captured.

**The provincial drug and administrative database (RAMQ)**

The RAMQ beneficiary demographic database provided data on individual age, gender, and mortality, and census data provided income and education. [20] Information on each drug dispensed was obtained from the prescription claims database and included the drug name, quantity, date, and duration for each prescription. The medical services claims database provided information on the beneficiary, date, type, provider, and location of service delivery (e.g., inpatient, emergency, clinic) for all medical services remunerated on a fee-for-service basis.

**Study Procedure: Evaluating the gap between actual and recommended asthma treatment using the Asthma Decision Support System (ADSS)**

The ADSS is integrated into the MOXXI electronic prescribing drug management application with patient information retrieved by real-time integration with the beneficiary, prescription and medical services claims files of the RAMQ. Using information from the prescription drug management platform, the ADSS uses the profile of existing drugs and health problems to customize recommended changes in asthma drug therapy. For this study, recommendations aimed at optimizing asthma treatment were generated on two index dates, September 15 2007 (index date 1) and March 15 2008 (index date 2), representing peak times for asthma symptoms.

In the ADSS, asthma control is determined based on overuse of short acting beta agonists (SABA) and visits to the Emergency Department (ED) for a respiratory problem over a 3 month period before the index date. Based on a previously validated algorithm, a patient is considered to be not

well controlled if the sum of the quantity of all SABA medications dispensed to the patient within the last 3 months exceeds 250 doses1, [21] and/or they visited an ED for a respiratory related problem in the last 3 months. Only asthma drugs that were 1) prescribed and dispensed within one year of the index date, and 2) active (i.e. based on prescription algorithms it is likely that the person has a supply of the medication) or expired within 30 days prior to the index date were considered when generating the recommendations.

Patient-specific recommendations related to drug therapy are translated into pre-formatted prescriptions in the drug management platform. The ADSS is structured to support the Canadian Consensus guidelines for Asthma Management. [22] Recommendations are categorised based on control status. For individuals in control, recommendations generated are one of three categories: maintain treatment, decrease treatment, or maintain or decrease treatment. Recommendations also include options for action plan prescriptions for patients who are in control. For individuals not well controlled recommendations are either to increase treatment or to refer to a specialist. Within each recommendation category, physicians are presented with specific recommendations for medications and doses to achieve the desired level of drug treatment.

**Data Analysis**

Results were calculated for each index date. Descriptive statistics were used to characterize the study population and to evaluate differences between individuals with and without RAMQ coverage for prescription drugs. For individuals with RAMQ coverage, the proportion of individuals under each recommendation category was evaluated among individuals classified as 'well controlled' and 'not well controlled', and descriptive statistics were used to compare the characteristics of patients across categories. Multivariable logistic regression was used to estimate the probability of being

[1] 250 doses is based on the most commonly prescribed SABA salbutamol 100mcg, 2 inhalations at a time, or the equivalent for other fast acting bronchodilators in the last three months.

classified in control or not well controlled as a function of sociodemographic characteristics and healthcare utilization.

## Results

*Study Population and Insured Compared to Non-Insured*

47, 614 individuals with an asthma diagnosis were identified on index date 1, after removing individuals with a prior diagnosis of COPD (6018) and those ≤ 5 years old (Figure 1). Thirty five percent of individuals were RAMQ insured for prescription drugs at least 75% of the year prior to the index date, for both dates. On index date 2, 51 306 individuals with an asthma diagnosis were identified (Figure 2). Approximately the same proportion of individuals was classified as well controlled on index date 1 (93 %) and index date 2 (94%). As the distribution of individual characteristics, control status, and recommendation categories were similar on both index dates, we only report the results from index date 2 from this point on (Table 1).

Individuals who were RAMQ insured were on average older (mean=38±22) as compared to non-RAMQ insured individuals (mean=31±18) and had a greater percentage of individuals ≥ 60 years old, a larger proportion was female (61% versus 56%), and in the lower SES category (21% versus 6%). A greater proportion of RAMQ insured patients had 3 or more ED (16 versus 9%) and hospital visits (8 versus 3%) one year prior to the index date, and a diagnostic code for anxiety (11 compared to 7%) or depression (8 compared to 5%).

**Table 1: Characteristics of Study Participants with and without provincial health coverage (RAMQ)**

| | RAMQ Coverage | No RAMQ Coverage |
|---|---|---|
| | n=18 013 | n=33 293 |
| **Age mean (sd)** | 38,3 (21,8) | 30,81 (17,5) |
| **Age n (%)** | | |
| ≤ 17 | 3 963 (22,0 ) | 10 273 (30,9) |
| 18-39 | 5 129 (28,6 ) | 9 926 (29,8) |
| 40-59 | 5 254 (29,2) | 11 277 (33,9) |
| ≥ 60 | 3 637 (20,2) | 1 817 (5,5) |
| **Sex n (% female)** | 11 035 (61,3) | 18 665 (56,1) |
| **Income n (%) *** | | |
| Low SES | 3 490 (19,4) | 2 665 (8,0) |
| Middle SES | 13 148 (73.0) | 25 947 (78,0) |
| High SES | 1 230 (6,8 ) | 4 298 (13,0) |
| **Healthcare Utilization over 1 year prior to March 15, 2008** | | |
| **Medical *Phycisian* Visits** n (%)** | | |
| 0 visit | 1 736 (9,6 ) | 3 855 (11,6) |
| 1 visit | 1 998 (11,1) | 4 453 (13,4) |
| 2 visits | 1 895 (10,5) | 4 154 (12,5) |
| 3 or more visits | 12,384 (68,8) | 20 831 (62,6) |
| **Emergency Department Visits n (%)** | | |
| 0 visit | 10 435 (57,9) | 22 738 (68,0 ) |
| 1 visit | 3 139 (17,4) | 5 445 (16,4) |
| 2 visits | 1 698 (9,4) | 2 416 (7,3) |
| 3 or more visits | 2 741 (15,2) | 2 694 (8,1) |
| **Emergency Department Visits for asthma n (%)** | 1 313 (7,3) | 1 644 (4,9) |
| **Hospitalization** | | |
| 0 day | 14 890 (82,7) | 29 445 (88,4) |
| 1 day | 1 340 (7,4) | 2 072 (6,2) |
| 2 days | 445 (2,5) | 658 (2,0) |
| 3 or more days | 1 338 (7,4) | 1 118 (3,4) |
| **Co-Morbidity n (%)** | | |
| Depression | 1 400 (7,77) | 1 724 (5,2) |
| Anxiety | 1 913 (10,62) | 2 361 (7,1) |

* Around 1 % of missing values for each category

** Ambulatory and specialty care

*Control Status and Recommendation Categories*

Among the 18 013 individuals who were RAMQ insured for prescription drugs, 94% were classified as well controlled and 7% as not well controlled over 3 months prior to the index date (Figure 1).

63 % of individuals who were not well controlled were in the ≥ 40 age group and 26% in the low SES category compared to 49% and 19%, respectively, in the well controlled group. These individuals also had a higher Charlson Co-morbidity Index of 2.11 as compared to 1.6 among those well controlled. A larger proportion of individuals among those not well controlled had a diagnostic code for depression, anxiety, mental illness, and a cardiac related condition. Among those not well controlled 69% (n=667) had at least 1 ED visit (past 3 months), and 74% a medical visit associated with a respiratory problem (in the past year). In comparison 13% (n=2,039) of those well controlled had at least one ED visit and 52% medical visit related to a respiratory problem.

53% of patients in the not well controlled group had an active prescription for an ICS, 20% a combination therapy, and 14% as compared to 36%, 10%, and 6% in the well controlled group. 63% and 42% of not well and well controlled, respectively, had an active prescription for a fast-acting beta agonist (FABA). At index date 1, all individuals not well controlled had asthma drugs as compared to 9.2 % of those well controlled who had no asthma drugs dispensed.

Table 2 presents the incremental regression coefficients for the demographic, healthcare utilization, and co-morbidity variables hypothesized to be associated with control status. Healthcare utilization including, ≥ 3 days of hospitalization (OR=4.58), and ≥ 3 visits to the ED (for reasons other than a respiratory problem) (OR=2.32), was found to be most strongly associated with control status.

Being male (OR=.85), from a low SES (OR= 1.9), and in the 40-59 age group increased the odds of having asthma that was not well controlled.

**Table 2: Multivariable Logistic Regression Models for Identifying Individuals Controlled and Not Well Controlled**

| Variable | OR (95%CI) Control Status |
|---|---|
| **Age mean (sd)** | |
| ≤ 17 | Reference |
| 18-39 | 0.56 (0.44, 0.72) |
| 40-59 | 2.19(1.73, 2.77) |
| ≥ 60 | 1.19 (1, 1.42) |
| **Sex n (% female)** | . |
| Male | Reference |
| Female | 85 (.74, .98) |
| **Income n (%) *** | |
| High SES | Reference |
| Middle SES | 1.44 (1.04, 1.98) |
| Low SES | 1.90 (1.35, 2.68) |
| **Healthcare Utilization over 1 year prior to March 15, 2008** | |
| Medical *Physician* *Visits n (%) | |
| 0 visit | Reference |
| 1 visit | .73 (.47,1.2) |
| 2 visits | .82 (.53,1.28) |
| ≥ 3 visits | 1.62 (1.162.27) |
| **Emergency Department Visits (other than resp)n (%)** | |
| 0 visit | Reference |
| 1 visit | 1.38(1.14,1.66) |
| 2 visits | 1.46(1.16,1.84) |
| ≥3 visits | 2.32(1.94,2.8) |
| **Hospitalisation** | |
| 0 day | Reference |
| 1 day | 2.24(1.55,3.27) |
| 2 days | 2.88(1.79,4.6) |
| 3 or more days | 4.58 (3.36,6.22) |
| **Co-Morbidity n (%)** | |
| Charlson co-morbidity index | 1.04 (1.01, 1.08) |
| Anxiety No | Reference |
| Yes | 1.26 (1.05,1.52 ) |

* General practitioner and specialist

***Recommendation category by control group***

The distribution of individuals across recommendation categories is presented in Table 3.

For 8% (1198/15843) in control, and 21% (201/960) of those not well controlled, a recommendation could not be determined by the ADSS either because the patient 1) had dispensed prescriptions for an inappropriate combination of medications that the ADSS could not reconcile to provide an appropriate recommendation (e.g. a LABA with two prescriptions for combination therapy) or, 2) dispensed two medications that resulted in a duplication of therapy. For those not well controlled, those in the *duplicate/inappropriate* category had a larger proportion in the lower SES, a higher co-morbiditiy index and more frequent ambulatory and hospital visits.

Among individuals well controlled, the largest proportion of individuals were in the *maintain treatment* category (50.6%), followed by *maintain/decrease treatment* (28.2%), and *decrease treatment* (2.7%). Almost all individuals not well controlled had the recommendation to *increase treatment* (88%) with a small proportion in the *refer* category (1%). Reasons for the low referral to specialty care needs to be closely examined, and may be related to uncertainty of primary care physicians of when to refer patients, and/or patients may not go see specialists once referred. [23] Regardless of the recommendation category, the largest proportion of individuals was in the 40-59 age group; except for *maintain treatment* that had a larger proportion of individuals in the 18-39 age group. The middle SES was the largest for all recommendation groups and the proportion of females was the same across all categories. Individuals in the *refer* category were on average older than those in the other categories, but comparable on many of the other characteristics.

**Table 3: Comparison of characteristics of individuals in each recommendation category (based on primary recommendation).**

| | In Control N=14989 | | | | Not Well Controlled N=1245 | | |
|---|---|---|---|---|---|---|---|
| | **Maintain n=9564** | **Maintain/Decrease n=4349** | **Decrease n=474** | **Duplicate/ Inappropriate n=602** | **Increase n=1 090** | **Refer n=17** | **Duplicate/ Inappropriate n=138** |
| **Age mean (sd)** | 41,8 (19,2) | 38,2 (22,7) | 44,8 (21,6) | 45,9 (20,3) | 40,4 (21,5) | 57,1 (9,3) | 46,6 (16,0) |
| **Age n (%)** | | | | | | | |
| ≤ 17 | 919 (9,6) | 1 115 (25,6) | 74 (15,6) | 68 (11,3) | 189 (17,3) | 0 | 6 (4,4) |
| 18-39 | 3 561 (37,2) | 996 (22,9) | 86 (18,1) | 123 (20,4) | 310 (28,4) | 0 | 33 (23,9) |
| 40-59 | 2 987 (31,2) | 1 269 (29,2) | 195 (41,1) | 260 (43,2) | 372 (34,1) | 10 (58,8) | 79 (57,2) |
| ≥ 60 | 2 097 (21,9) | 969 (22,3) | 119 (25,1) | 151 (25,1) | 219 (20,1) | 7 (41,2) | 20 (14,5) |
| **Sex n (% F)** | 6 073 (63,5) | 2 659 (61,1) | 303 (63,9) | 381 (63,3) | 709 (65,0) | 12 (70,6) | 101 (73,2) |
| **Income n (%) *** | | | | | | | |
| Low SES | 1 684 (17,6) | 923 (21,2) | 117 (24,7) | 156 (25,9) | 237 (21,7) | 4 (23,5) | 43 (31,2) |
| Middle SES | 7 028 (73,5) | 3 161 (72,7) | 330 (69,6) | 420 (69,8) | 802 (73,6) | 13 (76,5) | 90 (65,2) |
| High SES | 763 (8,0) | 228 (5,2) | 25 (5,3) | 22 (3,6) | 47 (4,3) | 0 | 5 (3,6) |
| **Medical Visits mean (sd) past year** | | | | | | | |
| *All* | 8,78 (13,1) | 9,68 (13,8) | 12,62(13,3) | 12,87(13,4) | 16,52 (22,2) | 29,29 (21,3) | 24,99 (26,1) |
| *Ambulatory* | 7,72 (9,6) | 8,31 (9,2) | 10,89 (9,5) | 11,13 (9,5) | 13,53(15,0) | 19,94 (10,0) | 20,01 (18,1) |
| *Hospitalized* | 1,07 (6,8) | 1,37 (7,7) | 1,73 (7,4) | 1,73 (7,6) | 2,99 (11,6) | 9,35 (16,4) | 4,98 (13,3) |
| **Medical Visits n (%) past year** | | | | | | | |
| ***Phycisian*** | | | | | | | |
| 0 visit | 1 036 (10,8) | 265 (6,1) | 14 (3,0) | 22 (3,6) | 62 (5,7) | 0 | 7 (5,1) |
| 1 visit | 1048 (10,96) | 451 (10,4) | 31 (6,5) | 40 (6,6) | 76 (7,0) | 0 | 5 (3,6) |
| 2 visits | 1000 (10,5) | 486 (11,2) | 41 (8,6) | 26 (4,3) | 81 (7,4) | 0 | 2 (1,4) |
| 3 or more visits | 6 480 (67,8) | 3 147 (72,4) | 388 (81,9) | 514 (85,4) | 871 (79,9) | 17 (100) | 124 (89,9) |
| ***ER*** | | | | | | | |
| 0 visit | 5 995 (62,7) | 2 501 (57,5) | 240 (50,6) | 289 (48,0) | 200 (18,4) | 1 (5,9) | 25 (18,1) |
| 1 visit | 1 565 (16,4) | 790 (18,2) | 89 (18,8) | 118 (19,6) | 221 (20,3) | 3 (17,6) | 21 (15,2) |
| 2 visits | 846 (8,8) | 414 (9,5) | 59 (12,4) | 63 (10,5) | 172 (15,8) | 1 (5,9) | 9 (6,5) |
| 3 or more visits | 1 158 (12,1) | 644 (14,8) | 86 (18,1) | 132 (21,9) | 497 (45,6) | 12 (70,6) | 83 (60,2) |
| **ED- for respiratory problems** | | | | | | | |
| 0 visit | 8 781 (91,8) | 3 792 (87,2) | 394 (83,1) | 491 (81,6) | 294 (27,0) | 4 (23,5) | 38 (27,5) |
| 1 visit | 593 (6,2) | 402 (9,2) | 52 (11,0) | 64 (10,6) | 450 (41,3) | 4 (23,5) | 27 (19,6) |
| 2 visits | 142 (1,5) | 105 (2,4) | 15 (3,2) | 25 (4,2) | 188 (17,2) | 3 (17,65) | 22 (15,9) |
| 3 or more visits | 48 (0,5) | 50 (1,2) | 13 (2,7) | 22 (3,7) | 158 (14,5) | 6 (35,3) | 51 (37,0) |
| **ED- NOT for respiratory problems** | | | | | | | |
| 0 visit | 6 268 (65,5) | 2 712 (62,4) | 265 (55,9) | 326 (54,2) | 456 (41,8) | 4 (23,5) | 45 (32,6) |
| 1 visit | 1 535 (16,1) | 742 (17,1) | 94 (19,8) | 118 (19,6) | 205 (18,8) | 3 (17,6) | 29 (21,0) |
| 2 visits | 746 (7,8) | 370(8,5) | 49 (10,3) | 58 (9,6) | 117 (10,7) | 3 (17,6) | 14 (10,1) |
| 3 or more visits | 1 015 (10,6) | 525 (12,1) | 66 (13,9) | 100 (16,6) | 312 (28,6) | 7 (41,2) | 50 (36,2) |
| **Hospitalization** | | | | | | | |
| 0 day | 8 046 (84,1) | 3 581 (82,3) | 356 (75,1) | 449 (74,6) | 774 (71,0) | 5 (29,4) | 78 (56,5) |
| 1 day | 697 (7,3) | 318 (7,3) | 39 (8,2) | 62 (10,3) | 100 (9,2) | 3 (17,6) | 17 (12,3) |
| 2 days | 215 (2,2) | 107 (2,5) | 20 (4,2) | 23 (3,8) | 44 (4,0) | 1 (5,9) | 3 (2,2) |
| 3 or more days | 606 (6,3) | 343 (7,9) | 59 (12,4) | 68 (11,3) | 172 (15,8) | 8 (47,1) | 40 (29,0) |

| | In Control N=14989 | | | | Not Well Controlled N=1245 | | |
|---|---|---|---|---|---|---|---|
| | **Maintain n=9564** | **Maintain/Decrease n=4349** | **Decrease n=474** | **Duplicate/ Inappropriate n=602** | **Increase n=1 090** | **Refer n=17** | **Duplicate/ Inappropriate n=138** |
| **Hospitalization- for respiratory problems** | | | | | | | |
| 0 day | 9 370 (98,0) | 4 210 (96,8) | 447 (94,3) | 563 (93,5) | 990 (90,8) | 14 (82,4) | 109 (79,0) |
| 1 day | 100 (1,0) | 60 (1,4) | 7 (1,5) | 20 (3,3) | 33 (3,0) | 0 | 7 (5,1) |
| 2 days | 32 (0,3) | 32 (0,74) | 4 (0,8) | 5 (0,8) | 14 (1,3) | 0 | 3 (2,2) |
| 3 or more days | 62 (0,6) | 47 (1,1) | 16 (3,4) | 14 (2,3) | 53 (4,9) | 3 (17,6) | 19 (13,8) |
| **Asthma Medications** | **mean (sd) range past year** | | | | | | |
| FABA | 0,61 (1,7) | 2,93 (3,8) | 4,32 (5,2) | 4,95 (5,1) | 2,50 (4,4) | 5,00 (5,2) | 6,82 (6,8) |
| ICS | 0,2 (0,7) | 2,3(2,9) | 1,4(2,6) | 3,6(3,8) | 1,4(2,4) | 0,9 (1,7) | 3,5(3,9) |
| Leukotrienes | 0,1 (1,4) | 0,4(3,0) | 6,7(10,0) | 1,5 (4,8) | 0,8(4,4) | 3,3(5,1) | 3,9 (11,5) |
| Combination Therapy | 0,0 (0,4) | 1,2 (2,9) | 5,1(4,9) | 2,18 (3,9) | 1,0 (2,7) | 7,7 (4,5) | 3,0 (4,3) |
| Other | 0,2(1,8) | 0,8(3,4) | 2,9(6,8) | 2,36 (3,9) | 1,8(17,0) | 2,1 (2,5) | 4,45 (6,6) |
| **Control Status n (%)** | | | | | | | |
| Overuse FABA | 0 | 0 | 0 | 0 | 1 (0,1) | 0 | 0 |
| ER visits for Asthma | 0 | 0 | 0 | 0 | 1 076 (98,7) | 17 (100) | 135 (97,8) |
| ER or FABA | 0 | 0 | 0 | 0 | 1 076 (98,7) | 17 (100) | 135 (97,8) |
| **Co-Morbidity Index** | 1,6 (1,5) | 1,6 (1,5) | 1,8 (1,6) | 1,9 (1,9) | 1,8(2,0) | 2,2 (1,4) | 2,6 (2,5) |

- Less than 1 % of missing values for each category
- ED=emergency department

## DISCUSSION

The purpose of this study was to evaluate the discrepancy between current asthma management and recommended guidelines using the provincial administrative databases and an ADSS. The present study represents an example of how decision support systems can be used to monitor guideline adherence, and to identify individuals at risk of poor outcomes to provide targeted interventions. To our knowledge this is the first time that a decision support system has been used to evaluate disease management at a population level.

As expected, individuals who were provincially insured were on average older, from a lower SES, and a higher proportion used healthcare services. A larger proportion compared to those non-provincially insured also had a diagnosis code for anxiety and depression.

The algorithms used to identify individuals with asthma and evaluate control status were validated in previous work. [24, 25] The majority of individuals well controlled were on an appropriate quantity of asthma treatment. We found, however, that ~ 31% of those well controlled could benefit from a medication review and potentially lower doses of asthma medications.

The majority of individuals not well controlled had the recommendation to increase treatment and for these individuals there was an opportunity to change therapy according to the existing guidelines. [26] The SMART inhaler helps address needs for increase in therapy, as it allows patients to use their as-needed medication because of declining asthma control—as is very often the case—evolving exacerbations will possibly be treated at an early stage and a further worsening of asthma may possibly be prevented. The SMART inhaler is not a recommended yet part of

Canadian guidelines, however, with emerging evidence of its benefits for marinating control compared to other alternatives, [27, 28] it will be included in the next version of guidelines and become more commonly prescribed for Canadian patients. Individuals who were not well controlled were in the 40-59 age range, and had a more complex health profile with greater co-morbidity, including a higher proportion with a diagnosis of anxiety or depression as compared to those well-controlled. The logistic regression analysis in our study also supported these conclusions. These individuals represent a more vulnerable sub-group of the asthma population, and place a greater burden on the healthcare system given the higher proportion that had an ED visit or hospitalization. As such, they require closer monitoring and review of medication to reach doses sufficient to maintain asthma control, or to review reasons for failed treatment.

In this study we were not able to generate a recommendation for a larger proportion of individuals not well controlled compared to controlled either because they were dispensed prescriptions for an inappropriate combination of medications that the ADSS could not reconcile to provide an appropriate recommendation, or they were dispensed two medications that resulted in a duplication of therapy. These cases in themselves represent a segment of the asthma population that requires closer review of their prescribed medication.

The generation of asthma recommendations at a population level using an administrative database allows individuals not receiving treatment based on guidelines to be identified. We found that many individuals with non-controlled asthma visit a physician 3 or more times per year, and potentially represent missed opportunities to optimize treatment. Possible reasons for our findings may include the lack of knowledge of PCPs of guidelines in general, especially for more complicated cases. It may also be, however, that patients are not going to see the same physician, or are switching

physicians to ensure access to SABAs. In such situations, physicians may be reluctant to conduct a complete medication review if they do not perceive themselves as the primary provider for the patient.

Other physician concerns may be the reluctance to prescribe ICS and/or concern regarding polypharmacy with multiple inhalers. [29] This is where the role of pharmacists is important as they can see individuals' entire medication dispensing history and have been shown to be effective in managing asthma patients in particular if supported by an ADSS. [30]

Previous studies have also found that physicians do not adopt guidelines in their practice because of perceived appropriateness of the guidelines. [13, 31] Surveys have shown that they believe that guidelines do not take into account the heterogeneity of asthma and do not account for individual patient variations in response to treatment, [32] and other factors that impact response to asthma therapy such as age and co-morbidities.

Further, patient non-adherence to prescribed therapy and not having prescribed medications filled may also explain the findings from our study. Patient beliefs about the negative impact and benefits of their medications, [33] their confidence to manage their asthma, and not seeking care early enough to prevent exacerbations have all been identified as contributors to poor outcomes for asthma.

Mechanisms to identify patients who need closer follow-up and evaluation have been identified as an important need for primary healthcare. [3, 34, 35] Future initiatives can include linking administrative databases to decision support systems that can help identify individuals who need

closer monitoring and follow-up and allow for targeted services such as visit reminders sent to patients or to their care provider. The ongoing implementation of electronic health records and patient health portals will facilitate this approach. Information can be fed back to physicians and pharmacists to improve patient management, and initiate care early on, before individuals experience deteriorations in health.

**Limitations**

Our approach for identifying individuals with asthma and assessing asthma status may have underestimated the percentage out of control in our study. We examined asthma control on two index dates, and went back 3 months prior to the index date to assess control status. A more sensitive algorithm that treats control as a time varying covariate would likely provide a more accurate evaluation of control status. In addition, at the time that the ADSS was being developed, the SMART treatments, that allow for the same inhaler to be used as a preventative and rescue inhaler were not commonly used or part of the guidelines. Therefore, they were not programmed as part of the ADSS and not included in the recommendations.

Further, use of decision support during clinical encounters allow for a patient-reported assessment of symptoms at the time when recommendations are generated, and allow for a more accurate assessment of asthma control. We were also limited to generating recommendations for those provincially insured that represent a more vulnerable segment of the population.

**Conclusions**

This study demonstrated how a decision support system linked to an administrative database could be used to identify individuals in the population that require a review of asthma treatment. Such an approach can help identify individuals with uncontrolled asthma or prescriptions that deviate from

recommended treatment to intervene early. This study provides a model for monitoring adherence to guidelines for other chronic conditions such as hypertension and diabetes.

**Funding Support**

Health Canada and the Canadian Institute of Health Research supported the development of the asthma decision support system. S Ahmed is supported by a Fonds de la Recherche en Santé du Quebec (FRSQ) research career award.

Ahmed, Tamblyn,Winslade

**References**

1. Shenolikar R, Song X, Anderson JA, et al. Costs of asthma among US working adults. *Am J Manag Care* 2011;17:409-16.

2. Schatz M, Zeiger RS, Yang SJ, et al. The relationship of asthma impairment determined by psychometric tools to future asthma exacerbations. *Chest* 2012;141:66-72.

3. Urrutia I, Aguirre U, Pascual S, et al. Impact of anxiety and depression on disease control and quality of life in asthma patients. *J Asthma* 2012;49:201-8.

4. Colice GL, Ostrom NK, Geller DE, et al. The CHOICE survey: high rates of persistent and uncontrolled asthma in the United States. *Ann Allergy Asthma Immunol* 2012;108:157-62.

5. Glaxo Wellcome I. 2000:1-31.

6. Bousquet J, Mantzouranis E, Cruz AA, et al. Uniform definition of asthma severity, control, and exacerbations: document presented for the World Health Organization Consultation on Severe Asthma. *J Allergy Clin Immunol* 2010;126:926-38.

7. Krahn MD, Berka C, Langlois P,et al. Direct and Indirect Costs of Asthma in Canada, 1990 3465. *CMAJ* 1996;154:821-31.

8. US Department of Health and Human Services OoDPaHP. Healthy People 2020 Washington,DC, 2010.

9. Maciejewski ML, Chen SY, Au DH. Adult asthma disease management: an analysis of studies, approaches, outcomes, and methods. *Respir Care* 2009;54:878-86.

10. Legorreta AP, Christian-Herman J, O'Connor RD,et al. Compliance with National Asthma Management Guidelines and Specialty Care: A Health Mantenance Organization Experience. *Arch Intern Med* 1998;158:457-64.

11. Adams RJ, Fuhlbrigge A, Guilbert T, et al. Inadequate use of asthma medication in the United States: results of the asthma in America national population survey. *J Allergy Clin Immunol* 2002;110:58-64.

12. Flor-Escriche X, Rodriguez-Mas M, Espiau M, et al. Compliance with guidelines in the treatment of asthma exacerbations in primary care. *Ther Adv Respir Dis* 2011;5:369-75.

13. Rank MA, Liesinger JT, Ziegenfuss JY, et al. The impact of asthma medication guidelines on asthma controller use and on asthma exacerbation rates comparing 1997-1998 and 2004-2005. *Ann Allergy Asthma Immunol* 2012;108:9-13.

14. Cazzola M, Segreti A, Bettoncelli G, et al. Change in asthma and COPD prescribing by Italian general practitioners between 2006 and 2008. *Prim Care Respir J* 2011;20:291-8.

15. Arnlind MH, Wettermark B, Nokela M, et al. Regional variation and adherence to guidelines for drug treatment of asthma. *Eur J Clin Pharmacol* 2010;66:187-98.

16. Lougheed MD, Olajos-Clow J, Szpiro K, et al. Multicentre evaluation of an emergency department asthma care pathway for adults. *CJEM* 2009;11:215-29.

17. Roshanov PS, Misra S, Gerstein HC, et al. Computerized clinical decision support systems for chronic disease management: a decision-maker-researcher partnership systematic review. *Implement Sci* 2011;6:92.

18. Tamblyn R, Huang A, Perreault R, et al. The medical office of the twenty-first century (MOXXI): evaluation of the effectiveness of computerised decision support in reducing inappropriate prescribing in primary care. *CMAJ* 2003;169:549-56.

19. Kawasumi Y, Abrahamowicz M, Ernst P, et al. Development and validation of a predictive algorithm to identify adult asthmatics from medical services and pharmacy claims databases. *Health Serv Res* 201;46:939-63.

20. Tamblyn RM, Laprise R, Hanley JA, et al. Adverse events associated with prescription drug cost-sharing among poor and elderly persons. *JAMA* 2001;285:421-9.

21. Schatz M, Zeiger RS, Vollmer WM, et al. Validation of a beta-agonist long-term asthma control scale derived from computerized pharmacy data. *J Allergy ClinImmunol* 2006;117:995-1000.

22. Lemiere C, Bai T, Balter M, et al. Adult Asthma Consensus Guidelines update 2003. *Can Respir J* 2004;11 (Suppl A):9A-18A.

23. Archives of Internal Medicine. *JAMA*. 2001;161.

24. Spitzer WO, Suissa S, Ernst P, et al. The use of beta-agonists and the risk of death and near death from asthma. *N Engl J Med* 1992;326:501-6.

25. Wilchesky M, Tamblyn RM, Huang A. Validation of Diagnostic Codes in Medical Services Claims Data. *Can J Clin Pharmacol* 2001;8:39-39.

26. Becker A, Lemiere C, Berube D, et al. Summary of recommendations from the Canadian Asthma Consensus guidelines, 2003. *CMAJ* 2005;173(Suppl 6):S3-11.

27. Boursquet J, Boulet LP, Peters MJ, et al. Budesonide/formoterol for maintenance and relief in uncontrolled asthma vs. high-dose salmeterol/fluticasone. *Respir Med* 2007;101:2437-46.

28. Kuna P, Peters M, Manjra A, et al. Effect of budesonide/formoterol maintenance and reliever therapy on asthma exacerbations. *Int J Clin Pract* 2007;61:725-36.

29. Navaratnam P, Jayawant SS, Pedersen CA, et al. Asthma pharmacotherapy prescribing in the ambulatory population of the United States: evidence of nonadherence to national guidelines and implications for elderly people. *J Am Geriatr Soc* 2008;56:1312-7.

30. Armour C, Bosnic-Anticevich S, Brillant M, et al. Pharmacy Asthma Care Program (PACP) improves outcomes for patients in the community. *Thorax* 2007;62:496-502.

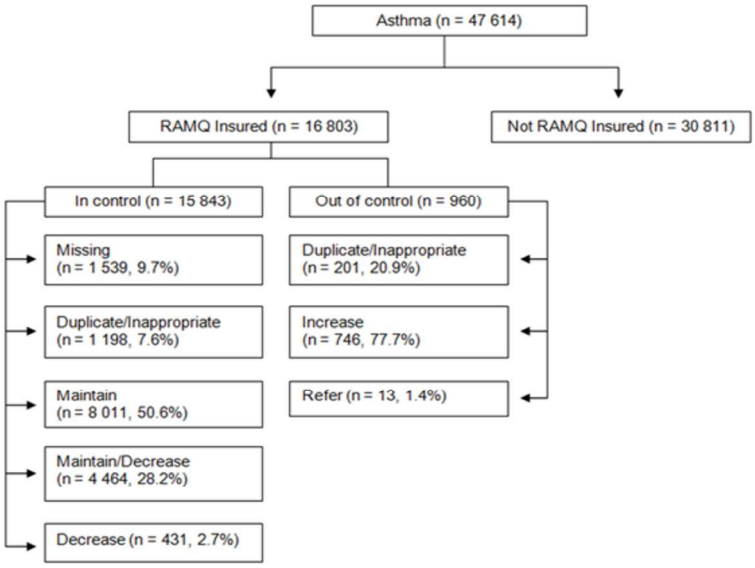
31. Bracha Y, Brottman G, Carlson A. Physicians, guidelines, and cognitive tasks. *Eval Health Prof* 2011;34:309-35.

32. Yeh KW, Chen SH, Chiang LC, et al. Survey of asthma care in Taiwan: a comparison of asthma specialists and general practitioners. *Ann Allergy Asthma Immunol* 2006;96:593-9.

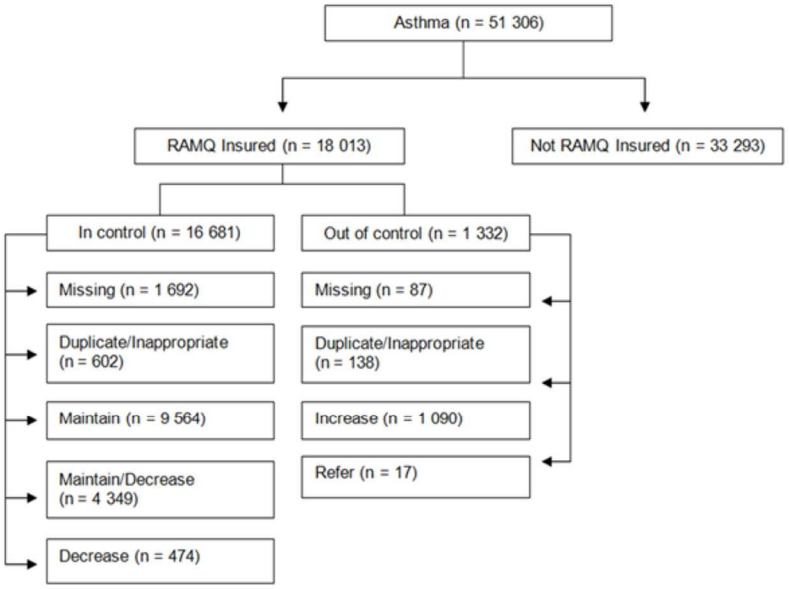
33. Brunton SA, Graham LM, Stoloff SW. Primary care management of patients with asthma. *J Fam Pract* 2011;60(Suppl 5):S1-8.

34. Razykov I, Newton EG, Lober J, et al. Daily SMS reminders for asthma treatment adherence: A comment on Strandbygaard et al. *Respir Med* 2010;104:1234-5; author reply1236.

35 Martens JD, van der Weijden T, Winkens RA, et al. Feasibility and acceptability of a computerised system with automated reminders for prescribing behaviour in primary care. *Int J Med Inform* 2008;77:199-207.




Study Population and recommendation categories for September 15, 2007 (index date 1)
100x58mm (300 x 300 DPI)




Study Population and recommendation categories for March 15, 2008 (index date 2)
110x71mm (300 x 300 DPI)

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

| | Item No | Recommendation |
|---|---|---|
| **Title and abstract** | 1 | (*a*) Indicate the study's design with a commonly used term in the title or the abstract (page 1) |
| | | (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found (page 3) |
| **Introduction** | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported (page 4) |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses (page 5 and 6) |
| **Methods** | | |
| Study design | 4 | Present key elements of study design early in the paper (page 7) |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection (page 6-7) |
| Participants | 6 | (*a*) Give the eligibility criteria, and the sources and methods of selection of participants (page 7) |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable (page 8) |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group (page 8-9) |
| Bias | 9 | Describe any efforts to address potential sources of bias (page 8) |
| Study size | 10 | Explain how the study size was arrived at (page 7) |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why (page 8) |
| Statistical methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding (page 8) |
| | | (*b*) Describe any methods used to examine subgroups and interactions (page 8) |
| | | (*c*) Explain how missing data were addressed (n/a) |
| | | (*d*) If applicable, describe analytical methods taking account of sampling strategy (n/a) |
| | | (*e*) Describe any sensitivity analyses (n/a) |
| **Results** | | |
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (page 9) |
| | | (b) Give reasons for non-participation at each stage (n/a) |
| | | (c) Consider use of a flow diagram (refer to figures 1 and 2) |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (table on page 10) |
| | | (b) Indicate number of participants with missing data for each variable of interest (in figures 1 and 2) |
| Outcome data | 15* | Report numbers of outcome events or summary measures (page 13) |
| Main results | 16 | (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (page 9) |

| | | |
|---|---|---|
| | | (*b*) Report category boundaries when continuous variables were categorized (n/a) |
| | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period (n/a) |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses (n/a) |
| **Discussion** | | |
| Key results | 18 | Summarise key results with reference to study objectives (page 16-17) |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias (page 19) |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence (page 17-18) |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results (end of page 17-18) |
| **Other information** | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based (page 21) |

*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ open

# Using decision support for population tracking of adherence to recommended asthma guidelines



| | |
|---|---|
| Journal: | *BMJ Open* |
| Manuscript ID: | bmjopen-2013-003759.R1 |
| Article Type: | Research |
| Date Submitted by the Author: | 11-Nov-2013 |
| Complete List of Authors: | Ahmed, Sara; McGill University, Faculty of Medicine<br>Tamblyn, Robyn; McGill University, Faculty of Medicine<br>Winslade, Nancy; McGill University, Faculty of Medicine |
| Primary Subject Heading: | Health informatics |
| Secondary Subject Heading: | Health informatics, Medical management |
| Keywords: | Asthma < THORACIC MEDICINE, Health informatics < BIOTECHNOLOGY & BIOINFORMATICS, EPIDEMIOLOGY |
| | |

**Using decision support for population tracking of adherence to recommended asthma guidelines**

**Sara Ahmed [1,3,4], Robyn Tamblyn [2,3], Nancy Winslade [2,3]**

[1]Faculty of Medicine, School of Physical and Occupational Therapy, McGill University
3654 Prom. Sir William Osler, Montreal, QC, H3G 1Y5, Canada

[2]Faculty of Medicine, Clinical and Health Informatics, McGill University

1140 Pine avenue west, Montreal, QC, H3A 1A3, Canada

[3] McGill University Health Center, Clinical Epidemiology

[4] **Centre de Recherche Interdisciplinaire en Réadaptation** du Montréal Métropolitain

**Corresponding author**

Sara Ahmed

Faculty of Medicine, McGill University
3654 Prom. Sir William Osler, Montreal, QC, H3G 1Y5, Canada
E-mail: sara.ahmed@mcgill.ca

**Word Count:** 3092

**Figures:** 2

**Tables**: 3

**Keywords**: Asthma, clinical practice guidelines, disease management, decision support, administrative database

**What is the key question?** What is the discrepancy between actual asthma treatments individuals' receive as recorded in the provincial administrative database as compared to those recommended by evidence-based guidelines as defined within an asthma decision support system.

**What is the bottom line; and why read on?** Decision support systems that define evidence-based guidelines, linked to an administrative database, can be used to identify individuals with uncontrolled asthma or prescriptions that deviate from recommended treatment at a population level.

**Why read on?** The methods and approach from the current study can provide an opportunity for physicians to intervene early and can be used to evaluate adherence to evidence-based guidelines and indicators of disease management for other patient populations.

**Abstract**

Objective: Decision support systems linked to administrative databases provide a unique opportunity to monitor adherence to guidelines and target disease management strategies to patients not receiving guideline-based therapy. The objective of this study was to evaluate the discrepancy between actual asthma treatments prescribed by primary care physicians compared to those recommended by evidence-based guidelines using a decision support tool linked to a provincial health administrative database.

Design: The drug and medical services information of individuals with asthma were identified from the provincial health database and were pushed through an asthma decision support system (ADSS). Recommendations aimed at optimizing asthma treatment were generated on two index dates, September 15 2007 (index date 1) and March 15 2008 (index date 2).

Setting: Primary care settings in a large Canadian metropolitan area.

Participants: Individuals with asthma and provincial health insurance

Primary and secondary outcome measures: well controlled asthma

Results: 16, 803 eligible individuals were identified on index date 1, and 18, 103 on index date 2. The distribution of recommendation categories were similar on both index dates. 94% were classified as well controlled and 7% as not well controlled. Among individuals well controlled, the largest proportion of individuals were in the maintain treatment category (50.6%), followed by maintain/decrease treatment (28.2%), and decrease treatment (2.7%). Almost all individuals not well controlled had the recommendation to increase treatment (88%) with a small proportion in the refer category (1%).

Conclusions: The ADSS was able to identify sub-groups of patients from an administrative database that could benefit from a medication review and possible change. Decision support systems linked to an administrative database can be used to identify individuals with uncontrolled asthma or prescriptions that

deviate from recommended treatment. When connected to the point of care, this can provide an opportunity for physicians to intervene early.

**Article Summary**

1) Article Focus –

- The objective of this study was to evaluate the discrepancy between actual asthma treatments prescribed by primary care physicians compared to those recommended by evidence-based guidelines using a decision support tool linked to a provincial health administrative database.

2) Key Messages - up to three bullet points outlining the key messages and significance of the study.

- Decision support systems that define evidence-based guidelines, linked to an administrative database, can be used to identify individuals with uncontrolled asthma or prescriptions that deviate from recommended treatment at a population level.
- When connected to the point of care, discrepancies between decision support and actual care can provide an opportunity for physicians to intervene early.
- The methods and approach from the current study can be used to evaluate adherence to evidence-based guidelines and indicators of disease management for other patient populations, at a population level if administrative databases are available or at the point of care if linked to an electronic health record.

3) Strengths and Limitations

- The availability of a provincial administrative database and decision support system allowed us to assess guideline adherence, and to identify sub-groups of individuals at risk of poor outcomes.

- The administrative database only includes individuals who are provincially insured and therefore discrepancies could not be examined for individuals with private insurance.

- The proportion of individuals with poor asthma control may have been underestimated as control status was evaluated over a 3-month period.

**Introduction**

Asthma poses a significant burden on healthcare resources and costs, [1] and results in reduced individual functioning and quality of life. [2, 3] Over the past 10 years there have been tremendous improvements in the scientific understanding of asthma and its treatment, and these findings have been made available to clinicians through the development of clinical practice guidelines. Despite achieving such sentinel milestones in asthma care, over 50% [4, 5] of individuals remain poorly controlled in the U.S. and Canada, with similar estimates worldwide. [6] This has translated into $306 million per year in direct costs for providing health management for approximately 2.2 million Canadians diagnosed with asthma. With appropriate disease management over $135 million in costs and reductions in physical and mental health can be prevented. [7]

Healthcare organizations worldwide have been charged with improving asthma outcomes over the next 2-3 years, with the aim of reducing hospitalizations and deaths related to asthma. [8] Several barriers for optimal management result in poor outcomes for asthma, [9] including clinician-related (non-adherence to guidelines), patient-related (non-adherence to treatment), and treatment- related barriers (cost, complexity of treatment). In moving towards improving clinical outcomes potentially modifiable barriers must be identified and targeted through appropriate interventions. A mechanism is needed to identify problematic asthma management so that gaps in care and barriers can be further evaluated and managed.

One potentially modifiable barrier is the gap between optimal versus actual asthma management as reflected by the lack of adoption of guidelines by clinicians or non-adherence of patients to recommended

care. [10, 11] Much of the costs of asthma care are related to poor disease control due to under-use of effective prophylactic therapies, and inadequate monitoring of disease control. At a population level there are few mechanisms available for tracking disease-management indicators for asthma to evaluate the current application of guidelines. Several studies have evaluated divergence from asthma guidelines, [12, 13] but have not been able to accurately estimate non-adherence to guidelines among a representative sample of individuals. Evaluations of adherence have mostly relied on chart reviews and clinician or patient reports which are difficult to complete for a large number of patients across several healthcare settings. [14-16]

Decision support systems are designed to facilitate uptake of evidence- based guidelines with the expectation that adherence to such guidelines will improve health outcomes. [17] Typically, decision support systems are used at the point of care. Such systems, however, may also have an alternate benefit of allowing population monitoring of adherence to disease management guidelines when the decision support algorithms are linked to administrative databases. By pushing through administrative health data including diagnoses, healthcare utilization and medication information, algorithms can be used to generate recommendations for optimizing treatment. In turn, patterns of under-optimization of treatment can be identified to monitor adherence to guidelines and target specific physician and patient sub-groups with disease management interventions.

The implementation of an asthma decision support system linked to provincial health insurance information represents a novel approach and facilitates the evaluation of the gap between recommended and actual treatment. We have developed a new methodology for assessing the quality of asthma

management and asthma control in the population. Using evidence based decision-support systems developed to guide physicians using computerized physician order entry and electronic medical record systems, we developed a program for sequentially entering, assessing and extracting individual and summarized population level quality monitoring and control status indicators. Using population level administrative data for over 16,000 asthma patients, we then used this program to evaluate asthma status and quality of adherence to national guidelines in a Quebec population on two randomly selected days in the spring and fall. This information is needed for asthma management, and can be used for identifying opportunities to target interventions and improve asthma outcomes.

In this study we examined the discrepancy between actual asthma treatments as recorded in the provincial administrative database compared to those recommended by evidence-based guidelines as defined in the asthma decision support system on two index dates.

## METHODS

### Study population

The drug and medical services information of patients cared for by primary care physicians (PCP) participating in the Medical Office of the 21st Century(MOXXI) study [18] in a large metropolitan area was used to evaluate adherence to asthma treatment guidelines. PCPs were identified by professional association master lists and contacted by letter and telephone to determine their interest in participating in the MOXXI project. Patients of these physicians were identified from the Quebec provincial health data base (RAMQ) medical service claims, physician, and beneficiary files. McGill University IRB approval was

obtained for this study and PCPs who accepted provided consent for the research team to receive patient anonymised administrative data.

All patients with an ICD 9 code for asthma, with no prior diagnosis for COPD, and who were ≥ 5 years old were identified from RAMQ based on algorithms validated in prior research. [19] For the purposes of this study, only patients with full drug coverage by RAMQ were included to ensure that all drugs dispensed were captured.

**The provincial drug and administrative database (RAMQ)**

The RAMQ beneficiary demographic database provided data on individual age, gender, and mortality, and census data provided income and education. [20] Information on each drug dispensed was obtained from the prescription claims database and included the drug name, quantity, date, and duration for each prescription. The medical services claims database provided information on the beneficiary, date, type, provider, and location of service delivery (e.g., inpatient, emergency, clinic) for all medical services remunerated on a fee-for-service basis.

**Study Procedure: Evaluating the gap between actual and recommended asthma treatment using the Asthma Decision Support System (ADSS)**

The ADSS is integrated into the MOXXI electronic prescribing drug management application with patient information retrieved by real-time integration with the beneficiary, prescription and medical services

claims files of the RAMQ. Using information from the prescription drug management platform, the ADSS uses the profile of existing drugs and health problems to customize recommended changes in asthma drug therapy. For this study, recommendations aimed at optimizing asthma treatment were generated on two index dates, September 15 2007 (index date 1) and March 15 2008 (index date 2), representing peak times for asthma symptoms.

In the ADSS, asthma control is determined based on overuse of short acting beta agonists (SABA) and visits to the Emergency Department (ED) for a respiratory problem over a 3 month period before the index date. Based on a previously validated algorithm, a patient is considered to be not well controlled if the sum of the quantity of all SABA medications dispensed to the patient within the last 3 months exceeds 250 doses1, [21] and/or they visited an ED for a respiratory related problem in the last 3 months. Only asthma drugs that were 1) prescribed and dispensed within one year of the index date, and 2) active (i.e. based on prescription algorithms it is likely that the person has a supply of the medication) or expired within 30 days prior to the index date were considered when generating the recommendations.

Patient-specific recommendations related to drug therapy are translated into pre-formatted prescriptions in the drug management platform. The ADSS is structured to support the Canadian Consensus guidelines for Asthma Management. [22] Recommendations are categorised based on control status. For individuals in control, recommendations generated are one of three categories: maintain treatment, decrease treatment, or maintain or decrease treatment. Recommendations also include options for action plan

[1] 250 doses is based on the most commonly prescribed SABA salbutamol 100mcg, 2 inhalations at a time, or the equivalent for other fast acting bronchodilators in the last three months.

prescriptions for patients who are in control. For individuals not well controlled recommendations are either to increase treatment or to refer to a specialist. Within each recommendation category, physicians are presented with specific recommendations for medications and doses to achieve the desired level of drug treatment.

**Data Analysis**

Results were calculated for each index date. Descriptive statistics were used to characterize the study population and to evaluate differences between individuals with and without RAMQ coverage for prescription drugs. For individuals with RAMQ coverage, the proportion of individuals under each recommendation category was evaluated among individuals classified as 'well controlled' and 'not well controlled', and descriptive statistics were used to compare the characteristics of patients across categories. Multivariable logistic regression was used to estimate the probability of being classified in control or not well controlled as a function of sociodemographic characteristics and healthcare utilization.

**Results**

*Study Population and Insured Compared to Non-Insured*

47, 614 individuals with an asthma diagnosis were identified on index date 1, after removing individuals with a prior diagnosis of COPD (6018) and those ≤ 5 years old (Figure 1). Thirty five percent of individuals were RAMQ insured for prescription drugs at least 75% of the year prior to the index date, for both dates. On index date 2, 51 306 individuals with an asthma diagnosis were identified (Figure 2). Approximately the same proportion of individuals was classified as well controlled on index date 1 (93 %) and index date 2

(94%). As the distribution of individual characteristics, control status, and recommendation categories were similar on both index dates, we only report the results from index date 2 from this point on (Table 1).

Individuals who were RAMQ insured were on average older (mean=38±22) as compared to non-RAMQ insured individuals (mean=31±18) and had a greater percentage of individuals ≥ 60 years old, a larger proportion was female (61% versus 56%), and in the lower SES category (21% versus 6%). A greater proportion of RAMQ insured patients had 3 or more ED (16 versus 9%) and hospital visits (8 versus 3%) one year prior to the index date, and a diagnostic code for anxiety (11 compared to 7%) or depression (8 compared to 5%).



**Table 1: Characteristics of Study Participants with and without provincial health coverage (RAMQ)**

| | RAMQ Coverage | No RAMQ Coverage |
|---|---|---|
| | **n=18 013** | **n=33 293** |
| **Age mean (sd)** | 38,3 (21,8) | 30,81 (17,5) |
| **Age n (%)** | | |

| | | |
|---|---|---|
| ≤ 17 | 3 963 (22,0 ) | 10 273 (30,9) |
| 18-39 | 5 129 (28,6 ) | 9 926 (29,8) |
| 40-59 | 5 254 (29,2) | 11 277 (33,9) |
| ≥ 60 | 3 637 (20,2) | 1 817 (5,5) |
| **Sex n (% female)** | 11 035 (61,3) | 18 665 (56,1) |
| **Income n (%) *** | | |
| Low SES | 3 490 (19,4) | 2 665 (8,0) |
| Middle SES | 13 148 (73.0) | 25 947 (78,0) |
| High SES | 1 230 (6,8 ) | 4 298 (13,0) |
| **Healthcare Utilization over 1 year prior to March 15, 2008** | | |
| **Medical *Phycisian* Visits** n (%)** | | |
| 0 visit | 1 736 (9,6 ) | 3 855 (11,6) |
| 1 visit | 1 998 (11,1) | 4 453 (13,4) |
| 2 visits | 1 895 (10,5) | 4 154 (12,5) |
| 3 or more visits | 12,384 (68,8) | 20 831 (62,6) |
| **Emergency Department Visits n (%)** | | |
| 0 visit | 10 435 (57,9) | 22 738 (68,0 ) |
| 1 visit | 3 139 (17,4) | 5 445 (16,4) |
| 2 visits | 1 698 (9,4) | 2 416 (7,3) |
| 3 or more visits | 2 741 (15,2) | 2 694 (8,1) |
| **Emergency Department Visits for asthma n (%)** | 1 313 (7,3) | 1 644 (4,9) |
| **Hospitalization** | | |

Ahmed, Tamblyn,Winslade

| | | |
|---|---|---|
| 0 day | 14 890 (82,7) | 29 445 (88,4) |
| 1 day | 1 340 (7,4) | 2 072 (6,2) |
| 2 days | 445 (2,5) | 658 (2,0) |
| 3 or more days | 1 338 (7,4) | 1 118 (3,4) |
| **Co-Morbidity n (%)** | | |
| Depression | 1 400 (7,77) | 1 724 (5,2) |
| Anxiety | 1 913 (10,62) | 2 361 (7,1) |

* Around 1 % of missing values for each category

** Ambulatory and specialty care

*Control Status and Recommendation Categories*

Among the 18 013 individuals who were RAMQ insured for prescription drugs, 94% were classified as well controlled and 7% as not well controlled over 3 months prior to the index date (Figure 1).

63 % of individuals who were not well controlled were in the ≥ 40 age group and 26% in the low SES category compared to 49% and 19%, respectively, in the well controlled group. These individuals also had a higher Charlson Co-morbidity Index of 2.11 as compared to 1.6 among those well controlled. A larger proportion of individuals among those not well controlled had a diagnostic code for depression, anxiety, mental illness, and a cardiac related condition. Among those not well controlled 69% (n=667) had at least 1 ED visit (past 3 months), and 74% a medical visit associated with a respiratory problem (in the past year). In comparison 13% (n=2,039) of those well controlled had at least one ED visit and 52% medical visit related to a respiratory problem.

53% of patients in the not well controlled group had an active prescription for an ICS, 20% a combination therapy, and 14% as compared to 36%, 10%, and 6% in the well controlled group. 63% and 42% of not well and well controlled, respectively, had an active prescription for a fast-acting beta agonist (FABA). At index date 1, all individuals not well controlled had asthma drugs as compared to 9.2 % of those well controlled who had no asthma drugs dispensed.

Table 2 presents the incremental regression coefficients for the demographic, healthcare utilization, and co-morbidity variables hypothesized to be associated with control status. Healthcare utilization including, ≥ 3 days of hospitalization (OR=4.58), and ≥ 3 visits to the ED (for reasons other than a respiratory problem) (OR=2.32), was found to be most strongly associated with control status. Being male (OR=.85), from a low SES (OR= 1.9), and in the 40-59 age group increased the odds of having asthma that was not well controlled.

**Table 2: Multivariable Logistic Regression Models for Identifying Individuals Controlled and Not Well Controlled**

| Variable | | OR (95%CI) Control Status |
|---|---|---|
| **Age mean (sd)** | | |
| | ≤ 17 | Reference |
| | 18-39 | 0.56 (0.44, 0.72) |
| | 40-59 | 2.19(1.73, 2.77) |
| | ≥ 60 | 1.19 (1, 1.42) |
| **Sex n (% female)** | | . |

Ahmed, Tamblyn,Winslade

| | |
|---|---|
| Male | Reference |
| Female | 85 (.74, .98) |
| **Income n (%) *** | |
| High SES | Reference |
| Middle SES | 1.44 (1.04, 1.98) |
| Low SES | 1.90 (1.35, 2.68) |
| **Healthcare Utilization over 1 year prior to March 15, 2008** | |
| Medical *Physician* *Visits n (%) | |
| 0 visit | Reference |
| 1 visit | .73 (.47,1.2) |
| 2 visits | .82 (.53,1.28) |
| ≥ 3 visits | 1.62 (1.162.27) |
| **Emergency Department Visits (other than resp)n (%)** | |
| 0 visit | Reference |
| 1 visit | 1.38(1.14,1.66) |
| 2 visits | 1.46(1.16,1.84) |
| ≥3 visits | 2.32(1.94,2.8) |
| **Hospitalisation** | |
| 0 day | Reference |
| 1 day | 2.24(1.55,3.27) |
| 2 days | 2.88(1.79,4.6) |
| 3 or more days | 4.58 (3.36,6.22) |

| | |
|---|---|
| **Co-Morbidity n (%)** | |
| Charlson co-morbidity index | 1.04 (1.01, 1.08) |
| Anxiety No | Reference |
| Yes | 1.26 (1.05,1.52 ) |

* General practitioner and specialist

***Recommendation category by control group***

The distribution of individuals across recommendation categories is presented in Table 3.

For 8% (1198/15843) in control, and 21% (201/960) of those not well controlled, a recommendation could not be determined by the ADSS either because the patient 1) had dispensed prescriptions for an inappropriate combination of medications that the ADSS could not reconcile to provide an appropriate recommendation (e.g. a LABA with two prescriptions for combination therapy) or, 2) dispensed two medications that resulted in a duplication of therapy. For those not well controlled, those in the *duplicate/inappropriate* category had a larger proportion in the lower SES, a higher co-morbiditiy index and more frequent ambulatory and hospital visits.

Among individuals well controlled, the largest proportion of individuals were in the *maintain treatment* category (50.6%), followed by *maintain/decrease treatment* (28.2%), and *decrease treatment* (2.7%). Almost all individuals not well controlled had the recommendation to *increase treatment* (88%) with a small proportion in the *refer* category (1%). Reasons for the low referral to specialty care needs to be closely examined, and may be related to uncertainty of primary care physicians of when to refer patients, and/or patients may not go see specialists once referred. [23] Regardless of the recommendation category, the

largest proportion of individuals was in the 40-59 age group; except for *maintain treatment* that had a larger proportion of individuals in the 18-39 age group. The middle SES was the largest for all recommendation groups and the proportion of females was the same across all categories. Individuals in the *refer* category were on average older than those in the other categories, but comparable on many of the other characteristics.

Ahmed, Tamblyn,Winslade

**Table 3: Comparison of characteristics of individuals in each recommendation category (based on primary recommendation).**

| | In Control N=14989 | | | | Not Well Controlled N=1245 | | |
|---|---|---|---|---|---|---|---|
| | **Maintain n=9564** | **Maintain/Decrease n=4349** | **Decrease n=474** | **Duplicate/ Inappropriate n=602** | **Increase n=1 090** | **Refer n=17** | **Duplicate/ Inappropriate n=138** |
| **Age mean (sd)** | 41,8 (19,2) | 38,2 (22,7) | 44,8 (21,6) | 45,9 (20,3) | 40,4 (21,5) | 57,1 (9,3) | 46,6 (16,0) |
| **Age n (%)** | | | | | | | |
| ≤ 17 | 919 (9,6) | 1 115 (25,6) | 74 (15,6) | 68 (11,3) | 189 (17,3) | 0 | 6 (4,4) |
| 18-39 | 3 561 (37,2) | 996 (22,9) | 86 (18,1) | 123 (20,4) | 310 (28,4) | 0 | 33 (23,9) |
| 40-59 | 2 987 (31,2) | 1 269 (29,2) | 195 (41,1) | 260 (43,2) | 372 (34,1) | 10 (58,8) | 79 (57,2) |
| ≥ 60 | 2 097 (21,9) | 969 (22,3) | 119 (25,1) | 151 (25,1) | 219 (20,1) | 7 (41,2) | 20 (14,5) |
| **Sex n (% F)** | 6 073 (63,5) | 2 659 (61,1) | 303 (63,9) | 381 (63,3) | 709 (65,0) | 12 (70,6) | 101 (73,2) |
| **Income n (%) *** | | | | | | | |
| Low SES | 1 684 (17,6) | 923 (21,2) | 117 (24,7) | 156 (25,9) | 237 (21,7) | 4 (23,5) | 43 (31,2) |
| Middle SES | 7 028 (73,5) | 3 161 (72,7) | 330 (69,6) | 420 (69,8) | 802 (73,6) | 13 (76,5) | 90 (65,2) |
| High SES | 763 (8,0) | 228 (5,2) | 25 (5,3) | 22 (3,6) | 47 (4,3) | 0 | 5 (3,6) |
| **Medical Visits mean (sd) past year** | | | | | | | |
| *All* | 8,78 (13,1) | 9,68 (13,8) | 12,62(13,3) | 12,87(13,4) | 16,52 (22,2) | 29,29 (21,3) | 24,99 (26,1) |
| *Ambulatory* | 7,72 (9,6) | 8,31 (9,2) | 10,89 (9,5) | 11,13 (9,5) | 13,53(15,0) | 19,94 (10,0) | 20,01 (18,1) |
| *Hospitalized* | 1,07 (6,8) | 1,37 (7,7) | 1,73 (7,4) | 1,73 (7,6) | 2,99 (11,6) | 9,35 (16,4) | 4,98 (13,3) |

| | In Control N=14989 | | | | Not Well Controlled N=1245 | | |
|---|---|---|---|---|---|---|---|
| | Maintain n=9564 | Maintain/Decrease n=4349 | Decrease n=474 | Duplicate/ Inappropriate n=602 | Increase n=1 090 | Refer n=17 | Duplicate/ Inappropriate n=138 |
| **Medical Visits n (%) past year** | | | | | | | |
| ***Phycisian*** | | | | | | | |
| 0 visit | 1 036 (10,8) | 265 (6,1) | 14 (3,0) | 22 (3,6) | 62 (5,7) | 0 | 7 (5,1) |
| 1 visit | 1048 (10,96) | 451 (10,4) | 31 (6,5) | 40 (6,6) | 76 (7,0) | 0 | 5 (3,6) |
| 2 visits | 1000 (10,5) | 486 (11,2) | 41 (8,6) | 26 (4,3) | 81 (7,4) | 0 | 2 (1,4) |
| 3 or more visits | 6 480 (67,8) | 3 147 (72,4) | 388 (81,9) | 514 (85,4) | 871 (79,9) | 17 (100) | 124 (89,9) |
| ***ER*** | | | | | | | |
| 0 visit | 5 995 (62,7) | 2 501 (57,5) | 240 (50,6) | 289 (48,0) | 200 (18,4) | 1 (5,9) | 25 (18,1) |
| 1 visit | 1 565 (16,4) | 790 (18,2) | 89 (18,8) | 118 (19,6) | 221 (20,3) | 3 (17,6) | 21 (15,2) |
| 2 visits | 846 (8,8) | 414 (9,5) | 59 (12,4) | 63 (10,5) | 172 (15,8) | 1 (5,9) | 9 (6,5) |
| 3 or more visits | 1 158 (12,1) | 644 (14,8) | 86 (18,1) | 132 (21,9) | 497 (45,6) | 12 (70,6) | 83 (60,2) |
| **ED- for respiratory problems** | | | | | | | |
| 0 visit | 8 781 (91,8) | 3 792 (87,2) | 394 (83,1) | 491 (81,6) | 294 (27,0) | 4 (23,5) | 38 (27,5) |
| 1 visit | 593 (6,2) | 402 (9,2) | 52 (11,0) | 64 (10,6) | 450 (41,3) | 4 (23,5) | 27 (19,6) |
| 2 visits | 142 (1,5) | 105 (2,4) | 15 (3,2) | 25 (4,2) | 188 (17,2) | 3 (17,65) | 22 (15,9) |
| 3 or more visits | 48 (0,5) | 50 (1,2) | 13 (2,7) | 22 (3,7) | 158 (14,5) | 6 (35,3) | 51 (37,0) |
| **ED- NOT for respiratory problems** | | | | | | | |
| 0 visit | 6 268 (65,5) | 2 712 (62,4) | 265 (55,9) | 326 (54,2) | 456 | 4 (23,5) | 45 (32,6) |

| | In Control N=14989 | | | | Not Well Controlled N=1245 | | |
|---|---|---|---|---|---|---|---|
| | Maintain n=9564 | Maintain/Decrease n=4349 | Decrease n=474 | Duplicate/ Inappropriate n=602 | Increase n=1 090 | Refer n=17 | Duplicate/ Inappropriate n=138 |
| | | | | | (41,8) | | |
| 1 visit | 1 535 (16,1) | 742 (17,1) | 94 (19,8) | 118 (19,6) | 205 (18,8) | 3 (17,6) | 29 (21,0) |
| 2 visits | 746 (7,8) | 370(8,5) | 49 (10,3) | 58 (9,6) | 117 (10,7) | 3 (17,6) | 14 (10,1) |
| 3 or more visits | 1 015 (10,6) | 525 (12,1) | 66 (13,9) | 100 (16,6) | 312 (28,6) | 7 (41,2) | 50 (36,2) |
| **Hospitalization** | | | | | | | |
| 0 day | 8 046 (84,1) | 3 581 (82,3) | 356 (75,1) | 449 (74,6) | 774 (71,0) | 5 (29,4) | 78 (56,5) |
| 1 day | 697 (7,3) | 318 (7,3) | 39 (8,2) | 62 (10,3) | 100 (9,2) | 3 (17,6) | 17 (12,3) |
| 2 days | 215 (2,2) | 107 (2,5) | 20 (4,2) | 23 (3,8) | 44 (4,0) | 1 (5,9) | 3 (2,2) |
| 3 or more days | 606 (6,3) | 343 (7,9) | 59 (12,4) | 68 (11,3) | 172 (15,8) | 8 (47,1) | 40 (29,0) |
| **Hospitalization- for respiratory problems** | | | | | | | |
| 0 day | 9 370 (98,0) | 4 210 (96,8) | 447 (94,3) | 563 (93,5) | 990 (90,8) | 14 (82,4) | 109 (79,0) |
| 1 day | 100 (1,0) | 60 (1,4) | 7 (1,5) | 20 (3,3) | 33 (3,0) | 0 | 7 (5,1) |
| 2 days | 32 (0,3) | 32 (0,74) | 4 (0,8) | 5 (0,8) | 14 (1,3) | 0 | 3 (2,2) |
| 3 or more days | 62 (0,6) | 47 (1,1) | 16 (3,4) | 14 (2,3) | 53 (4,9) | 3 (17,6) | 19 (13,8) |
| **Asthma Medications mean (sd) range past year** | | | | | | | |
| FABA | 0,61 (1,7) | 2,93 (3,8) | 4,32 (5,2) | 4,95 (5,1) | 2,50 (4,4) | 5,00 (5,2) | 6,82 (6,8) |
| ICS | 0,2 (0,7) | 2,3(2,9) | 1,4(2,6) | 3,6(3,8) | 1,4(2,4) | 0,9 (1,7) | 3,5(3,9) |
| Leukotrienes | 0,1 (1,4) | 0,4(3,0) | 6,7(10,0) | 1,5 (4,8) | 0,8(4,4) | 3,3(5,1) | 3,9 (11,5) |
| Combination Therapy | 0,0 (0,4) | 1,2 (2,9) | 5,1(4,9) | 2,18 (3,9) | 1,0 (2,7) | 7,7 (4,5) | 3,0 (4,3) |

| | In Control N=14989 | | | | Not Well Controlled N=1245 | | |
|---|---|---|---|---|---|---|---|
| | **Maintain n=9564** | **Maintain/Decrease n=4349** | **Decrease n=474** | **Duplicate/ Inappropriate n=602** | **Increase n=1 090** | **Refer n=17** | **Duplicate/ Inappropriate n=138** |
| Other | 0,2(1,8) | 0,8(3,4) | 2,9(6,8) | 2,36 (3,9) | 1,8(17,0) | 2,1 (2,5) | 4,45 (6,6) |
| **Control Status n (%)** | | | | | | | |
| Overuse FABA | 0 | 0 | 0 | 0 | 1 (0,1) | 0 | 0 |
| ER visits for Asthma | 0 | 0 | 0 | 0 | 1 076 (98,7) | 17 (100) | 135 (97,8) |
| ER or FABA | 0 | 0 | 0 | 0 | 1 076 (98,7) | 17 (100) | 135 (97,8) |
| **Co-Morbidity Index** | 1,6 (1,5) | 1,6 (1,5) | 1,8 (1,6) | 1,9 (1,9) | 1,8(2,0) | 2,2 (1,4) | 2,6 (2,5) |

- Less than 1 % of missing values for each category
- ED=emergency department

**DISCUSSION**

The purpose of this study was to evaluate the discrepancy between current asthma management and recommended guidelines using the provincial administrative databases and an ADSS. The present study represents an example of how decision support systems can be used to monitor guideline adherence, and to identify individuals at risk of poor outcomes to provide targeted interventions. To our knowledge this is the first time that a decision support system has been used to evaluate disease management at a population level.

As expected, individuals who were provincially insured were on average older, from a lower SES, and a higher proportion used healthcare services. A larger proportion compared to those non-provincially insured also had a diagnosis code for anxiety and depression.

The algorithms used to identify individuals with asthma and evaluate control status were validated in previous work. [24, 25] The majority of individuals well controlled were on an appropriate quantity of asthma treatment. We found, however, that ~ 31% of those well controlled could benefit from a medication review and potentially lower doses of asthma medications.

The majority of individuals not well controlled had the recommendation to increase treatment and for these individuals there was an opportunity to change therapy according to the existing guidelines. [26] The SMART inhaler helps address needs for increase in therapy, as it allows patients to use their as-needed

medication because of declining asthma control—as is very often the case—evolving exacerbations will possibly be treated at an early stage and a further worsening of asthma may possibly be prevented. The SMART inhaler is not a recommended yet part of Canadian guidelines, however, with emerging evidence of its benefits for marinating control compared to other alternatives, [27, 28] it will be included in the next version of guidelines and become more commonly prescribed for Canadian patients. Individuals who were not well controlled were in the 40-59 age range, and had a more complex health profile with greater co-morbidity, including a higher proportion with a diagnosis of anxiety or depression as compared to those well-controlled. The logistic regression analysis in our study also supported these conclusions. These individuals represent a more vulnerable sub-group of the asthma population, and place a greater burden on the healthcare system given the higher proportion that had an ED visit or hospitalization. As such, they require closer monitoring and review of medication to reach doses sufficient to maintain asthma control, or to review reasons for failed treatment.

In this study we were not able to generate a recommendation for a larger proportion of individuals not well controlled compared to controlled either because they were dispensed prescriptions for an inappropriate combination of medications that the ADSS could not reconcile to provide an appropriate recommendation, or they were dispensed two medications that resulted in a duplication of therapy. These cases in themselves represent a segment of the asthma population that requires closer review of their prescribed medication.

The generation of asthma recommendations at a population level using an administrative database allows individuals not receiving treatment based on guidelines to be identified. We found that many individuals

with non-controlled asthma visit a physician 3 or more times per year, and potentially represent missed opportunities to optimize treatment. Possible reasons for our findings may include the lack of knowledge of PCPs of guidelines in general, especially for more complicated cases. It may also be, however, that patients are not going to see the same physician, or are switching physicians to ensure access to SABAs. In such situations, physicians may be reluctant to conduct a complete medication review if they do not perceive themselves as the primary provider for the patient.

Other physician concerns may be the reluctance to prescribe ICS and/or concern regarding polypharmacy with multiple inhalers. [29] This is where the role of pharmacists is important as they can see individuals' entire medication dispensing history and have been shown to be effective in managing asthma patients in particular if supported by an ADSS. [30]

Previous studies have also found that physicians do not adopt guidelines in their practice because of perceived appropriateness of the guidelines. [13, 31] Surveys have shown that they believe that guidelines do not take into account the heterogeneity of asthma and do not account for individual patient variations in response to treatment, [32] and other factors that impact response to asthma therapy such as age and co-morbidities.

Further, patient non-adherence to prescribed therapy and not having prescribed medications filled may also explain the findings from our study. Patient beliefs about the negative impact and benefits of their medications, [33] their confidence to manage their asthma, and not seeking care early enough to prevent exacerbations have all been identified as contributors to poor outcomes for asthma.

Mechanisms to identify patients who need closer follow-up and evaluation have been identified as an important need for primary healthcare. [3, 34, 35] Future initiatives can include linking administrative databases to decision support systems that can help identify individuals who need closer monitoring and follow-up and allow for targeted services such as visit reminders sent to patients or to their care provider. The ongoing implementation of electronic health records and patient health portals will facilitate this approach. Information can be fed back to physicians and pharmacists to improve patient management, and initiate care early on, before individuals experience deteriorations in health.

**Conclusions**

This study demonstrated how a decision support system linked to an administrative database could be used to identify individuals in the population that require a review of asthma treatment. Such an approach can help identify individuals with uncontrolled asthma or prescriptions that deviate from recommended treatment to intervene early. This study provides a model for monitoring adherence to guidelines for other chronic conditions such as hypertension and diabetes.

**Limitations**

Our approach for identifying individuals with asthma and assessing asthma status may have underestimated the percentage out of control in our study. We examined asthma control on two index dates, and went back 3 months prior to the index date to assess control status. A more sensitive algorithm

that treats control as a time varying covariate would likely provide a more accurate evaluation of control status. In addition, at the time that the ADSS was being developed, the SMART treatments, that allow for the same inhaler to be used as a preventative and rescue inhaler were not commonly used or part of the guidelines. Therefore, they were not programmed as part of the ADSS and not included in the recommendations.

Further, use of decision support during clinical encounters allow for a patient-reported assessment of symptoms at the time when recommendations are generated, and allow for a more accurate assessment of asthma control. We were also limited to generating recommendations for those provincially insured that represent a more vulnerable segment of the population.

**Funding Support**

Health Canada and the Canadian Institute of Health Research supported the development of the asthma decision support system. S Ahmed is supported by a Fonds de la Recherche en Santé du Quebec (FRSQ) research career award.

**Contributorship Statement**

SA RT and NW were involved in:

- the conception and design, analysis and interpretation of data,
- drafting the article and revising it critically for important intellectual content,
- final approval of the version to be published.

**Competing Interests**

No competing interests

**Data Sharing Statement**

Additional data regarding the study sample characteristics and guidelines generated from the decision support system can be provided upon request from the corresponding author.

**References**

1. Shenolikar R, Song X, Anderson JA, et al. Costs of asthma among US working adults. *Am J Manag Care* 2011;17:409-16.

2. Schatz M, Zeiger RS, Yang SJ, et al. The relationship of asthma impairment determined by psychometric tools to future asthma exacerbations. *Chest* 2012;141:66-72.

3. Urrutia I, Aguirre U, Pascual S, et al. Impact of anxiety and depression on disease control and quality of life in asthma patients. *J Asthma* 2012;49:201-8.

4. Colice GL, Ostrom NK, Geller DE, et al. The CHOICE survey: high rates of persistent and uncontrolled asthma in the United States. *Ann Allergy Asthma Immunol* 2012;108:157-62.

5. Glaxo Wellcome I. 2000:1-31.

6. Bousquet J, Mantzouranis E, Cruz AA, et al. Uniform definition of asthma severity, control, and exacerbations: document presented for the World Health Organization Consultation on Severe Asthma. *J Allergy Clin Immunol* 2010;126:926-38.

7. Krahn MD, Berka C, Langlois P,et al. Direct and Indirect Costs of Asthma in Canada, 1990 3465. *CMAJ* 1996;154:821-31.

8. US Department of Health and Human Services OoDPaHP. Healthy People 2020 Washington,DC, 2010.

9. Maciejewski ML, Chen SY, Au DH. Adult asthma disease management: an analysis of studies, approaches, outcomes, and methods. *Respir Care* 2009;54:878-86.

10. Legorreta AP, Christian-Herman J, O'Connor RD,et al. Compliance with National Asthma Management Guidelines and Specialty Care: A Health Mantenance Organization Experience. *Arch Intern Med* 1998;158:457-64.

11. Adams RJ, Fuhlbrigge A, Guilbert T, et al. Inadequate use of asthma medication in the United States: results of the asthma in America national population survey. *J Allergy Clin Immunol* 2002;110:58-64.

12. Flor-Escriche X, Rodriguez-Mas M, Espiau M, et al. Compliance with guidelines in the treatment of asthma exacerbations in primary care. *Ther Adv Respir Dis* 2011;5:369-75.

13. Rank MA, Liesinger JT, Ziegenfuss JY, et al. The impact of asthma medication guidelines on asthma controller use and on asthma exacerbation rates comparing 1997-1998 and 2004-2005. *Ann Allergy Asthma Immunol* 2012;108:9-13.

14. Cazzola M, Segreti A, Bettoncelli G, et al. Change in asthma and COPD prescribing by Italian general practitioners between 2006 and 2008. *Prim Care Respir J* 2011;20:291-8.

15. Arnlind MH, Wettermark B, Nokela M, et al. Regional variation and adherence to guidelines for drug treatment of asthma. *Eur J Clin Pharmacol* 2010;66:187-98.

16. Lougheed MD, Olajos-Clow J, Szpiro K, et al. Multicentre evaluation of an emergency department asthma care pathway for adults. *CJEM* 2009;11:215-29.

17. Roshanov PS, Misra S, Gerstein HC, et al. Computerized clinical decision support systems for chronic disease management: a decision-maker-researcher partnership systematic review. *Implement Sci* 2011;6:92.

18. Tamblyn R, Huang A, Perreault R, et al. The medical office of the twenty-first century (MOXXI): evaluation of the effectiveness of computerised decision support in reducing inappropriate prescribing in primary care. *CMAJ* 2003;169:549-56.

19. Kawasumi Y, Abrahamowicz M, Ernst P, et al. Development and validation of a predictive algorithm to identify adult asthmatics from medical services and pharmacy claims databases. *Health Serv Res* 201;46:939-63.

20. Tamblyn RM, Laprise R, Hanley JA, et al. Adverse events associated with prescription drug cost-sharing among poor and elderly persons. *JAMA* 2001;285:421-9.

21. Schatz M, Zeiger RS, Vollmer WM, et al. Validation of a beta-agonist long-term asthma control scale derived from computerized pharmacy data. *J Allergy ClinImmunol* 2006;117:995-1000.

22. Lemiere C, Bai T, Balter M, et al. Adult Asthma Consensus Guidelines update 2003. *Can Respir J* 2004;11 (Suppl A):9A-18A.

23. Archives of Internal Medicine. *JAMA*. 2001;161.

24. Spitzer WO, Suissa S, Ernst P, et al. The use of beta-agonists and the risk of death and near death from asthma. *N Engl J Med* 1992;326:501-6.

25. Wilchesky M, Tamblyn RM, Huang A. Validation of Diagnostic Codes in Medical Services Claims Data. *Can J Clin Pharmacol* 2001;8:39-39.

26. Becker A, Lemiere C, Berube D, et al. Summary of recommendations from the Canadian Asthma Consensus guidelines, 2003. *CMAJ* 2005;173(Suppl 6):S3-11.

27. Boursquet J, Boulet LP, Peters MJ, et al. Budesonide/formoterol for maintenance and relief in uncontrolled asthma vs. high-dose salmeterol/fluticasone. *Respir Med* 2007;101:2437-46.

28. Kuna P, Peters M, Manjra A, et al. Effect of budesonide/formoterol maintenance and reliever therapy on asthma exacerbations. *Int J Clin Pract* 2007;61:725-36.

29. Navaratnam P, Jayawant SS, Pedersen CA, et al. Asthma pharmacotherapy prescribing in the ambulatory population of the United States: evidence of nonadherence to national guidelines and implications for elderly people. *J Am Geriatr Soc* 2008;56:1312-7.

30. Armour C, Bosnic-Anticevich S, Brillant M, et al. Pharmacy Asthma Care Program (PACP) improves outcomes for patients in the community. *Thorax* 2007;62:496-502.

31. Bracha Y, Brottman G, Carlson A. Physicians, guidelines, and cognitive tasks. *Eval Health Prof* 2011;34:309-35.

32. Yeh KW, Chen SH, Chiang LC, et al. Survey of asthma care in Taiwan: a comparison of asthma specialists and general practitioners. *Ann Allergy Asthma Immunol* 2006;96:593-9.

33. Brunton SA, Graham LM, Stoloff SW. Primary care management of patients with asthma. *J Fam Pract* 2011;60(Suppl 5):S1-8.

34. Razykov I, Newton EG, Lober J, et al. Daily SMS reminders for asthma treatment adherence: A comment on Strandbygaard et al. *Respir Med* 2010;104:1234-5; author reply1236.

35 Martens JD, van der Weijden T, Winkens RA, et al. Feasibility and acceptability of a computerised system with automated reminders for prescribing behaviour in primary care. *Int J Med Inform* 2008;77:199-207.

# Using decision support for population tracking of adherence to recommended asthma guidelines

**Running head: Decision Support for Population Tracking of Adherence**

**Sara Ahmed [1,3,4], Robyn Tamblyn [2,3], Nancy Winslade [2,3]**

[1]Faculty of Medicine, School of Physical and Occupational Therapy, McGill University
3654 Prom. Sir William Osler, Montreal, QC, H3G 1Y5, Canada

[2]Faculty of Medicine, Clinical and Health Informatics, McGill University
1140 Pine avenue west, Montreal, QC, H3A 1A3, Canada

[3] McGill University Health Center, Clinical Epidemiology

[4] Centre de Recherche Interdisciplinaire en Réadaptation du Montréal Métropolitain

**Corresponding author**

Sara Ahmed
Faculty of Medicine, McGill University
3654 Prom. Sir William Osler, Montreal, QC, H3G 1Y5, Canada
514 934-1934 ext: 36910
E-mail: sara.ahmed@mcgill.ca

**Word Count:** 3092
**Figures:** 2
**Tables**: 3

**Keywords**: Asthma, clinical practice guidelines, disease management, decision support, administrative database

2

**Article Summary**

1) Article Focus –

- The objective of this study was to evaluate the discrepancy between actual asthma treatments prescribed by primary care physicians ~~compared~~ to those recommended by evidence-based guidelines using a decision support tool linked to a provincial health administrative database.

2) Key Messages - up to three bullet points outlining the key messages and significance of the study.

- Decision support systems that define evidence-based guidelines, linked to an administrative database, can be used to identify individuals with uncontrolled asthma or prescriptions that deviate from recommended treatment at a population level.

- When connected to the point of care, discrepancies between decision support and actual care can provide an opportunity for physicians to intervene early.

- The methods ~~and approach from the current~~in this study can be ~~used~~ applied in future work to evaluate adherence to evidence-based guidelines ~~and indicators of disease management for other patient populations,~~ at a population level if administrative databases are available, or at the point of care if linked to an electronic health record.

3) Strengths and Limitations

- The availability of a provincial administrative database and decision support system allowed us to assess guideline adherence, and to identify sub-groups of individuals at risk of poor outcomes.

- The administrative database only includes individuals who are provincially insured and therefore discrepancies could not be examined for individuals with private insurance.

- The proportion of individuals with poor asthma control may have been underestimated as control status was evaluated over a 3-month period.

4

**Abstract**

Background: Decision support systems linked to administrative databases provide a unique opportunity to monitor adherence to guidelines and target disease management strategies to patients not receiving guideline-based therapy. Objective: The objective of this study was to evaluate the discrepancy between actual asthma treatments prescribed by primary care physicians compared to those recommended by evidence-based guidelines using a decision support tool linked to a provincial health administrative database. Methods: The drug and medical services information of individuals with asthma were identified from the provincial health database and were pushed through an asthma decision support system (ADSS). Recommendations aimed at optimizing asthma treatment were generated on two index dates, September 15 2007 (index date 1) and March 15 2008 (index date 2).

Results: 16, 803 individuals with asthma and provincial health insurance were identified on index date 1, and 18, 103 on index date 2. The distribution of recommendation categories were similar on both index dates. 94% were classified as well controlled and 7% as not well controlled. Among individuals well controlled, the largest proportion of individuals were in the *maintain treatment* category (50.6%), followed by *maintain/decrease treatment* (28.2%), and *decrease treatment* (2.7%). Almost all individuals not well controlled had the recommendation to *increase treatment* (88%) with a small proportion in the *refer* category (1%). Conclusions: The ADSS was able to identify sub-groups of patients from an administrative database that could benefit from a medication review and possible change. Decision support systems linked to an administrative database can be used to identify individuals with uncontrolled asthma or prescriptions that deviate from recommended treatment. When connected to the point of care, this can provide an opportunity for physicians to intervene early.

**Introduction**

Asthma poses a significant burden on healthcare resources and costs, (1) and results in reduced individual functioning and quality of life. (2, 3) Over the past 10 years there have been tremendous improvements in the scientific understanding of asthma and its treatment, and these findings have been made available to clinicians through the development of clinical practice guidelines. Despite achieving such sentinel milestones in asthma care, over 50% (4, 5) of individuals remain poorly controlled in the U.S. and Canada, with similar estimates worldwide. (6) This has translated into ~~$306~~ 654 million and 7189 million dollars (equivalent to US dollars in 2008) ~~per year in~~in one year for direct and indirect in ~~Canda~~Canada and the US, respectively~~costs for providing health management for approximately 2.2 million Canadians diagnosed with asthma. With appropriate disease management over $135 million in costs and reductions in physical and mental health can be prevented~~. (7)

Healthcare organizations worldwide have been charged with improving asthma outcomes over the next 2-3 years, with the aim of reducing hospitalizations and deaths related to asthma. (8) Several barriers for optimal management result in poor outcomes for asthma, (9) including clinician-related (non-adherence to guidelines), patient-related (non-adherence to treatment), and treatment- related barriers (cost, complexity of treatment). In moving towards improving clinical outcomes potentially modifiable barriers must be identified and targeted through appropriate interventions. A mechanism is needed to identify problematic asthma management so that gaps in care and barriers can be further evaluated and managed.

One potentially modifiable barrier is the gap between optimal versus actual asthma management as

reflected by the lack of adoption of guidelines by clinicians or non-adherence of patients to recommended care. (10, 11) Much of the costs of asthma care are related to poor disease control due to under-use of effective prophylactic therapies, and inadequate monitoring of disease control. (7)At a population level there are few mechanisms available for tracking disease-management indicators for asthma to evaluate the current application of guidelines. Several studies have evaluated divergence from asthma guidelines, (12, 13) but have not been able to accurately estimate non-adherence to guidelines among a representative sample of individuals. Evaluations of adherence have mostly relied on chart reviews and clinician or patient reports which are difficult to complete for a large number of patients across several healthcare settings. (14-16)

Decision support systems are designed to facilitate uptake of evidence- based guidelines with the expectation that adherence to such guidelines will improve health outcomes. (17) Typically, decision support systems are used at the point of care. Such systems, however, may also have an alternate benefit of allowing population monitoring of adherence to disease management guidelines when the decision support algorithms are linked to administrative databases. By pushing through administrative health data including diagnoses, healthcare utilization and medication information, algorithms can be used to generate recommendations for optimizing treatment. In turn, patterns of under-optimization of treatment can be identified to monitor adherence to guidelines and target specific physician and patient sub-groups with disease management interventions.

The implementation of an asthma decision support system linked to provincial health insurance information represents a novel approach and facilitates the evaluation of the gap between recommended and actual treatment. We have developed a new methodology for assessing the quality of asthma management and asthma control in the population. Using evidence based

decision-support systems developed to guide physicians using computerized physician order entry and electronic medical record systems, we developed a program for sequentially entering, assessing and extracting individual and summarized population level quality monitoring and control status indicators. Using population level administrative data for over 16,000 asthma patients, we then used this program to evaluate asthma status and quality of adherence to national guidelines in a Quebec population on two randomly selected days in the ~~spring~~fall 2007 and spring 2008~~fall~~. This information is needed for asthma management, and can be used for identifying opportunities to target interventions and improve asthma outcomes.

In this study we examined the discrepancy between actual asthma treatments as recorded in the provincial administrative database compared to those recommended by evidence-based guidelines as defined in the asthma decision support system on two index dates.

## METHODS

### Study population

The drug and medical services information of patients cared for by primary care physicians (PCP) participating in the Medical Office of the 21st Century(MOXXI) study (18) in a large metropolitan area was used to evaluate adherence to asthma treatment guidelines. PCPs were identified by professional association master lists and contacted by letter and telephone to determine their interest in participating in the MOXXI project. Patients of these physicians were identified from the Quebec provincial health data base (RAMQ) medical service claims, physician, and beneficiary files. McGill University IRB approval was obtained for this study and PCPs who accepted provided consent for the research team to receive patient anonymised administrative data.

All patients with an ICD–9 code for asthma, with no prior diagnosis for Chronic Obstructuve Pulmonary Disease (COPD), and who were ≥ 5 years old were identified from RAMQ based on algorithms validated in prior research. (19) For the purposes of this study, only patients with full drug coverage by RAMQ were included to ensure that all drugs dispensed were captured.

**The provincial drug and administrative database (RAMQ)**

The RAMQ beneficiary demographic database provided data on individual age, gender, and mortality, and census data provided income and education. (20) Information on each drug dispensed was obtained from the prescription claims database and included the drug name, quantity, date, and duration for each prescription. The medical services claims database provided information on the beneficiary, date, type, provider, and location of service delivery (e.g., inpatient, emergency, clinic) for all medical services remunerated on a fee-for-service basis.

**Study Procedure: Evaluating the gap between actual and recommended asthma treatment using the Asthma Decision Support System (ADSS)**

The ADSS is integrated into the MOXXI electronic prescribing drug management application with patient information retrieved by real-time integration with the beneficiary, prescription and medical services claims files of the RAMQ. Using information from the prescription drug management platform, the ADSS uses the profile of existing drugs and health problems to customize recommended changes in asthma drug therapy. For this study, recommendations aimed at optimizing asthma treatment were generated on two index dates, September 15 2007 (index date 1) and March 15 2008 (index date 2), representing peak times for asthma symptoms.

In the ADSS, asthma control is determined based on overuse of short acting beta agonists (SABA) and visits to the Emergency Department (ED) for a respiratory problem over a 3 month period before the index date. Based on a previously validated algorithm, a patient is considered to be not well controlled if the sum of the quantity of all SABA medications dispensed to the patient within the last 3 months exceeds 250 doses1, (21) and/or they visited an ED for a respiratory related problem in the last 3 months. Only asthma drugs that were 1) prescribed and dispensed within one year of the index date, and 2) active (i.e. based on prescription algorithms it is likely that the person has a supply of the medication) or expired within 30 days prior to the index date were considered when generating the recommendations.

Patient-specific recommendations related to drug therapy are translated into pre-formatted prescriptions in the drug management platform. The ADSS is structured to support the Canadian Consensus guidelines for Asthma Management. (22) Recommendations are categorised based on control status. For individuals in control, recommendations generated are one of three categories: maintain treatment, decrease treatment, or maintain or decrease treatment. Recommendations also include options for action plan prescriptions for patients who are in control. For individuals not well controlled recommendations are either to increase treatment or to refer to a specialist. Within each recommendation category, physicians are presented with specific recommendations for medications and doses to achieve the desired level of drug treatment.

**Data Analysis**

Results were calculated for each index date. Descriptive statistics were used to characterize the study population and to evaluate differences between individuals with and without RAMQ coverage

[1] 250 doses is based on the most commonly prescribed SABA salbutamol 100mcg, 2 inhalations at a time, or the equivalent for other fast acting bronchodilators in the last three months.

for prescription drugs. For individuals with RAMQ coverage, the proportion of individuals under each recommendation category was evaluated among individuals classified as 'well controlled' and 'not well controlled', and descriptive statistics were used to compare the characteristics of patients across categories. Multivariable logistic regression was used to estimate the probability of being classified in control or not well controlled as a function of sociodemographic characteristics and healthcare utilization.

**Results**

*Study Population and Insured Compared to Non-Insured*

A total of 47, 614 individuals with an asthma diagnosis were identified on index date 1, after removing individuals with a prior diagnosis of COPD (6018) and those ≤ 5 years old (Figure 1). Thirty five percent of individuals were RAMQ insured for prescription drugs at least 75% of the year prior to the index date, for both dates. On index date 2, 51, 306 individuals with an asthma diagnosis were identified (Figure 2). Approximately the same proportion of individuals was classified as well controlled on index date 1 (93 %) and index date 2 (94%). As the distribution of individual characteristics, control status, and recommendation categories were similar on both index dates, we only report the results from index date 2 from this point on (Table 1).

Individuals who were RAMQ insured were on average older (mean=38±22) as compared to non-RAMQ insured individuals (mean=31±18) and had a greater percentage of individuals ≥ 60 years old, a larger proportion was female (61% versus 56%), and in the lower socioeconomic status (SES) category (21% versus 6%). A greater proportion of RAMQ insured patients had 3 or more ED (16 versus 9%) and hospital visits (8 versus 3%) one year prior to the index date, and a diagnostic code for anxiety (11 compared to 7%) or depression (8 compared to 5%).

12

**Table 1** Characteristics of Study Participants with and without provincial health coverage (RAMQ) on index date 2*

| | RAMQ Coverage | No RAMQ Coverage |
|---|---|---|
| | **n=18 013** | **n=33 293** |
| **Age mean (sd)** | 38,3 (21.8) | 30,81 (17,5) |
| **Age n (%)** | | |
| ≤ 17 | 3 963 (22.0 ) | 10 273 (30,9) |
| 18-39 | 5 129 (28.6 ) | 9 926 (29,8) |
| 40-59 | 5 254 (29,2) | 11 277 (33.9) |
| ≥ 60 | 3 637 (20,2) | 1 817 (5.5) |
| **Sex n (% female)** | 11 035 (61,3) | 18 665 (56.1) |
| **Income n (%) *** | | |
| Low SES | 3 490 (19.4) | 2 665 (8.0) |
| Middle SES | 13 148 (73.0) | 25 947 (78.0) |
| High SES | 1 230 (6.8 ) | 4 298 (13.0) |
| **Healthcare Utilization over 1 year prior to March 15. 2008** | | |
| **Medical ~~Phycisian~~*Physician*** | | |
| **Visits** n (%)** | | |
| 0 visit | 1 736 (9.6 ) | 3 855 (11.6) |
| 1 visit | 1 998 (11.1) | 4 453 (13.4) |
| 2 visits | 1 895 (10.5) | 4 154 (12.5) |
| 3 or more visits | 12.384 (68.8) | 20 831 (62.6) |
| **Emergency Department Visits n (%)** | | |
| 0 visit | 10 435 (57.9) | 22 738 (68.0 ) |
| 1 visit | 3 139 (17.4) | 5 445 (16.4) |
| 2 visits | 1 698 (9.4) | 2 416 (7.3) |
| 3 or more visits | 2 741 (15.2) | 2 694 (8.1) |
| **Emergency Department Visits for asthma n (%)** | 1 313 (7.3) | 1 644 (4.9) |
| **Hospitalization** | | |
| 0 day | 14 890 (82.7) | 29 445 (88.4) |
| 1 day | 1 340 (7.4) | 2 072 (6.2) |
| 2 days | 445 (2.5) | 658 (2.0) |
| 3 or more days | 1 338 (7.4) | 1 118 (3.4) |
| **Co-Morbidity n (%)** | | |
| Depression | 1 400 (7.77) | 1 724 (5.2) |
| Anxiety | 1 913 (10.62) | 2 361 (7.1) |

* Around 1 % of missing values for each category; All differences between RAMQ and Non-RAMQ insured are significant, p<0.01.

** Ambulatory and specialty care

*Control Status and Recommendation Categories*

Among the 18 013 individuals who were RAMQ insured for prescription drugs, 93% were classified as well controlled and 7% as not well controlled over 3 months prior to the index date (Figure 1).

63 % of individuals who were not well controlled were in the ≥ 40 age group and 26% in the low SES category compared to 49% and 19%, respectively, in the well controlled group. These individuals also had a higher Charlson Co-morbidity Index of 2.11 as compared to 1.6 among those well controlled. A larger proportion of individuals among those not well controlled had a diagnostic code for depression, anxiety, mental illness, and a cardiac related condition. Among those not well controlled 69% (n=667) had at least 1 ED visit (past 3 months), and 74% a medical visit associated with a respiratory problem (in the past year). In comparison 13% (n=2,039) of those well controlled had at least one ED visit and 52% medical visit related to a respiratory problem.

53% of patients in the not well controlled group had an active prescription for an ICS, 20% a combination therapy, and 14% as compared to 36%, 10%, and 6% in the well controlled group. 63% and 42% of not well and well controlled, respectively, had an active prescription for a fast-acting beta agonist (FABA). At index date 1, all individuals not well controlled had asthma drugs as compared to 9.2 % of those well controlled who had no asthma drugs dispensed.

Table 2 presents the incremental regression coefficients for the demographic, healthcare utilization, and co-morbidity variables hypothesized to be associated with control status. Healthcare utilization including, ≥ 3 days of hospitalization (OR=4.58), and ≥ 3 visits to the ED (for reasons other than a

respiratory problem) (OR=2.32), was found to be most strongly associated with control status. Being male (OR=.85), from a low SES (OR= 1.9), and in the 40-59 age group increased the odds of having asthma that was not well controlled.

**Table 2** Multivariable Logistic Regression Models for Identifying Individuals Controlled and Not Well Controlled

| Variable | OR (95%CI) Control Status |
|---|---|
| **Age mean (sd)** | |
| ≤ 17 | Reference |
| 18-39 | 0.56 (0.44, 0.72) |
| 40-59 | 2.19(1.73, 2.77) |
| ≥ 60 | 1.19 (1, 1.42) |
| **Sex n (% female)** | |
| Male | Reference |
| Female | 85 (.74, .98) |
| **Income n (%) *** | |
| High SES | Reference |
| Middle SES | 1.44 (1.04, 1.98) |
| Low SES | 1.90 (1.35, 2.68) |
| **Healthcare Utilization over 1 year prior to March 15, 2008** | |
| Medical *Physician* *Visits n (%) | |
| 0 visit | Reference |
| 1 visit | .73 (.47,1.2) |
| 2 visits | .82 (.53,1.28) |
| ≥ 3 visits | 1.62 (1.162.27) |
| **Emergency Department Visits (other than resp)n (%)** | |
| 0 visit | Reference |
| 1 visit | 1.38(1.14,1.66) |
| 2 visits | 1.46(1.16,1.84) |
| ≥3 visits | 2.32(1.94,2.8) |
| **Hospitalisation** | |
| 0 day | Reference |
| 1 day | 2.24(1.55,3.27) |
| 2 days | 2.88(1.79,4.6) |
| 3 or more days | 4.58 (3.36,6.22) |
| **Co-Morbidity n (%)** | |
| Charlson co-morbidity index | 1.04 (1.01, 1.08) |
| Anxiety No | Reference |

| | | |
|---|---|---|
| | Yes | 1.26 (1.05,1.52 ) |

* General practitioner and specialist

***Recommendation category by control group***

The distribution of individuals across recommendation categories is presented in Table 3.

For 8% (1198/15843) in control, and 21% (201/960) of those not well controlled, a recommendation could not be determined by the ADSS either because the patient 1) had dispensed prescriptions for an inappropriate combination of medications that the ADSS could not reconcile to provide an appropriate recommendation (e.g. a LABA with two prescriptions for combination therapy) or, 2) dispensed two medications that resulted in a duplication of therapy. For those not well controlled, those in the *duplicate/inappropriate* category had a larger proportion in the lower SES, a higher co-morbiditiy index and more frequent ambulatory and hospital visits.

Among individuals well controlled, the largest proportion of individuals were in the *maintain treatment* category (50.6%), followed by *maintain/decrease treatment* (28.2%), and *decrease treatment* (2.7%). Almost all individuals not well controlled had the recommendation to *increase treatment* (88%) with a small proportion in the *refer* category (1%). Reasons for the low referral to specialty care needs to be closely examined, and may be related to uncertainty of primary care physicians of when to refer patients, and/or patients may not go see specialists once referred. (23) Regardless of the recommendation category, the largest proportion of individuals was in the 40-59 age group; except for *maintain treatment* that had a larger proportion of individuals in the 18-39 age group. The middle SES was the largest for all recommendation groups and the proportion of females was the same across all categories. Individuals in the *refer* category were on average older than those in the other categories, but comparable on many of the other characteristics.

**Table 3** Comparison of characteristics of individuals in each recommendation category (based on primary recommendation)*

| | In Control N=14989 | | | | Not Well Controlled N=1245 | | |
|---|---|---|---|---|---|---|---|
| | **Maintain** n=9564 | **Maintain/Decrease** n=4349 | **Decrease** n=474 | **Duplicate/ Inappropriate** n=602 | **Increase** n=1 090 | **Refer** n=17 | **Duplicate/ Inappropriate** n=138 |
| **Age mean (sd)** | 41.8 (19.2) | 38.2 (22.7) | 44.8 (21.6) | 45.9 (20.3) | 40.4 (21.5) | 57.1 (9.3) | 46.6 (16.0) |
| **Age n (%)** | | | | | | | |
| ≤ 17 | 919 (9.6) | 1 115 (25.6) | 74 (15.6) | 68 (11.3) | 189 (17.3) | 0 | 6 (4.4) |
| 18-39 | 3 561 (37.2) | 996 (22.9) | 86 (18.1) | 123 (20.4) | 310 (28.4) | 0 | 33 (23.9) |
| 40-59 | 2 987 (31.2) | 1 269 (29.2) | 195 (41.1) | 260 (43.2) | 372 (34.1) | 10 (58.8) | 79 (57.2) |
| ≥ 60 | 2 097 (21.9) | 969 (22.3) | 119 (25.1) | 151 (25.1) | 219 (20.1) | 7 (41.2) | 20 (14.5) |
| **Sex n (% F)** | 6 073 (63.5) | 2 659 (61.1) | 303 (63.9) | 381 (63.3) | 709 (65.0) | 12 (70.6) | 101 (73.2) |
| **Income n (%) *** | | | | | | | |
| Low SES | 1 684 (17.6) | 923 (21.2) | 117 (24.7) | 156 (25.9) | 237 (21.7) | 4 (23.5) | 43 (31.2) |
| Middle SES | 7 028 (73.5) | 3 161 (72.7) | 330 (69.6) | 420 (69.8) | 802 (73.6) | 13 (76.5) | 90 (65.2) |
| High SES | 763 (8.0) | 228 (5.2) | 25 (5.3) | 22 (3.6) | 47 (4.3) | 0 | 5 (3.6) |
| **Medical Visits mean (sd) past year** | | | | | | | |
| *All* | 8.78 (13.1) | 9.68 (13.8) | 12.62(13.3) | 12.87(13.4) | 16.52 (22.2) | 29.29 (21.3) | 24.99 (26.1) |
| *Ambulatory* | 7.72 (9.6) | 8.31 (9.2) | 10.89 (9.5) | 11.13 (9.5) | 13.53(15.0) | 19.94 (10.0) | 20.01 (18.1) |
| *Hospitalized* | 1.07 (6.8) | 1.37 (7.7) | 1.73 (7.4) | 1.73 (7.6) | 2.99 (11.6) | 9.35 (16.4) | 4.98 (13.3) |
| **Medical Visits n (%) past year** | | | | | | | |
| ***Phycisian*** | | | | | | | |
| 0 visit | 1 036 (10.8) | 265 (6.1) | 14 (3.0) | 22 (3.6) | 62 (5.7) | 0 | 7 (5.1) |
| 1 visit | 1048 (10.96) | 451 (10.4) | 31 (6.5) | 40 (6.6) | 76 (7.0) | 0 | 5 (3.6) |
| 2 visits | 1000 (10.5) | 486 (11.2) | 41 (8.6) | 26 (4.3) | 81 (7.4) | 0 | 2 (1.4) |
| 3 or more visits | 6 480 (67.8) | 3 147 (72.4) | 388 (81.9) | 514 (85.4) | 871 (79.9) | 17 (100) | 124 (89.9) |
| ***ER*** | | | | | | | |
| 0 visit | 5 995 (62.7) | 2 501 (57.5) | 240 (50.6) | 289 (48.0) | 200 (18.4) | 1 (5.9) | 25 (18.1) |
| 1 visit | 1 565 (16.4) | 790 (18.2) | 89 (18.8) | 118 (19.6) | 221 (20.3) | 3 (17.6) | 21 (15.2) |
| 2 visits | 846 (8.8) | 414 (9.5) | 59 (12.4) | 63 (10.5) | 172 (15.8) | 1 (5.9) | 9 (6.5) |
| 3 or more visits | 1 158 (12.1) | 644 (14.8) | 86 (18.1) | 132 (21.9) | 497 (45.6) | 12 (70.6) | 83 (60.2) |
| **ED- for respiratory problems** | | | | | | | |
| 0 visit | 8 781 (91.8) | 3 792 (87.2) | 394 (83.1) | 491 (81.6) | 294 (27.0) | 4 (23.5) | 38 (27.5) |
| 1 visit | 593 (6.2) | 402 (9.2) | 52 (11.0) | 64 (10.6) | 450 (41.3) | 4 (23.5) | 27 (19.6) |
| 2 visits | 142 (1.5) | 105 (2.4) | 15 (3.2) | 25 (4.2) | 188 (17.2) | 3 (17.65) | 22 (15.9) |
| 3 or more visits | 48 (0.5) | 50 (1.2) | 13 (2.7) | 22 (3.7) | 158 (14.5) | 6 (35.3) | 51 (37.0) |
| **ED- NOT for respiratory problems** | | | | | | | |
| 0 visit | 6 268 (65.5) | 2 712 (62.4) | 265 (55.9) | 326 (54.2) | 456 (41.8) | 4 (23.5) | 45 (32.6) |
| 1 visit | 1 535 (16.1) | 742 (17.1) | 94 (19.8) | 118 (19.6) | 205 (18.8) | 3 (17.6) | 29 (21.0) |
| 2 visits | 746 (7.8) | 370(8.5) | 49 (10.3) | 58 (9.6) | 117 (10.7) | 3 (17.6) | 14 (10.1) |
| 3 or more visits | 1 015 (10.6) | 525 (12.1) | 66 (13.9) | 100 (16.6) | 312 (28.6) | 7 (41.2) | 50 (36.2) |
| **Hospitalization** | | | | | | | |
| 0 day | 8 046 (84.1) | 3 581 (82.3) | 356 (75.1) | 449 (74.6) | 774 (71.0) | 5 (29.4) | 78 (56.5) |
| 1 day | 697 (7.3) | 318 (7.3) | 39 (8.2) | 62 (10.3) | 100 (9.2) | 3 (17.6) | 17 (12.3) |
| 2 days | 215 (2.2) | 107 (2.5) | 20 (4.2) | 23 (3.8) | 44 (4.0) | 1 (5.9) | 3 (2.2) |
| 3 or more days | 606 (6.3) | 343 (7.9) | 59 (12.4) | 68 (11.3) | 172 (15.8) | 8 (47.1) | 40 (29.0) |

| | In Control N=14989 | | | | Not Well Controlled N=1245 | | |
|---|---|---|---|---|---|---|---|
| | Maintain n=9564 | Maintain/Decrease n=4349 | Decrease n=474 | Duplicate/ Inappropriate n=602 | Increase n=1 090 | Refer n=17 | Duplicate/ Inappropriate n=138 |
| **Hospitalization- for respiratory problems** | | | | | | | |
| 0 day | 9 370 (98.0) | 4 210 (96.8) | 447 (94.3) | 563 (93.5) | 990 (90.8) | 14 (82.4) | 109 (79.0) |
| 1 day | 100 (1.0) | 60 (1.4) | 7 (1.5) | 20 (3.3) | 33 (3.0) | 0 | 7 (5.1) |
| 2 days | 32 (0.3) | 32 (0.74) | 4 (0.8) | 5 (0.8) | 14 (1.3) | 0 | 3 (2.2) |
| 3 or more days | 62 (0.6) | 47 (1.1) | 16 (3.4) | 14 (2.3) | 53 (4.9) | 3 (17.6) | 19 (13.8) |
| **Asthma Medications mean (sd) range past year** | | | | | | | |
| FABA | 0.61 (1.7) | 2.93 (3.8) | 4.32 (5.2) | 4.95 (5.1) | 2.50 (4.4) | 5.00 (5.2) | 6.82 (6.8) |
| ICS | 0.2 (0.7) | 2.3(2.9) | 1.4(2.6) | 3.6(3.8) | 1.4(2.4) | 0.9 (1.7) | 3.5(3.9) |
| Leukotrienes | 0.1 (1.4) | 0.4(3.0) | 6.7(10.0) | 1.5 (4.8) | 0.8(4.4) | 3.3(5.1) | 3.9 (11.5) |
| Combination Therapy | 0.0 (0.4) | 1.2 (2.9) | 5.1(4.9) | 2.18 (3.9) | 1.0 (2.7) | 7.7 (4.5) | 3.0 (4.3) |
| Other | 0.2(1.8) | 0.8(3.4) | 2.9(6.8) | 2.36 (3.9) | 1.8(17.0) | 2.1 (2.5) | 4.45 (6.6) |
| **Control Status n (%)** | | | | | | | |
| Overuse FABA | 0 | 0 | 0 | 0 | 1 (0.1) | 0 | 0 |
| ED visits for Asthma | 0 | 0 | 0 | 0 | 1 076 (98.7) | 17 (100) | 135 (97.8) |
| ER or FABA | 0 | 0 | 0 | 0 | 1 076 (98.7) | 17 (100) | 135 (97.8) |
| **Co-Morbidity Index** | 1.6 (1.5) | 1.6 (1.5) | 1.8 (1.6) | 1.9 (1.9) | 1.8(2.0) | 2.2 (1.4) | 2.6 (2.5) |

*10% (n= missing for well controlled and 7% for not well controlled; Less than 1 % of missing values for each category; ED=emergency department

**DISCUSSION**

The purpose of this study was to evaluate the discrepancy between current asthma management and recommended guidelines using the provincial administrative databases and an ADSS. The present study represents an example of how decision support systems can be used to monitor guideline adherence, and to identify individuals at risk of poor outcomes to provide targeted interventions. To our knowledge this is the first time that a decision support system has been used to evaluate disease management at a population level.

As expected, individuals who were provincially insured were on average older, from a lower SES, and a higher proportion used healthcare services. A larger proportion compared to those non-provincially insured also had a diagnosis code for anxiety and depression.

The algorithms used to identify individuals with asthma and evaluate control status were validated in previous work. (24, 25) The majority of individuals well controlled were on an appropriate quantity of asthma treatment. We found, however, that ~ 31% of those well controlled could benefit from a medication review and potentially lower doses of asthma medications.

The majority of individuals not well controlled had the recommendation to increase treatment and for these individuals there was an opportunity to change therapy according to the existing guidelines. (26) The SMART inhaler helps address needs for increase in therapy, as it allows patients to use their as-needed medication because of declining asthma control—as is very often the case—evolving exacerbations will possibly be treated at an early stage and a further worsening of asthma may possibly be prevented. The SMART inhaler is not a recommended yet part of Canadian guidelines, however, with emerging evidence of its benefits for marinating control

compared to other alternatives, (27, 28) it will be included in the next version of guidelines and become more commonly prescribed for Canadian patients. Individuals who were not well controlled were in the 40-59 age range, and had a more complex health profile with greater co-morbidity, including a higher proportion with a diagnosis of anxiety or depression as compared to those well-controlled. The logistic regression analysis in our study also supported these conclusions. These individuals represent a more vulnerable sub-group of the asthma population, and place a greater burden on the healthcare system given the higher proportion that had an ED visit or hospitalization. As such, they require closer monitoring and review of medication to reach doses sufficient to maintain asthma control, or to review reasons for failed treatment.

In this study we were not able to generate a recommendation for a larger proportion of individuals not well controlled compared to controlled either because they were dispensed prescriptions for an inappropriate combination of medications that the ADSS could not reconcile to provide an appropriate recommendation, or they were dispensed two medications that resulted in a duplication of therapy. These cases in themselves represent a segment of the asthma population that requires closer review of their prescribed medication.

The generation of asthma recommendations at a population level using an administrative database allows individuals not receiving treatment based on guidelines to be identified. We found that many individuals with non-controlled asthma visit a physician 3 or more times per year, and potentially represent missed opportunities to optimize treatment. Possible reasons for our findings may include the lack of knowledge of PCPs of guidelines in general, especially for more complicated cases. It may also be, however, that patients are not going to see the same physician, or are switching physicians to ensure access to SABAs. In such situations, physicians may be reluctant to conduct a

complete medication review if they do not perceive themselves as the primary provider for the patient.

Other physician concerns may be the reluctance to prescribe ICS and/or concern regarding polypharmacy with multiple inhalers. (29) This is where the role of pharmacists is important as they can see individuals' entire medication dispensing history and have been shown to be effective in managing asthma patients in particular if supported by an ADSS. (30)

Previous studies have also found that physicians do not adopt guidelines in their practice because of perceived appropriateness of the guidelines. (13, 31) Surveys have shown that they believe that guidelines do not take into account the heterogeneity of asthma and do not account for individual patient variations in response to treatment, (32) and other factors that impact response to asthma therapy such as age and co-morbidities.

Further, patient non-adherence to prescribed therapy and not having prescribed medications filled may also explain the findings from our study. Patient beliefs about the negative impact and benefits of their medications, (33) their confidence to manage their asthma, and not seeking care early enough to prevent exacerbations have all been identified as contributors to poor outcomes for asthma.(34)

Mechanisms to identify patients who need closer follow-up and evaluation have been identified as an important need for primary healthcare. (3, 34, 35) Future initiatives can include linking administrative databases to decision support systems that can help identify individuals who need closer monitoring and follow-up and allow for targeted services such as visit reminders sent to

patients or to their care provider. The ongoing implementation of electronic health records and patient health portals will facilitate this approach. Information can be fed back to physicians and pharmacists to improve patient management, and initiate care early on, before individuals experience deteriorations in health.

**Limitations**

Our approach for identifying individuals with asthma and assessing asthma status may have underestimated the percentage out of control in our study. We examined asthma control on two index dates, and went back 3 months prior to the index date to assess control status. A more sensitive algorithm that treats control as a time varying covariate would likely provide a more accurate evaluation of control status. Also, because we used administrative data and not clinical information from an electronic medical record to generate recommendations, we were not able to use asthma severity and relapse as part of the asthma control ~~algorithm .~~ algorithm. Finally, previous studies that have reported higher levels of not well-controlled individuals were based on self-reports as opposed to administrative data. ~~In addition,~~

A~~a~~t the time that the ADSS was being developed, the SMART treatments, that allow for the same inhaler to be used as a preventative and rescue inhaler were not commonly used or part of the guidelines. Therefore, they were not programmed as part of the ADSS and not included in the recommendations. Further, the ADSS does not distinguish between SABA nebulizer and MDI. ~~–~~. ~~Furthe~~Finally~~r~~, use of decision support during clinical encounters allow for a patient-reported assessment of symptoms at the time when recommendations are generated, and allow for a more accurate assessment of asthma control. We were also limited to generating recommendations for those provincially insured that represent a more vulnerable segment of the population.

**Conclusions**

This study demonstrated how a decision support system linked to an administrative database could be used to identify individuals in the population that require a review of asthma treatment. Such an approach can help identify individuals with uncontrolled asthma or prescriptions that deviate from recommended treatment to intervene early. This study provides a model for monitoring adherence to guidelines for other chronic conditions such as hypertension and diabetes.

**Declaration of Interest**

Health Canada and the Canadian Institute of Health Research supported the development of the asthma decision support system. S Ahmed is supported by a Fonds de la Recherche en Santé du Quebec (FRSQ) research career award.

## References

1. Shenolikar R, Song X, Anderson JA, Chu BC, Cantrell CR. Costs of asthma among US working adults. Am J Manag Care.2011;17:409-16.

2. Schatz M, Zeiger RS, Yang SJ, Chen W, Crawford W, Sajjan S, et al. The relationship of asthma impairment determined by psychometric tools to future asthma exacerbations. Chest 2012;141:66-72.

3. Urrutia I, Aguirre U, Pascual S, Esteban C, Ballaz A, Arrizubieta I, et al. Impact of anxiety and depression on disease control and quality of life in asthma patients. J Asthma 2012;49:201-8.

4. Colice GL, Ostrom NK, Geller DE, Anolik R, Blaiss M, Marcus P, et al. The CHOICE survey: high rates of persistent and uncontrolled asthma in the United States. Ann Allergy Asthma Immunol 2012;108:157-62.

5. Glaxo Wellcome I. 2000:1-31.

6. Bousquet J, Mantzouranis E, Cruz AA, Ait-Khaled N, Baena-Cagnani CE, Bleecker ER, et al. Uniform definition of asthma severity, control, and exacerbations: document presented for the World Health Organization Consultation on Severe Asthma. J Allergy Clin Immunol 2010;126:926-38.

7. Katayoun Bahadori, Mary M Doyle-Waters, Carlo Marra, Larry Lynd, Kadria Alasaly, John Swiston and J Mark FitzGerald. Economic burden of asthma: a systematic review BMC Pulmonary Medicine 2009, **9**:24 doi:10.1186/1471-2466-9-24

8. US Department of Health and Human Services OoDPaHP. Healthy People 2020 Washington,DC2010 [B0132]. Available from:

http://www.healthypeople.gov/2020/TopicsObjectives2020/pdfs/HP2020_brochure_with_LHI_508.pdf.

9. Maciejewski ML, Chen SY, Au DH. Adult asthma disease management: an analysis of studies, approaches, outcomes, and methods. Respir Care 2009;54:878-86.

10. Legorreta AP, Christian-Herman J, O'Connor RD, Hasan MM, Evans R, Leung KM. Compliance with National Asthma Management Guidelines and Specialty Care: A Health Mantenance Organization Experience. Arch Intern Med 1998;158:457-64.

11. Adams RJ, Fuhlbrigge A, Guilbert T, Lozano P, Martinez F. Inadequate use of asthma medication in the United States: results of the asthma in America national population survey. J Allergy Clin Immunol 2002;110:58-64.

12. Flor-Escriche X, Rodriguez-Mas M, Espiau M, Castan-Ensenat X, Vigata-Reig JM, Poblet-Cortes R, et al. Compliance with guidelines in the treatment of asthma exacerbations in primary care. Ther Adv Respir Dis 2011;5:369-75.

13. Rank MA, Liesinger JT, Ziegenfuss JY, Branda ME, Lim KG, Yawn BP, et al. The impact of asthma medication guidelines on asthma controller use and on asthma exacerbation rates comparing 1997-1998 and 2004-2005. Ann Allergy Asthma Immunol 2012;108:9-13.

14. Cazzola M, Segreti A, Bettoncelli G, Calzetta L, Cricelli C, Pasqua F, et al. Change in asthma and COPD prescribing by Italian general practitioners between 2006 and 2008. Prim Care Respir J 2011;20:291-8.

15. Arnlind MH, Wettermark B, Nokela M, Hjemdahl P, Rehnberg C, Jonsson EW. Regional variation and adherence to guidelines for drug treatment of asthma. Eur J Clin Pharmacol 2010 ;66:187-98.

16. Lougheed MD, Olajos-Clow J, Szpiro K, Moyse P, Julien B, Wang M, et al. Multicentre evaluation of an emergency department asthma care pathway for adults. CJEM 2009;11:215-29.

17. Roshanov PS, Misra S, Gerstein HC, Garg AX, Sebaldt RJ, Mackay JA, et al. Computerized clinical decision support systems for chronic disease management: a decision-maker-researcher partnership systematic review. Implement Sci 2011;6:92.

18. Tamblyn R, Huang A, Perreault R, Jacques A, Roy D, Hanley J, et al. The medical office of the twenty-first century (MOXXI): evaluation of the effectiveness of computerised decision support in reducing inappropriate prescribing in primary care. CMAJ 2003;169:549-56.

19. Kawasumi Y, Abrahamowicz M, Ernst P, Tamblyn R. Development and validation of a predictive algorithm to identify adult asthmatics from medical services and pharmacy claims databases. Health Serv Res 2011;46:939-63.

20. Tamblyn RM, Laprise R, Hanley JA, Abrahamowicz M, Scott S, Mayo N, et al. Adverse events associated with prescription drug cost-sharing among poor and elderly persons. JAMA 2001;285:421-9.

21. Schatz M, Zeiger RS, Vollmer WM, Mosen D, Apter AJ, Stibolt TB, et al. Validation of a beta-agonist long-term asthma control scale derived from computerized pharmacy data. J Allergy ClinImmunol 2006;117:995-1000.

22. Lemiere C, Bai T, Balter M, Bayliff C, Becker A, Boulet LP, et al. Adult Asthma Consensus Guidelines update 2003. Can Respir J 2004;11 Suppl A:9A-18A.

23. Archives of Internal Medicine. JAMA 2001;161.

24. Spitzer WO, Suissa S, Ernst P, Horwitz RI, Habbick B, Cockcroft D, et al. The use of beta-agonists and the risk of death and near death from asthma. N Engl J Med 1992;326:501-6.

25. Wilchesky M, Tamblyn RM, Huang A. Validation of Diagnostic Codes in Medical Services Claims Data. Can J Clin Pharmacol 2001;8:39-39.

26. Becker A, Lemiere C, Berube D, Boulet LP, Ducharme FM, FitzGerald M, et al. Summary of recommendations from the Canadian Asthma Consensus guidelines, 2003. CMAJ 2005;173:S3-11.

27. Boursquet J, Boulet LP, Peters MJ, Magnussen H, Quiralte J, Martinez-Aguilar NE, et al. Budesonide/formoterol for maintenance and relief in uncontrolled asthma vs. high-dose salmeterol/fluticasone. Respir Med 2007;101:2437-46.

28. Kuna P, Peters M, Manjra A, Jorup C, Naya I, Martinez-Aguilar N, et al. Effect of budesonide/formoterol maintenance and reliever therapy on asthma exacerbations. Int J Clin Pract 2007;61:725-36.

29. Navaratnam P, Jayawant SS, Pedersen CA, Balkrishnan R. Asthma pharmacotherapy prescribing in the ambulatory population of the United States: evidence of nonadherence to national guidelines and implications for elderly people. J Am Geriatr Soc 2008;56:1312-7.

30. Armour C, Bosnic-Anticevich S, Brillant M, Burton D, Emmerton L, Krass I, et al. Pharmacy Asthma Care Program (PACP) improves outcomes for patients in the community. Thorax 2007;62:496-502.

31. Bracha Y, Brottman G, Carlson A. Physicians, guidelines, and cognitive tasks. Eval Health Prof 2011;34:309-35.

32. Yeh KW, Chen SH, Chiang LC, Chen LC, Huang JL. Survey of asthma care in Taiwan: a comparison of asthma specialists and general practitioners. Ann Allergy Asthma Immunol 2006;96:593-9.

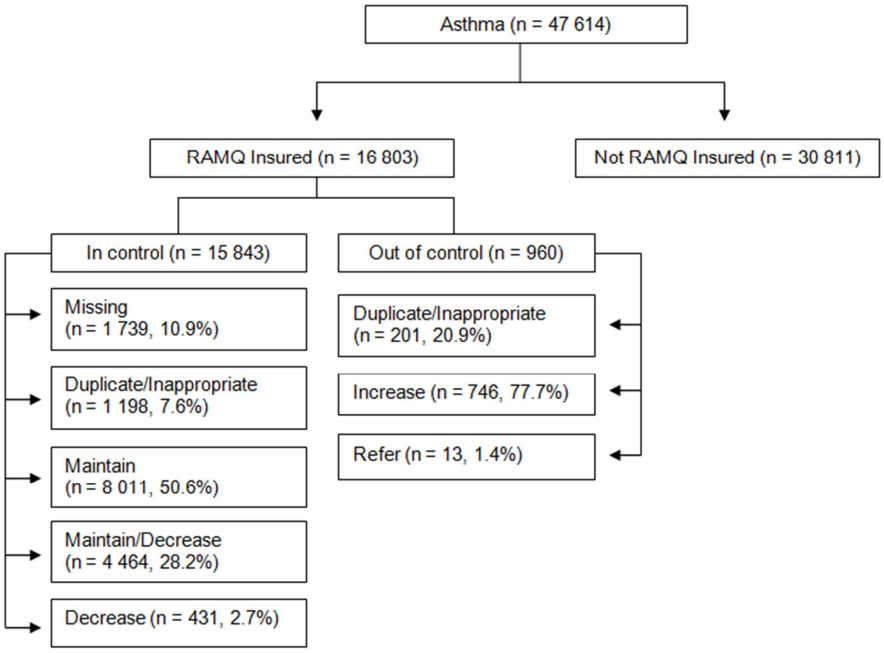
33. Brunton SA, Graham LM, Stoloff SW. Primary care management of patients with asthma. J Fam Pract 2011;60:S1-8.

34.Razykov I, Newton EG, Lober J, Thombs BD. Daily SMS reminders for asthma treatment adherence: A comment on Strandbygaard et al. Respir Med 2010;104:1234-5; author reply 1236.

35. Martens JD, van der Weijden T, Winkens RA, Kester AD, Geerts PJ, Evers SM, et al. Feasibility and acceptability of a computerised system with automated reminders for prescribing behaviour in primary care. Int J Med Inform 2008;77:199-207.

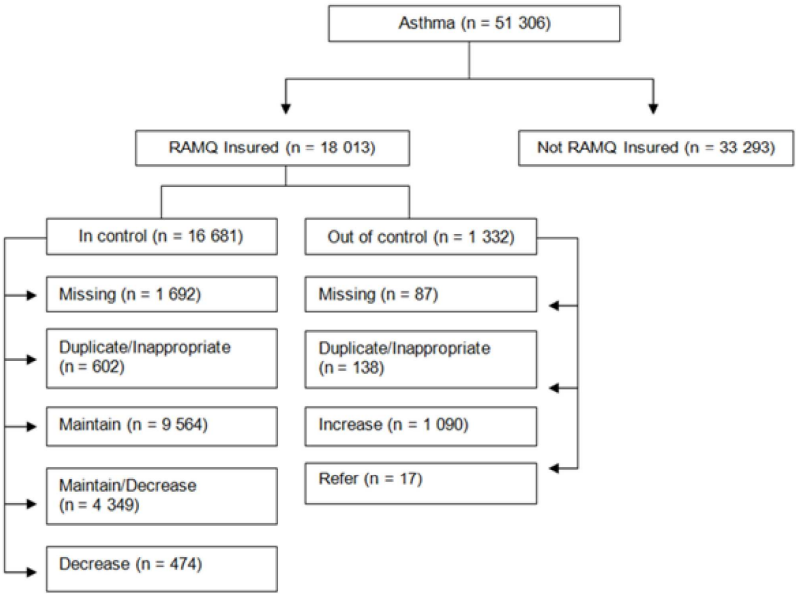
28

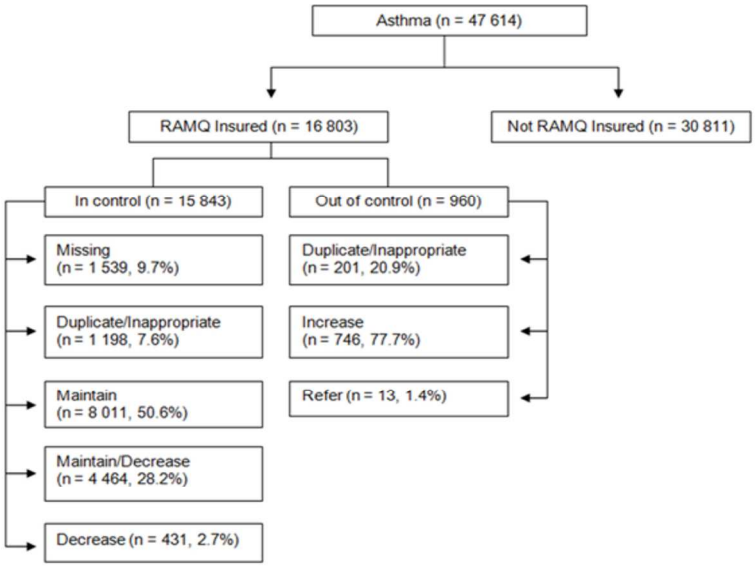
**Figure 1:** Study Population and recommendation categories for September 15, 2007 (index date 1)



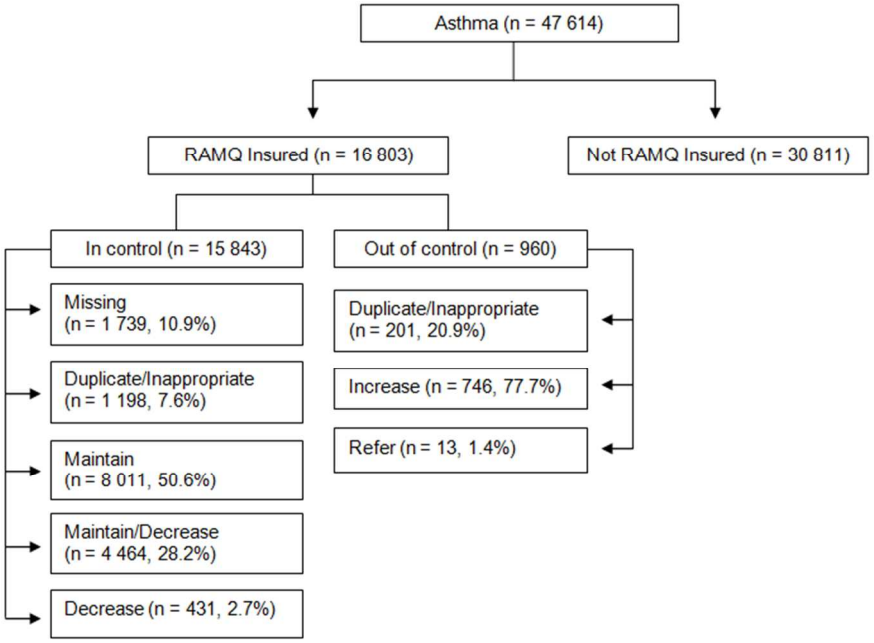
29

**Figure 2:** Study Population and recommendation categories for March 15, 2008 (index date 2)






Study Population and recommendation categories for September 15, 2007 (index date 1)
100x58mm (300 x 300 DPI)




254x190mm (300 x 300 DPI)

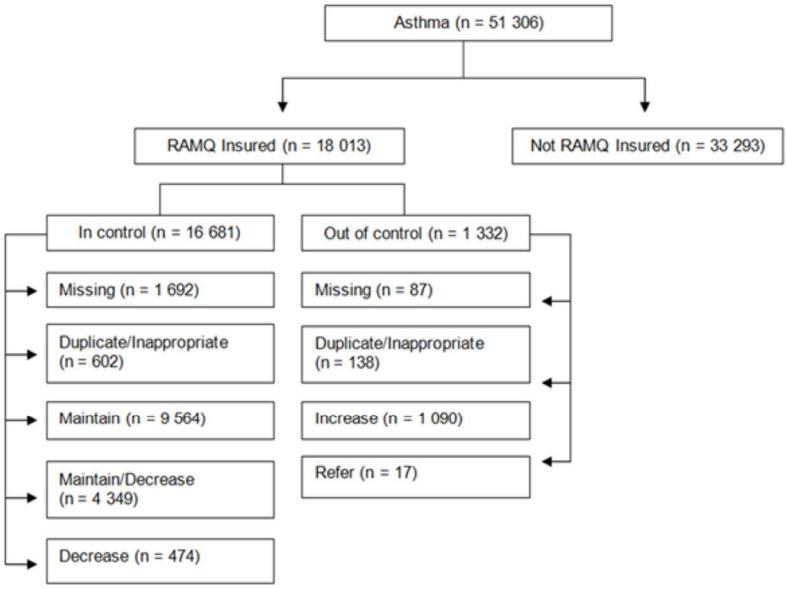
STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

| | Item No | Recommendation |
|---|---|---|
| **Title and abstract** | 1 | (*a*) Indicate the study's design with a commonly used term in the title or the abstract (page 1) |
| | | (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found (page 3) |
| **Introduction** | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported (page 4) |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses (page 5 and 6) |
| **Methods** | | |
| Study design | 4 | Present key elements of study design early in the paper (page 7) |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection (page 6-7) |
| Participants | 6 | (*a*) Give the eligibility criteria, and the sources and methods of selection of participants (page 7) |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable (page 8) |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group (page 8-9) |
| Bias | 9 | Describe any efforts to address potential sources of bias (page 8) |
| Study size | 10 | Explain how the study size was arrived at (page 7) |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why (page 8) |
| Statistical methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding (page 8) |
| | | (*b*) Describe any methods used to examine subgroups and interactions (page 8) |
| | | (*c*) Explain how missing data were addressed (n/a) |
| | | (*d*) If applicable, describe analytical methods taking account of sampling strategy (n/a) |
| | | (*e*) Describe any sensitivity analyses (n/a) |
| **Results** | | |
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (page 9) |
| | | (b) Give reasons for non-participation at each stage (n/a) |
| | | (c) Consider use of a flow diagram (refer to figures 1 and 2) |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (table on page 10) |
| | | (b) Indicate number of participants with missing data for each variable of interest (in figures 1 and 2) |
| Outcome data | 15* | Report numbers of outcome events or summary measures (page 13) |
| Main results | 16 | (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (page 9) |

| | | |
|---|---|---|
| | | (*b*) Report category boundaries when continuous variables were categorized (n/a) |
| | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period (n/a) |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses (n/a) |
| **Discussion** | | |
| Key results | 18 | Summarise key results with reference to study objectives (page 16-17) |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias (page 19) |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence (page 17-18) |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results (end of page 17-18) |
| **Other information** | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based (page 21) |

*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.




Study Population and recommendation categories for March 15, 2008 (index date 2)
110x71mm (300 x 300 DPI)

**Using decision support for population tracking of adherence to recommended asthma guidelines**

**Running head: Decision Support for Population Tracking of Adherence**

**Sara Ahmed [1,3,4], Robyn Tamblyn [2,3], Nancy Winslade [2,3]**

[1]Faculty of Medicine, School of Physical and Occupational Therapy, McGill University
3654 Prom. Sir William Osler, Montreal, QC, H3G 1Y5, Canada

[2]Faculty of Medicine, Clinical and Health Informatics, McGill University
1140 Pine avenue west, Montreal, QC, H3A 1A3, Canada

[3] McGill University Health Center, Clinical Epidemiology

[4] Centre de Recherche Interdisciplinaire en Réadaptation du Montréal Métropolitain

**Corresponding author**

Sara Ahmed
Faculty of Medicine, McGill University
3654 Prom. Sir William Osler, Montreal, QC, H3G 1Y5, Canada
514 934-1934 ext: 36910
E-mail: sara.ahmed@mcgill.ca

**Word Count:** 3092
**Figures:** 2
**Tables**: 3

**Keywords**: Asthma, clinical practice guidelines, disease management, decision support, administrative database

**Article Summary**

1) Article Focus –

- The objective of this study was to evaluate the discrepancy between actual asthma treatments prescribed by primary care physicians ~~compared~~ to those recommended by evidence-based guidelines using a decision support tool linked to a provincial health administrative database.

2) Key Messages - up to three bullet points outlining the key messages and significance of the study.

- Decision support systems that define evidence-based guidelines, linked to an administrative database, can be used to identify individuals with uncontrolled asthma or prescriptions that deviate from recommended treatment at a population level.

- When connected to the point of care, discrepancies between decision support and actual care can provide an opportunity for physicians to intervene early.

- The methods ~~and approach from the current~~in this study can be ~~used~~ applied in future work to evaluate adherence to evidence-based guidelines ~~and indicators of disease management for other patient populations,~~ at a population level if administrative databases are available, or at the point of care if linked to an electronic health record.

3) Strengths and Limitations

- The availability of a provincial administrative database and decision support system allowed us to assess guideline adherence, and to identify sub-groups of individuals at risk of poor outcomes.

- The administrative database only includes individuals who are provincially insured and therefore discrepancies could not be examined for individuals with private insurance.

- The proportion of individuals with poor asthma control may have been underestimated as control status was evaluated over a 3-month period.

4

**Abstract**

~~Background:~~ Objective: Decision support systems linked to administrative databases provide a unique opportunity to monitor adherence to guidelines and target disease management strategies to patients not receiving guideline-based therapy. ~~Objective:~~ The objective of this study was to evaluate the discrepancy between actual asthma treatments prescribed by primary care physicians compared to those recommended by evidence-based guidelines using a decision support tool linked to a provincial health administrative database.

Design~~Methods~~: The drug and medical services information of individuals with asthma were identified from the provincial health database and were pushed through an asthma decision support system (ADSS). Recommendations aimed at optimizing asthma treatment were generated on two index dates, September 15 2007 (index date 1) and March 15 2008 (index date 2).

Setting: Primary care settings in a large Canadian metropolitan area.

Participants: Individuals with asthma and provincial health insurance

Primary and secondary outcome measures: well controlled asthma

Results: 16, 803 eligible individuals were identified on index date 1, and 18, 103 on index date 2. The distribution of recommendation categories were similar on both index dates. 94% were classified as well controlled and 7% as not well controlled. Among individuals well controlled, the largest proportion of individuals were in the *maintain treatment* category (50.6%), followed by *maintain/decrease treatment* (28.2%), and *decrease treatment* (2.7%). Almost all individuals not well controlled had the recommendation to *increase treatment* (88%) with a small proportion in the *refer* category (1%).

Conclusions: The ADSS was able to identify sub-groups of patients from an administrative database that could benefit from a medication review and possible change. Decision support systems linked to an administrative database can be used to identify individuals with uncontrolled asthma or

prescriptions that deviate from recommended treatment. When connected to the point of care, this can provide an opportunity for physicians to intervene early.

**Introduction**

Asthma poses a significant burden on healthcare resources and costs, (1) and results in reduced individual functioning and quality of life. (2, 3) Over the past 10 years there have been tremendous improvements in the scientific understanding of asthma and its treatment, and these findings have been made available to clinicians through the development of clinical practice guidelines. Despite achieving such sentinel milestones in asthma care, over 50% (4, 5) of individuals remain poorly controlled in the U.S. and Canada, with similar estimates worldwide. (6) This has translated into ~~$306~~ 654 million and 7189 million dollars (equivalent to US dollars in 2008) ~~per year in~~in one year for direct and indirect in ~~Canda~~Canada and the US, respectively~~costs for providing health management for approximately 2.2 million Canadians diagnosed with asthma. With appropriate disease management over $135 million in costs and reductions in physical and mental health can be prevented~~. (7)

Healthcare organizations worldwide have been charged with improving asthma outcomes over the next 2-3 years, with the aim of reducing hospitalizations and deaths related to asthma. (8) Several barriers for optimal management result in poor outcomes for asthma, (9) including clinician-related (non-adherence to guidelines), patient-related (non-adherence to treatment), and treatment- related barriers (cost, complexity of treatment). In moving towards improving clinical outcomes potentially modifiable barriers must be identified and targeted through appropriate interventions. A mechanism is needed to identify problematic asthma management so that gaps in care and barriers can be further evaluated and managed.

One potentially modifiable barrier is the gap between optimal versus actual asthma management as

reflected by the lack of adoption of guidelines by clinicians or non-adherence of patients to recommended care. (10, 11) Much of the costs of asthma care are related to poor disease control due to under-use of effective prophylactic therapies, and inadequate monitoring of disease control. (7)At a population level there are few mechanisms available for tracking disease-management indicators for asthma to evaluate the current application of guidelines. Several studies have evaluated divergence from asthma guidelines, (12, 13) but have not been able to accurately estimate non-adherence to guidelines among a representative sample of individuals. Evaluations of adherence have mostly relied on chart reviews and clinician or patient reports which are difficult to complete for a large number of patients across several healthcare settings. (14-16)

Decision support systems are designed to facilitate uptake of evidence- based guidelines with the expectation that adherence to such guidelines will improve health outcomes. (17) Typically, decision support systems are used at the point of care. Such systems, however, may also have an alternate benefit of allowing population monitoring of adherence to disease management guidelines when the decision support algorithms are linked to administrative databases. By pushing through administrative health data including diagnoses, healthcare utilization and medication information, algorithms can be used to generate recommendations for optimizing treatment. In turn, patterns of under-optimization of treatment can be identified to monitor adherence to guidelines and target specific physician and patient sub-groups with disease management interventions.

The implementation of an asthma decision support system linked to provincial health insurance information represents a novel approach and facilitates the evaluation of the gap between recommended and actual treatment. We have developed a new methodology for assessing the quality of asthma management and asthma control in the population. Using evidence based

decision-support systems developed to guide physicians using computerized physician order entry and electronic medical record systems, we developed a program for sequentially entering, assessing and extracting individual and summarized population level quality monitoring and control status indicators. Using population level administrative data for over 16,000 asthma patients, we then used this program to evaluate asthma status and quality of adherence to national guidelines in a Quebec population on two randomly selected days in the ~~spring~~fall 2007 and spring 2008~~fall~~. This information is needed for asthma management, and can be used for identifying opportunities to target interventions and improve asthma outcomes.

In this study we examined the discrepancy between actual asthma treatments as recorded in the provincial administrative database compared to those recommended by evidence-based guidelines as defined in the asthma decision support system on two index dates.

## METHODS

### Study population

The drug and medical services information of patients cared for by primary care physicians (PCP) participating in the Medical Office of the 21st Century(MOXXI) study (18) in a large metropolitan area was used to evaluate adherence to asthma treatment guidelines. PCPs were identified by professional association master lists and contacted by letter and telephone to determine their interest in participating in the MOXXI project. Patients of these physicians were identified from the Quebec provincial health data base (RAMQ) medical service claims, physician, and beneficiary files. McGill University IRB approval was obtained for this study and PCPs who accepted provided consent for the research team to receive patient anonymised administrative data.

All patients with an ICD–9 code for asthma, with no prior diagnosis for Chronic Obstructuve Pulmonary Disease (COPD), and who were ≥ 5 years old were identified from RAMQ based on algorithms validated in prior research. (19) For the purposes of this study, only patients with full drug coverage by RAMQ were included to ensure that all drugs dispensed were captured.

**The provincial drug and administrative database (RAMQ)**

The RAMQ beneficiary demographic database provided data on individual age, gender, and mortality, and census data provided income and education. (20) Information on each drug dispensed was obtained from the prescription claims database and included the drug name, quantity, date, and duration for each prescription. The medical services claims database provided information on the beneficiary, date, type, provider, and location of service delivery (e.g., inpatient, emergency, clinic) for all medical services remunerated on a fee-for-service basis.

**Study Procedure: Evaluating the gap between actual and recommended asthma treatment using the Asthma Decision Support System (ADSS)**

The ADSS is integrated into the MOXXI electronic prescribing drug management application with patient information retrieved by real-time integration with the beneficiary, prescription and medical services claims files of the RAMQ. Using information from the prescription drug management platform, the ADSS uses the profile of existing drugs and health problems to customize recommended changes in asthma drug therapy. For this study, recommendations aimed at optimizing asthma treatment were generated on two index dates, September 15 2007 (index date 1) and March 15 2008 (index date 2), representing peak times for asthma symptoms.

In the ADSS, asthma control is determined based on overuse of short acting beta agonists (SABA) and visits to the Emergency Department (ED) for a respiratory problem over a 3 month period before the index date. Based on a previously validated algorithm, a patient is considered to be not well controlled if the sum of the quantity of all SABA medications dispensed to the patient within the last 3 months exceeds 250 doses1, (21) and/or they visited an ED for a respiratory related problem in the last 3 months. Only asthma drugs that were 1) prescribed and dispensed within one year of the index date, and 2) active (i.e. based on prescription algorithms it is likely that the person has a supply of the medication) or expired within 30 days prior to the index date were considered when generating the recommendations.

Patient-specific recommendations related to drug therapy are translated into pre-formatted prescriptions in the drug management platform. The ADSS is structured to support the Canadian Consensus guidelines for Asthma Management. (22) Recommendations are categorised based on control status. For individuals in control, recommendations generated are one of three categories: maintain treatment, decrease treatment, or maintain or decrease treatment. Recommendations also include options for action plan prescriptions for patients who are in control. For individuals not well controlled recommendations are either to increase treatment or to refer to a specialist. Within each recommendation category, physicians are presented with specific recommendations for medications and doses to achieve the desired level of drug treatment.

**Data Analysis**

Results were calculated for each index date. Descriptive statistics were used to characterize the study population and to evaluate differences between individuals with and without RAMQ coverage

[1] 250 doses is based on the most commonly prescribed SABA salbutamol 100mcg, 2 inhalations at a time, or the equivalent for other fast acting bronchodilators in the last three months.

for prescription drugs. For individuals with RAMQ coverage, the proportion of individuals under each recommendation category was evaluated among individuals classified as 'well controlled' and 'not well controlled', and descriptive statistics were used to compare the characteristics of patients across categories. Multivariable logistic regression was used to estimate the probability of being classified in control or not well controlled as a function of sociodemographic characteristics and healthcare utilization.

**Results**

*Study Population and Insured Compared to Non-Insured*

A total of 47, 614 individuals with an asthma diagnosis were identified on index date 1, after removing individuals with a prior diagnosis of COPD (6018) and those ≤ 5 years old (Figure 1). Thirty five percent of individuals were RAMQ insured for prescription drugs at least 75% of the year prior to the index date, for both dates. On index date 2, 51, 306 individuals with an asthma diagnosis were identified (Figure 2). Approximately the same proportion of individuals was classified as well controlled on index date 1 (93 %) and index date 2 (94%). As the distribution of individual characteristics, control status, and recommendation categories were similar on both index dates, we only report the results from index date 2 from this point on (Table 1).

Individuals who were RAMQ insured were on average older (mean=38±22) as compared to non-RAMQ insured individuals (mean=31±18) and had a greater percentage of individuals ≥ 60 years old, a larger proportion was female (61% versus 56%), and in the lower socioeconomic status (SES) category (21% versus 6%). A greater proportion of RAMQ insured patients had 3 or more ED (16 versus 9%) and hospital visits (8 versus 3%) one year prior to the index date, and a diagnostic code for anxiety (11 compared to 7%) or depression (8 compared to 5%).

**Table 1** Characteristics of Study Participants with and without provincial health coverage (RAMQ) on index date 2*

| | RAMQ Coverage | No RAMQ Coverage |
|---|---|---|
| | **n=18 013** | **n=33 293** |
| **Age mean (sd)** | 38,3 (21.8) | 30,81 (17,5) |
| **Age n (%)** | | |
| ≤ 17 | 3 963 (22.0 ) | 10 273 (30,9) |
| 18-39 | 5 129 (28.6 ) | 9 926 (29,8) |
| 40-59 | 5 254 (29,2) | 11 277 (33.9) |
| ≥ 60 | 3 637 (20,2) | 1 817 (5.5) |
| **Sex n (% female)** | 11 035 (61,3) | 18 665 (56.1) |
| **Income n (%) *** | | |
| Low SES | 3 490 (19.4) | 2 665 (8.0) |
| Middle SES | 13 148 (73.0) | 25 947 (78.0) |
| High SES | 1 230 (6.8 ) | 4 298 (13.0) |
| **Healthcare Utilization over 1 year prior to March 15. 2008** | | |
| **Medical ~~Phycisian~~*Physician*** | | |
| **Visits** n (%)** | | |
| 0 visit | 1 736 (9.6 ) | 3 855 (11.6) |
| 1 visit | 1 998 (11.1) | 4 453 (13.4) |
| 2 visits | 1 895 (10.5) | 4 154 (12.5) |
| 3 or more visits | 12.384 (68.8) | 20 831 (62.6) |
| **Emergency Department Visits n (%)** | | |
| 0 visit | 10 435 (57.9) | 22 738 (68.0 ) |
| 1 visit | 3 139 (17.4) | 5 445 (16.4) |
| 2 visits | 1 698 (9.4) | 2 416 (7.3) |
| 3 or more visits | 2 741 (15.2) | 2 694 (8.1) |
| **Emergency Department Visits for asthma n (%)** | 1 313 (7.3) | 1 644 (4.9) |
| **Hospitalization** | | |
| 0 day | 14 890 (82.7) | 29 445 (88.4) |
| 1 day | 1 340 (7.4) | 2 072 (6.2) |
| 2 days | 445 (2.5) | 658 (2.0) |
| 3 or more days | 1 338 (7.4) | 1 118 (3.4) |
| **Co-Morbidity n (%)** | | |
| Depression | 1 400 (7.77) | 1 724 (5.2) |
| Anxiety | 1 913 (10.62) | 2 361 (7.1) |

* Around 1 % of missing values for each category; All differences between RAMQ and Non-RAMQ insured are significant, p<0.01.

** Ambulatory and specialty care

*Control Status and Recommendation Categories*

Among the 18 013 individuals who were RAMQ insured for prescription drugs, 93% were classified as well controlled and 7% as not well controlled over 3 months prior to the index date (Figure 1).

63 % of individuals who were not well controlled were in the ≥ 40 age group and 26% in the low SES category compared to 49% and 19%, respectively, in the well controlled group. These individuals also had a higher Charlson Co-morbidity Index of 2.11 as compared to 1.6 among those well controlled. A larger proportion of individuals among those not well controlled had a diagnostic code for depression, anxiety, mental illness, and a cardiac related condition. Among those not well controlled 69% (n=667) had at least 1 ED visit (past 3 months), and 74% a medical visit associated with a respiratory problem (in the past year). In comparison 13% (n=2,039) of those well controlled had at least one ED visit and 52% medical visit related to a respiratory problem.

53% of patients in the not well controlled group had an active prescription for an ICS, 20% a combination therapy, and 14% as compared to 36%, 10%, and 6% in the well controlled group. 63% and 42% of not well and well controlled, respectively, had an active prescription for a fast-acting beta agonist (FABA). At index date 1, all individuals not well controlled had asthma drugs as compared to 9.2 % of those well controlled who had no asthma drugs dispensed.

Table 2 presents the incremental regression coefficients for the demographic, healthcare utilization, and co-morbidity variables hypothesized to be associated with control status. Healthcare utilization including, ≥ 3 days of hospitalization (OR=4.58), and ≥ 3 visits to the ED (for reasons other than a

respiratory problem) (OR=2.32), was found to be most strongly associated with control status. Being male (OR=.85), from a low SES (OR= 1.9), and in the 40-59 age group increased the odds of having asthma that was not well controlled.

**Table 2** Multivariable Logistic Regression Models for Identifying Individuals Controlled and Not Well Controlled

| Variable | OR (95%CI) Control Status |
|---|---|
| **Age mean (sd)** | |
| ≤ 17 | Reference |
| 18-39 | 0.56 (0.44, 0.72) |
| 40-59 | 2.19(1.73, 2.77) |
| ≥ 60 | 1.19 (1, 1.42) |
| **Sex n (% female)** | |
| Male | Reference |
| Female | 85 (.74, .98) |
| **Income n (%) *** | |
| High SES | Reference |
| Middle SES | 1.44 (1.04, 1.98) |
| Low SES | 1.90 (1.35, 2.68) |
| **Healthcare Utilization over 1 year prior to March 15, 2008** | |
| Medical *Physician* *Visits n (%) | |
| 0 visit | Reference |
| 1 visit | .73 (.47,1.2) |
| 2 visits | .82 (.53,1.28) |
| ≥ 3 visits | 1.62 (1.162.27) |
| **Emergency Department Visits (other than resp)n (%)** | |
| 0 visit | Reference |
| 1 visit | 1.38(1.14,1.66) |
| 2 visits | 1.46(1.16,1.84) |
| ≥3 visits | 2.32(1.94,2.8) |
| **Hospitalisation** | |
| 0 day | Reference |
| 1 day | 2.24(1.55,3.27) |
| 2 days | 2.88(1.79,4.6) |
| 3 or more days | 4.58 (3.36,6.22) |
| **Co-Morbidity n (%)** | |
| Charlson co-morbidity index | 1.04 (1.01, 1.08) |
| Anxiety No | Reference |

16

| | |
|---|---|
| Yes | 1.26 (1.05,1.52 ) |

* General practitioner and specialist

***Recommendation category by control group***

The distribution of individuals across recommendation categories is presented in Table 3.

For 8% (1198/15843) in control, and 21% (201/960) of those not well controlled, a recommendation could not be determined by the ADSS either because the patient 1) had dispensed prescriptions for an inappropriate combination of medications that the ADSS could not reconcile to provide an appropriate recommendation (e.g. a LABA with two prescriptions for combination therapy) or, 2) dispensed two medications that resulted in a duplication of therapy. For those not well controlled, those in the *duplicate/inappropriate* category had a larger proportion in the lower SES, a higher co-morbiditiy index and more frequent ambulatory and hospital visits.

Among individuals well controlled, the largest proportion of individuals were in the *maintain treatment* category (50.6%), followed by *maintain/decrease treatment* (28.2%), and *decrease treatment* (2.7%). Almost all individuals not well controlled had the recommendation to *increase treatment* (88%) with a small proportion in the *refer* category (1%). Reasons for the low referral to specialty care needs to be closely examined, and may be related to uncertainty of primary care physicians of when to refer patients, and/or patients may not go see specialists once referred. (23) Regardless of the recommendation category, the largest proportion of individuals was in the 40-59 age group; except for *maintain treatment* that had a larger proportion of individuals in the 18-39 age group. The middle SES was the largest for all recommendation groups and the proportion of females was the same across all categories. Individuals in the *refer* category were on average older than those in the other categories, but comparable on many of the other characteristics.

**Table 3** Comparison of characteristics of individuals in each recommendation category (based on primary recommendation)*

| | In Control N=14989 | | | | Not Well Controlled N=1245 | | |
|---|---|---|---|---|---|---|---|
| | Maintain n=9564 | Maintain/Decrease n=4349 | Decrease n=474 | Duplicate/ Inappropriate n=602 | Increase n=1 090 | Refer n=17 | Duplicate/ Inappropriate n=138 |
| **Age mean (sd)** | 41.8 (19.2) | 38.2 (22.7) | 44.8 (21.6) | 45.9 (20.3) | 40.4 (21.5) | 57.1 (9.3) | 46.6 (16.0) |
| **Age n (%)** | | | | | | | |
| ≤ 17 | 919 (9.6) | 1 115 (25.6) | 74 (15.6) | 68 (11.3) | 189 (17.3) | 0 | 6 (4.4) |
| 18-39 | 3 561 (37.2) | 996 (22.9) | 86 (18.1) | 123 (20.4) | 310 (28.4) | 0 | 33 (23.9) |
| 40-59 | 2 987 (31.2) | 1 269 (29.2) | 195 (41.1) | 260 (43.2) | 372 (34.1) | 10 (58.8) | 79 (57.2) |
| ≥ 60 | 2 097 (21.9) | 969 (22.3) | 119 (25.1) | 151 (25.1) | 219 (20.1) | 7 (41.2) | 20 (14.5) |
| **Sex n (% F)** | 6 073 (63.5) | 2 659 (61.1) | 303 (63.9) | 381 (63.3) | 709 (65.0) | 12 (70.6) | 101 (73.2) |
| **Income n (%) *** | | | | | | | |
| Low SES | 1 684 (17.6) | 923 (21.2) | 117 (24.7) | 156 (25.9) | 237 (21.7) | 4 (23.5) | 43 (31.2) |
| Middle SES | 7 028 (73.5) | 3 161 (72.7) | 330 (69.6) | 420 (69.8) | 802 (73.6) | 13 (76.5) | 90 (65.2) |
| High SES | 763 (8.0) | 228 (5.2) | 25 (5.3) | 22 (3.6) | 47 (4.3) | 0 | 5 (3.6) |
| **Medical Visits mean (sd) past year** | | | | | | | |
| *All* | 8.78 (13.1) | 9.68 (13.8) | 12.62(13.3) | 12.87(13.4) | 16.52 (22.2) | 29.29 (21.3) | 24.99 (26.1) |
| *Ambulatory* | 7.72 (9.6) | 8.31 (9.2) | 10.89 (9.5) | 11.13 (9.5) | 13.53(15.0) | 19.94 (10.0) | 20.01 (18.1) |
| *Hospitalized* | 1.07 (6.8) | 1.37 (7.7) | 1.73 (7.4) | 1.73 (7.6) | 2.99 (11.6) | 9.35 (16.4) | 4.98 (13.3) |
| **Medical Visits n (%) past year** | | | | | | | |
| ***Phycisian*** | | | | | | | |
| 0 visit | 1 036 (10.8) | 265 (6.1) | 14 (3.0) | 22 (3.6) | 62 (5.7) | 0 | 7 (5.1) |
| 1 visit | 1048 (10.96) | 451 (10.4) | 31 (6.5) | 40 (6.6) | 76 (7.0) | 0 | 5 (3.6) |
| 2 visits | 1000 (10.5) | 486 (11.2) | 41 (8.6) | 26 (4.3) | 81 (7.4) | 0 | 2 (1.4) |
| 3 or more visits | 6 480 (67.8) | 3 147 (72.4) | 388 (81.9) | 514 (85.4) | 871 (79.9) | 17 (100) | 124 (89.9) |
| ***ER*** | | | | | | | |
| 0 visit | 5 995 (62.7) | 2 501 (57.5) | 240 (50.6) | 289 (48.0) | 200 (18.4) | 1 (5.9) | 25 (18.1) |
| 1 visit | 1 565 (16.4) | 790 (18.2) | 89 (18.8) | 118 (19.6) | 221 (20.3) | 3 (17.6) | 21 (15.2) |
| 2 visits | 846 (8.8) | 414 (9.5) | 59 (12.4) | 63 (10.5) | 172 (15.8) | 1 (5.9) | 9 (6.5) |
| 3 or more visits | 1 158 (12.1) | 644 (14.8) | 86 (18.1) | 132 (21.9) | 497 (45.6) | 12 (70.6) | 83 (60.2) |
| **ED- for respiratory problems** | | | | | | | |
| 0 visit | 8 781 (91.8) | 3 792 (87.2) | 394 (83.1) | 491 (81.6) | 294 (27.0) | 4 (23.5) | 38 (27.5) |
| 1 visit | 593 (6.2) | 402 (9.2) | 52 (11.0) | 64 (10.6) | 450 (41.3) | 4 (23.5) | 27 (19.6) |
| 2 visits | 142 (1.5) | 105 (2.4) | 15 (3.2) | 25 (4.2) | 188 (17.2) | 3 (17.65) | 22 (15.9) |
| 3 or more visits | 48 (0.5) | 50 (1.2) | 13 (2.7) | 22 (3.7) | 158 (14.5) | 6 (35.3) | 51 (37.0) |
| **ED- NOT for respiratory problems** | | | | | | | |
| 0 visit | 6 268 (65.5) | 2 712 (62.4) | 265 (55.9) | 326 (54.2) | 456 (41.8) | 4 (23.5) | 45 (32.6) |
| 1 visit | 1 535 (16.1) | 742 (17.1) | 94 (19.8) | 118 (19.6) | 205 (18.8) | 3 (17.6) | 29 (21.0) |
| 2 visits | 746 (7.8) | 370(8.5) | 49 (10.3) | 58 (9.6) | 117 (10.7) | 3 (17.6) | 14 (10.1) |
| 3 or more visits | 1 015 (10.6) | 525 (12.1) | 66 (13.9) | 100 (16.6) | 312 (28.6) | 7 (41.2) | 50 (36.2) |
| **Hospitalization** | | | | | | | |
| 0 day | 8 046 (84.1) | 3 581 (82.3) | 356 (75.1) | 449 (74.6) | 774 (71.0) | 5 (29.4) | 78 (56.5) |
| 1 day | 697 (7.3) | 318 (7.3) | 39 (8.2) | 62 (10.3) | 100 (9.2) | 3 (17.6) | 17 (12.3) |
| 2 days | 215 (2.2) | 107 (2.5) | 20 (4.2) | 23 (3.8) | 44 (4.0) | 1 (5.9) | 3 (2.2) |
| 3 or more days | 606 (6.3) | 343 (7.9) | 59 (12.4) | 68 (11.3) | 172 (15.8) | 8 (47.1) | 40 (29.0) |

18

| | In Control N=14989 | | | | Not Well Controlled N=1245 | | |
|---|---|---|---|---|---|---|---|
| | Maintain n=9564 | Maintain/Decrease n=4349 | Decrease n=474 | Duplicate/ Inappropriate n=602 | Increase n=1 090 | Refer n=17 | Duplicate/ Inappropriate n=138 |
| **Hospitalization- for respiratory problems** | | | | | | | |
| 0 day | 9 370 (98.0) | 4 210 (96.8) | 447 (94.3) | 563 (93.5) | 990 (90.8) | 14 (82.4) | 109 (79.0) |
| 1 day | 100 (1.0) | 60 (1.4) | 7 (1.5) | 20 (3.3) | 33 (3.0) | 0 | 7 (5.1) |
| 2 days | 32 (0.3) | 32 (0.74) | 4 (0.8) | 5 (0.8) | 14 (1.3) | 0 | 3 (2.2) |
| 3 or more days | 62 (0.6) | 47 (1.1) | 16 (3.4) | 14 (2.3) | 53 (4.9) | 3 (17.6) | 19 (13.8) |
| **Asthma Medications mean (sd) range past year** | | | | | | | |
| FABA | 0.61 (1.7) | 2.93 (3.8) | 4.32 (5.2) | 4.95 (5.1) | 2.50 (4.4) | 5.00 (5.2) | 6.82 (6.8) |
| ICS | 0.2 (0.7) | 2.3(2.9) | 1.4(2.6) | 3.6(3.8) | 1.4(2.4) | 0.9 (1.7) | 3.5(3.9) |
| Leukotrienes | 0.1 (1.4) | 0.4(3.0) | 6.7(10.0) | 1.5 (4.8) | 0.8(4.4) | 3.3(5.1) | 3.9 (11.5) |
| Combination Therapy | 0.0 (0.4) | 1.2 (2.9) | 5.1(4.9) | 2.18 (3.9) | 1.0 (2.7) | 7.7 (4.5) | 3.0 (4.3) |
| Other | 0.2(1.8) | 0.8(3.4) | 2.9(6.8) | 2.36 (3.9) | 1.8(17.0) | 2.1 (2.5) | 4.45 (6.6) |
| **Control Status n (%)** | | | | | | | |
| Overuse FABA | 0 | 0 | 0 | 0 | 1 (0.1) | 0 | 0 |
| ED visits for Asthma | 0 | 0 | 0 | 0 | 1 076 (98.7) | 17 (100) | 135 (97.8) |
| ER or FABA | 0 | 0 | 0 | 0 | 1 076 (98.7) | 17 (100) | 135 (97.8) |
| **Co-Morbidity Index** | 1.6 (1.5) | 1.6 (1.5) | 1.8 (1.6) | 1.9 (1.9) | 1.8(2.0) | 2.2 (1.4) | 2.6 (2.5) |

*10% (n= missing for well controlled and 7% for not well controlled; Less than 1 % of missing values for each category; ED=emergency department

**DISCUSSION**

The purpose of this study was to evaluate the discrepancy between current asthma management and recommended guidelines using the provincial administrative databases and an ADSS. The present study represents an example of how decision support systems can be used to monitor guideline adherence, and to identify individuals at risk of poor outcomes to provide targeted interventions. To our knowledge this is the first time that a decision support system has been used to evaluate disease management at a population level.

As expected, individuals who were provincially insured were on average older, from a lower SES, and a higher proportion used healthcare services. A larger proportion compared to those non-provincially insured also had a diagnosis code for anxiety and depression.

The algorithms used to identify individuals with asthma and evaluate control status were validated in previous work. (24, 25) The majority of individuals well controlled were on an appropriate quantity of asthma treatment. We found, however, that ~ 31% of those well controlled could benefit from a medication review and potentially lower doses of asthma medications.

The majority of individuals not well controlled had the recommendation to increase treatment and for these individuals there was an opportunity to change therapy according to the existing guidelines. (26) The SMART inhaler helps address needs for increase in therapy, as it allows patients to use their as-needed medication because of declining asthma control—as is very often the case—evolving exacerbations will possibly be treated at an early stage and a further worsening of asthma may possibly be prevented. The SMART inhaler is not a recommended yet part of Canadian guidelines, however, with emerging evidence of its benefits for marinating control

compared to other alternatives, (27, 28) it will be included in the next version of guidelines and become more commonly prescribed for Canadian patients. Individuals who were not well controlled were in the 40-59 age range, and had a more complex health profile with greater co-morbidity, including a higher proportion with a diagnosis of anxiety or depression as compared to those well-controlled. The logistic regression analysis in our study also supported these conclusions. These individuals represent a more vulnerable sub-group of the asthma population, and place a greater burden on the healthcare system given the higher proportion that had an ED visit or hospitalization. As such, they require closer monitoring and review of medication to reach doses sufficient to maintain asthma control, or to review reasons for failed treatment.

In this study we were not able to generate a recommendation for a larger proportion of individuals not well controlled compared to controlled either because they were dispensed prescriptions for an inappropriate combination of medications that the ADSS could not reconcile to provide an appropriate recommendation, or they were dispensed two medications that resulted in a duplication of therapy. These cases in themselves represent a segment of the asthma population that requires closer review of their prescribed medication.

The generation of asthma recommendations at a population level using an administrative database allows individuals not receiving treatment based on guidelines to be identified. We found that many individuals with non-controlled asthma visit a physician 3 or more times per year, and potentially represent missed opportunities to optimize treatment. Possible reasons for our findings may include the lack of knowledge of PCPs of guidelines in general, especially for more complicated cases. It may also be, however, that patients are not going to see the same physician, or are switching physicians to ensure access to SABAs. In such situations, physicians may be reluctant to conduct a

complete medication review if they do not perceive themselves as the primary provider for the patient.

Other physician concerns may be the reluctance to prescribe ICS and/or concern regarding polypharmacy with multiple inhalers. (29) This is where the role of pharmacists is important as they can see individuals' entire medication dispensing history and have been shown to be effective in managing asthma patients in particular if supported by an ADSS. (30)

Previous studies have also found that physicians do not adopt guidelines in their practice because of perceived appropriateness of the guidelines. (13, 31) Surveys have shown that they believe that guidelines do not take into account the heterogeneity of asthma and do not account for individual patient variations in response to treatment, (32) and other factors that impact response to asthma therapy such as age and co-morbidities.

Further, patient non-adherence to prescribed therapy and not having prescribed medications filled may also explain the findings from our study. Patient beliefs about the negative impact and benefits of their medications, (33) their confidence to manage their asthma, and not seeking care early enough to prevent exacerbations have all been identified as contributors to poor outcomes for asthma.(34)

Mechanisms to identify patients who need closer follow-up and evaluation have been identified as an important need for primary healthcare. (3, 34, 35) Future initiatives can include linking administrative databases to decision support systems that can help identify individuals who need closer monitoring and follow-up and allow for targeted services such as visit reminders sent to

patients or to their care provider. The ongoing implementation of electronic health records and patient health portals will facilitate this approach. Information can be fed back to physicians and pharmacists to improve patient management, and initiate care early on, before individuals experience deterioriations in health~~.~~.

**Limitations**

Our approach for identifying individuals with asthma and assessing asthma status may have underestimated the percentage out of control in our study. We examined asthma control on two index dates, and went back 3 months prior to the index date to assess control status. A more sensitive algorithm that treats control as a time varying covariate would likely provide a more accurate evaluation of control status. Also, because we used administrative data and not clinical information from an electronic medical record to generate recommendations, we were not able to use asthma severity and relapse as part of the asthma control ~~algorithm .~~ algorithm. Finally, previous studies that have reported higher levels of not well-controlled individuals were based on self-reports as opposed to administrative data. ~~In addition,~~

A~~a~~t the time that the ADSS was being developed, the SMART treatments, that allow for the same inhaler to be used as a preventative and rescue inhaler were not commonly used or part of the guidelines. Therefore, they were not programmed as part of the ADSS and not included in the recommendations.~~-~~ Further, the ADSS does not distinguish between SABA nebulizer and MDI. ~~–~~. ~~Furthe~~Finally~~r~~, use of decision support during clinical encounters allow for a patient-reported assessment of symptoms at the time when recommendations are generated, and allow for a more accurate assessment of asthma control. We were also limited to generating recommendations for those provincially insured that represent a more vulnerable segment of the population.

**Conclusions**

This study demonstrated how a decision support system linked to an administrative database could be used to identify individuals in the population that require a review of asthma treatment. Such an approach can help identify individuals with uncontrolled asthma or prescriptions that deviate from recommended treatment to intervene early. This study provides a model for monitoring adherence to guidelines for other chronic conditions such as hypertension and diabetes.

**Declaration of Interest**

Health Canada and the Canadian Institute of Health Research supported the development of the asthma decision support system. S Ahmed is supported by a Fonds de la Recherche en Santé du Quebec (FRSQ) research career award.

## References

1. Shenolikar R, Song X, Anderson JA, Chu BC, Cantrell CR. Costs of asthma among US working adults. Am J Manag Care.2011;17:409-16.

2. Schatz M, Zeiger RS, Yang SJ, Chen W, Crawford W, Sajjan S, et al. The relationship of asthma impairment determined by psychometric tools to future asthma exacerbations. Chest 2012;141:66-72.

3. Urrutia I, Aguirre U, Pascual S, Esteban C, Ballaz A, Arrizubieta I, et al. Impact of anxiety and depression on disease control and quality of life in asthma patients. J Asthma 2012;49:201-8.

4. Colice GL, Ostrom NK, Geller DE, Anolik R, Blaiss M, Marcus P, et al. The CHOICE survey: high rates of persistent and uncontrolled asthma in the United States. Ann Allergy Asthma Immunol 2012;108:157-62.

5. Glaxo Wellcome I. 2000:1-31.

6. Bousquet J, Mantzouranis E, Cruz AA, Ait-Khaled N, Baena-Cagnani CE, Bleecker ER, et al. Uniform definition of asthma severity, control, and exacerbations: document presented for the World Health Organization Consultation on Severe Asthma. J Allergy Clin Immunol 2010;126:926-38.

7. Katayoun Bahadori, Mary M Doyle-Waters, Carlo Marra, Larry Lynd, Kadria Alasaly, John Swiston and J Mark FitzGerald. Economic burden of asthma: a systematic review BMC Pulmonary Medicine 2009, **9**:24 doi:10.1186/1471-2466-9-24

8. US Department of Health and Human Services OoDPaHP. Healthy People 2020 Washington,DC2010 [B0132]. Available from:

http://www.healthypeople.gov/2020/TopicsObjectives2020/pdfs/HP2020_brochure_with_LHI_508.pdf.

9. Maciejewski ML, Chen SY, Au DH. Adult asthma disease management: an analysis of studies, approaches, outcomes, and methods. Respir Care 2009;54:878-86.

10. Legorreta AP, Christian-Herman J, O'Connor RD, Hasan MM, Evans R, Leung KM. Compliance with National Asthma Management Guidelines and Specialty Care: A Health Mantenance Organization Experience. Arch Intern Med 1998;158:457-64.

11. Adams RJ, Fuhlbrigge A, Guilbert T, Lozano P, Martinez F. Inadequate use of asthma medication in the United States: results of the asthma in America national population survey. J Allergy Clin Immunol 2002;110:58-64.

12. Flor-Escriche X, Rodriguez-Mas M, Espiau M, Castan-Ensenat X, Vigata-Reig JM, Poblet-Cortes R, et al. Compliance with guidelines in the treatment of asthma exacerbations in primary care. Ther Adv Respir Dis 2011;5:369-75.

13. Rank MA, Liesinger JT, Ziegenfuss JY, Branda ME, Lim KG, Yawn BP, et al. The impact of asthma medication guidelines on asthma controller use and on asthma exacerbation rates comparing 1997-1998 and 2004-2005. Ann Allergy Asthma Immunol 2012;108:9-13.

14. Cazzola M, Segreti A, Bettoncelli G, Calzetta L, Cricelli C, Pasqua F, et al. Change in asthma and COPD prescribing by Italian general practitioners between 2006 and 2008. Prim Care Respir J 2011;20:291-8.

15. Arnlind MH, Wettermark B, Nokela M, Hjemdahl P, Rehnberg C, Jonsson EW. Regional variation and adherence to guidelines for drug treatment of asthma. Eur J Clin Pharmacol 2010 ;66:187-98.

16. Lougheed MD, Olajos-Clow J, Szpiro K, Moyse P, Julien B, Wang M, et al. Multicentre evaluation of an emergency department asthma care pathway for adults. CJEM 2009;11:215-29.

17. Roshanov PS, Misra S, Gerstein HC, Garg AX, Sebaldt RJ, Mackay JA, et al. Computerized clinical decision support systems for chronic disease management: a decision-maker-researcher partnership systematic review. Implement Sci 2011;6:92.

18. Tamblyn R, Huang A, Perreault R, Jacques A, Roy D, Hanley J, et al. The medical office of the twenty-first century (MOXXI): evaluation of the effectiveness of computerised decision support in reducing inappropriate prescribing in primary care. CMAJ 2003;169:549-56.

19. Kawasumi Y, Abrahamowicz M, Ernst P, Tamblyn R. Development and validation of a predictive algorithm to identify adult asthmatics from medical services and pharmacy claims databases. Health Serv Res 2011;46:939-63.

20. Tamblyn RM, Laprise R, Hanley JA, Abrahamowicz M, Scott S, Mayo N, et al. Adverse events associated with prescription drug cost-sharing among poor and elderly persons. JAMA 2001;285:421-9.

21. Schatz M, Zeiger RS, Vollmer WM, Mosen D, Apter AJ, Stibolt TB, et al. Validation of a beta-agonist long-term asthma control scale derived from computerized pharmacy data. J Allergy ClinImmunol 2006;117:995-1000.

22. Lemiere C, Bai T, Balter M, Bayliff C, Becker A, Boulet LP, et al. Adult Asthma Consensus Guidelines update 2003. Can Respir J 2004;11 Suppl A:9A-18A.

23. Archives of Internal Medicine. JAMA 2001;161.

24. Spitzer WO, Suissa S, Ernst P, Horwitz RI, Habbick B, Cockcroft D, et al. The use of beta-agonists and the risk of death and near death from asthma. N Engl J Med 1992;326:501-6.

25. Wilchesky M, Tamblyn RM, Huang A. Validation of Diagnostic Codes in Medical Services Claims Data. Can J Clin Pharmacol 2001;8:39-39.

26. Becker A, Lemiere C, Berube D, Boulet LP, Ducharme FM, FitzGerald M, et al. Summary of recommendations from the Canadian Asthma Consensus guidelines, 2003. CMAJ 2005;173:S3-11.

27. Boursquet J, Boulet LP, Peters MJ, Magnussen H, Quiralte J, Martinez-Aguilar NE, et al. Budesonide/formoterol for maintenance and relief in uncontrolled asthma vs. high-dose salmeterol/fluticasone. Respir Med 2007;101:2437-46.

28. Kuna P, Peters M, Manjra A, Jorup C, Naya I, Martinez-Aguilar N, et al. Effect of budesonide/formoterol maintenance and reliever therapy on asthma exacerbations. Int J Clin Pract 2007;61:725-36.

29. Navaratnam P, Jayawant SS, Pedersen CA, Balkrishnan R. Asthma pharmacotherapy prescribing in the ambulatory population of the United States: evidence of nonadherence to national guidelines and implications for elderly people. J Am Geriatr Soc 2008;56:1312-7.

30. Armour C, Bosnic-Anticevich S, Brillant M, Burton D, Emmerton L, Krass I, et al. Pharmacy Asthma Care Program (PACP) improves outcomes for patients in the community. Thorax 2007;62:496-502.

31. Bracha Y, Brottman G, Carlson A. Physicians, guidelines, and cognitive tasks. Eval Health Prof 2011;34:309-35.

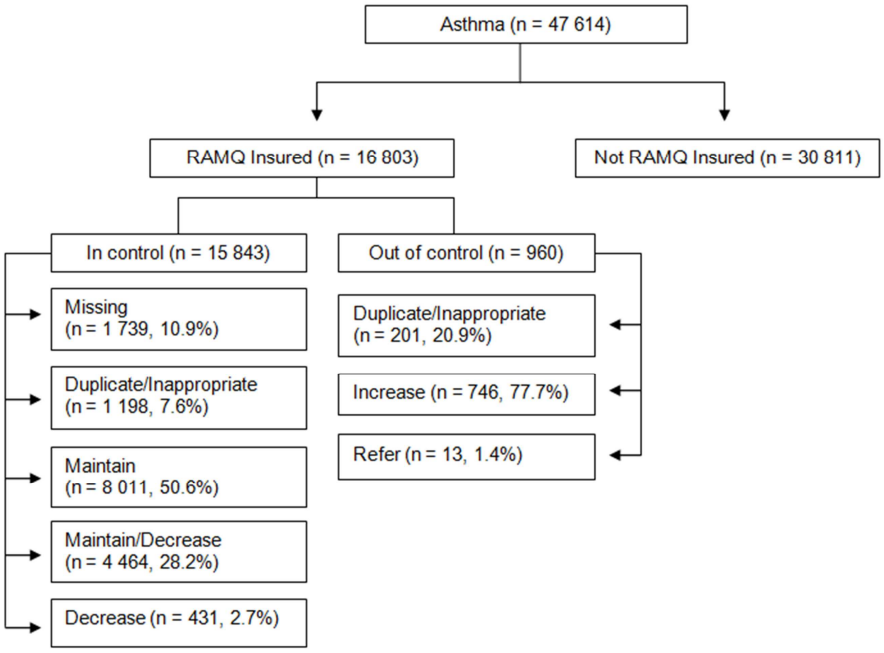
32. Yeh KW, Chen SH, Chiang LC, Chen LC, Huang JL. Survey of asthma care in Taiwan: a comparison of asthma specialists and general practitioners. Ann Allergy Asthma Immunol 2006;96:593-9.

33. Brunton SA, Graham LM, Stoloff SW. Primary care management of patients with asthma. J Fam Pract 2011;60:S1-8.

34.Razykov I, Newton EG, Lober J, Thombs BD. Daily SMS reminders for asthma treatment adherence: A comment on Strandbygaard et al. Respir Med 2010;104:1234-5; author reply 1236.

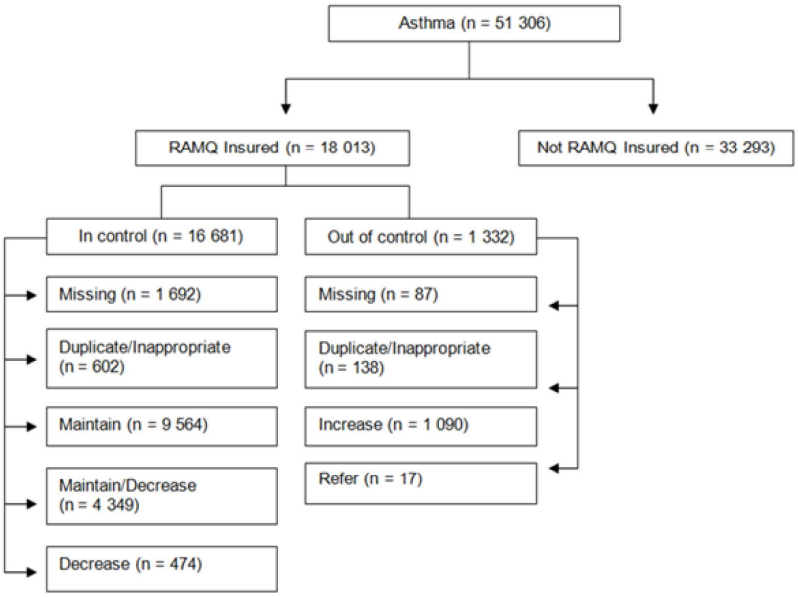
35. Martens JD, van der Weijden T, Winkens RA, Kester AD, Geerts PJ, Evers SM, et al. Feasibility and acceptability of a computerised system with automated reminders for prescribing behaviour in primary care. Int J Med Inform 2008;77:199-207.

**Figure 1:** Study Population and recommendation categories for September 15, 2007 (index date 1)



30

**Figure 2:** Study Population and recommendation categories for March 15, 2008 (index date 2)



# Using decision support for population tracking of adherence to recommended asthma guidelines

| | |
|---|---|
| Journal: | *BMJ Open* |
| Manuscript ID: | bmjopen-2013-003759.R2 |
| Article Type: | Research |
| Date Submitted by the Author: | 23-Dec-2013 |
| Complete List of Authors: | Ahmed, Sara; McGill University, Faculty of Medicine<br>Tamblyn, Robyn; McGill University, Faculty of Medicine<br>Winslade, Nancy; McGill University, Faculty of Medicine |
| Primary Subject Heading: | Health informatics |
| Secondary Subject Heading: | Health informatics, Medical management, Respiratory medicine |
| Keywords: | Asthma < THORACIC MEDICINE, Health informatics < BIOTECHNOLOGY & BIOINFORMATICS, EPIDEMIOLOGY |
| | |

**Using decision support for population tracking of adherence to recommended asthma guidelines**

**Sara Ahmed [1,3,4], Robyn Tamblyn [2,3], Nancy Winslade [2,3]**

[1]Faculty of Medicine, School of Physical and Occupational Therapy, McGill University
3654 Prom. Sir William Osler, Montreal, QC, H3G 1Y5, Canada

[2]Faculty of Medicine, Clinical and Health Informatics, McGill University

1140 Pine avenue west, Montreal, QC, H3A 1A3, Canada

[3] McGill University Health Center, Clinical Epidemiology

[4] **Centre de Recherche Interdisciplinaire en Réadaptation** du Montréal Métropolitain

**Corresponding author**

Sara Ahmed

Faculty of Medicine, McGill University
3654 Prom. Sir William Osler, Montreal, QC, H3G 1Y5, Canada
E-mail: sara.ahmed@mcgill.ca

**Word Count:** 3092

**Figures:** 2

**Tables**: 3

**Keywords**: Asthma, clinical practice guidelines, disease management, decision support, administrative database

**What is the key question?** What is the discrepancy between actual asthma treatments individuals' receive as recorded in the provincial administrative database as compared to those recommended by evidence-based guidelines as defined within an asthma decision support system.

**What is the bottom line; and why read on?** Decision support systems that define evidence-based guidelines, linked to an administrative database, can be used to identify individuals with uncontrolled asthma or prescriptions that deviate from recommended treatment at a population level.

**Why read on?** The methods and approach from the current study can provide an opportunity for physicians to intervene early and can be used to evaluate adherence to evidence-based guidelines and indicators of disease management for other patient populations.

Ahmed, Tamblyn,Winslade

**Abstract**

Objective: Decision support systems linked to administrative databases provide a unique opportunity to monitor adherence to guidelines and target disease management strategies to patients not receiving guideline-based therapy. The objective of this study was to evaluate the discrepancy between actual asthma treatments prescribed by primary care physicians compared to those recommended by evidence-based guidelines using a decision support tool linked to a provincial health administrative database.

Design: The drug and medical services information of individuals with asthma were identified from the provincial health database and were pushed through an asthma decision support system (ADSS). Recommendations aimed at optimizing asthma treatment were generated on two index dates, September 15 2007 (index date 1) and March 15 2008 (index date 2).

Setting: Primary care settings in a large Canadian metropolitan area.

Participants: Individuals with asthma and provincial health insurance

Primary and secondary outcome measures: well controlled asthma

Results: 16, 803 eligible individuals were identified on index date 1, and 18, 103 on index date 2. The distribution of recommendation categories were similar on both index dates. 94% were classified as well controlled and 7% as not well controlled. Among individuals well controlled, the largest proportion of individuals were in the maintain treatment category (50.6%), followed by maintain/decrease treatment (28.2%), and decrease treatment (2.7%). Almost all individuals not well controlled had the recommendation to increase treatment (88%) with a small proportion in the refer category (1%).

Conclusions: The ADSS was able to identify sub-groups of patients from an administrative database that could benefit from a medication review and possible change. Decision support systems linked to an administrative database can be used to identify individuals with uncontrolled asthma or prescriptions that

deviate from recommended treatment. When connected to the point of care, this can provide an opportunity for physicians to intervene early.

**Article Summary**

1) Article Focus –

- The objective of this study was to evaluate the discrepancy between actual asthma treatments prescribed by primary care physicians to those recommended by evidence-based guidelines using a decision support tool linked to a provincial health administrative database.

2) Key Messages - up to three bullet points outlining the key messages and significance of the study.

- Decision support systems that define evidence-based guidelines, linked to an administrative database, can be used to identify individuals with uncontrolled asthma or prescriptions that deviate from recommended treatment at a population level.
- When connected to the point of care, discrepancies between decision support and actual care can provide an opportunity for physicians to intervene early.
- The methods in this study can be applied in future work to evaluate adherence toevidence-based guidelines at a population level if administrative databases are available, or at the point of care if linked to an electronic health record.

3) Strengths and Limitations

- The availability of a provincial administrative database and decision support system allowed us to assess guideline adherence, and to identify sub-groups of individuals at risk of poor outcomes.
- The administrative database only includes individuals who are provincially insured and

therefore discrepancies could not be examined for individuals with private insurance.

- The proportion of individuals with poor asthma control may have been underestimated as control status was evaluated over a 3-month period.

**Introduction**

Asthma poses a significant burden on healthcare resources and costs, [1] and results in reduced individual functioning and quality of life. [2, 3] Over the past 10 years there have been tremendous improvements in the scientific understanding of asthma and its treatment, and these findings have been made available to clinicians through the development of clinical practice guidelines. Despite achieving such sentinel milestones in asthma care, over 50% [4, 5] of individuals remain poorly controlled in the U.S. and Canada, with similar estimates worldwide. [6] This has translated into direct and indirect costs of 654 million and 7.2 billion dollars (equivalent to US dollars in 2008) in Canada and the US, respectively [7]

Healthcare organizations worldwide have been charged with improving asthma outcomes over the next 2-3 years, with the aim of reducing hospitalizations and deaths related to asthma. [8] Several barriers for optimal management result in poor outcomes for asthma, [9] including clinician-related (non-adherence to guidelines), patient-related (non-adherence to treatment), and treatment- related barriers (cost, complexity of treatment). In moving towards improving clinical outcomes potentially modifiable barriers must be identified and targeted through appropriate interventions. A mechanism is needed to identify problematic asthma management so that gaps in care and barriers can be further evaluated and managed.

One potentially modifiable barrier is the gap between optimal versus actual asthma management as reflected by the lack of adoption of guidelines by clinicians or non-adherence of patients to recommended care. [10, 11] Much of the costs of asthma care are related to poor disease control due to under-use of

effective prophylactic therapies, and inadequate monitoring of disease control.[7] At a population level there are few mechanisms available for tracking disease-management indicators for asthma to evaluate the current application of guidelines. Several studies have evaluated divergence from asthma guidelines, [12, 13] but have not been able to accurately estimate non-adherence to guidelines among a representative sample of individuals. Evaluations of adherence have mostly relied on chart reviews and clinician or patient reports which are difficult to complete for a large number of patients across several healthcare settings. [14-16]

Decision support systems are designed to facilitate uptake of evidence- based guidelines with the expectation that adherence to such guidelines will improve health outcomes. [17] Typically, decision support systems are used at the point of care. Such systems, however, may also have an alternate benefit of allowing population monitoring of adherence to disease management guidelines when the decision support algorithms are linked to administrative databases. By pushing through administrative health data including diagnoses, healthcare utilization and medication information, algorithms can be used to generate recommendations for optimizing treatment. In turn, patterns of under-optimization of treatment can be identified to monitor adherence to guidelines and target specific physician and patient sub-groups with disease management interventions.

The implementation of an asthma decision support system linked to provincial health insurance information represents a novel approach and facilitates the evaluation of the gap between recommended and actual treatment. We have developed a new methodology for assessing the quality of asthma management and asthma control in the population. Using evidence based decision-support systems

developed to guide physicians using computerized physician order entry and electronic medical record systems, we developed a program for sequentially entering, assessing and extracting individual and summarized population level quality monitoring and control status indicators. Using population level administrative data for over 16,000 asthma patients, we then used this program to evaluate asthma status and quality of adherence to national guidelines in a Quebec population on two randomly selected days in fall 2007 and spring 2008. This information is needed for asthma management, and can be used for identifying opportunities to target interventions and improve asthma outcomes.

In this study we examined the discrepancy between actual asthma treatments as recorded in the provincial administrative database compared to those recommended by evidence-based guidelines as defined in the asthma decision support system on two index dates.

## METHODS

### Study population

The drug and medical services information of patients cared for by primary care physicians (PCP) participating in the Medical Office of the 21st Century(MOXXI) study [18] in a large metropolitan area was used to evaluate adherence to asthma treatment guidelines. PCPs were identified by professional association master lists and contacted by letter and telephone to determine their interest in participating in the MOXXI project. Patients of these physicians were identified from the Quebec provincial health data base (RAMQ) medical service claims, physician, and beneficiary files. McGill University IRB approval was

obtained for this study and PCPs who accepted provided consent for the research team to receive patient anonymised administrative data.

All patients with an ICD-9 code for asthma, with no prior diagnosis for Chronic Obstructive Pulmonary Disease (COPD), and who were ≥ 5 years old were identified from RAMQ based on algorithms validated in prior research. [19] For the purposes of this study, only patients with drug coverage by RAMQ for 75% of the year were included to ensure that all drugs dispensed were captured.

**The provincial drug and administrative database (RAMQ)**

The RAMQ beneficiary demographic database provided data on individual age, gender, and mortality, and census data provided income and education. [20] Information on each drug dispensed was obtained from the prescription claims database and included the drug name, quantity, date, and duration for each prescription. The medical services claims database provided information on the beneficiary, date, type, provider, and location of service delivery (e.g., inpatient, emergency, clinic) for all medical services remunerated on a fee-for-service basis.

**Study Procedure: Evaluating the gap between actual and recommended asthma treatment using the Asthma Decision Support System (ADSS)**

The ADSS is integrated into the MOXXI electronic prescribing drug management application with patient information retrieved by real-time integration with the beneficiary, prescription and medical services

claims files of the RAMQ. Using information from the prescription drug management platform, the ADSS uses the profile of existing drugs and health problems to customize recommended changes in asthma drug therapy. For this study, recommendations aimed at optimizing asthma treatment were generated on two index dates, September 15 2007 (index date 1) and March 15 2008 (index date 2), representing peak times for asthma symptoms.

In the ADSS, asthma control is determined based on overuse of short acting beta agonists (SABA) and visits to the Emergency Department (ED) for a respiratory problem over a 3 month period before the index date. Based on a previously validated algorithm, a patient is considered to be not well controlled if the sum of the quantity of all SABA medications dispensed to the patient within the last 3 months exceeds 250 doses1, [21] and/or they visited an ED for a respiratory related problem in the last 3 months. Only asthma drugs that were 1) prescribed and dispensed within one year of the index date, and 2) active (i.e. based on prescription algorithms it is likely that the person has a supply of the medication) or expired within 30 days prior to the index date were considered when generating the recommendations.

Patient-specific recommendations related to drug therapy are translated into pre-formatted prescriptions in the drug management platform. The ADSS is structured to support the Canadian Consensus guidelines for Asthma Management. [22] Recommendations are categorised based on control status. For individuals in control, recommendations generated are one of three categories: maintain treatment, decrease treatment, or maintain or decrease treatment. Recommendations also include options for action plan

[1] 250 doses is based on the most commonly prescribed SABA salbutamol 100mcg, 2 inhalations at a time, or the equivalent for other fast acting bronchodilators in the last three months.

prescriptions for patients who are in control. For individuals not well controlled recommendations are either to increase treatment or to refer to a specialist. Within each recommendation category, physicians are presented with specific recommendations for medications and doses to achieve the desired level of drug treatment.

**Data Analysis**

Results were calculated for each index date. Descriptive statistics were used to characterize the study population and to evaluate differences between individuals with and without RAMQ coverage for prescription drugs. For individuals with RAMQ coverage, the proportion of individuals under each recommendation category was evaluated among individuals classified as 'well controlled' and 'not well controlled', and descriptive statistics were used to compare the characteristics of patients across categories. Multivariable logistic regression was used to estimate the probability of being classified in control or not well controlled as a function of sociodemographic characteristics and healthcare utilization.

**Results**

*Study Population and Insured Compared to Non-Insured*

A total of 47, 614 individuals with an asthma diagnosis were identified on index date 1, after removing individuals with a prior diagnosis of COPD (6018) and those ≤ 5 years old (Figure 1). Thirty five percent of individuals were RAMQ insured for prescription drugs at least 75% of the year prior to the index date, for both dates. On index date 2, 51 306 individuals with an asthma diagnosis were identified (Figure 2). Approximately the same proportion of individuals was classified as well controlled on index date 1 (93 %) and index date 2 (94%). As the distribution of individual characteristics, control status, and

recommendation categories were similar on both index dates, we only report the results from index date 2 from this point on (Table 1).

Individuals who were RAMQ insured were on average older (mean=38±22) as compared to non-RAMQ insured individuals (mean=31±18) and had a greater percentage of individuals ≥ 60 years old, a larger proportion was female (61% versus 56%), and in the lower socioeconiomic status (SES) category (21% versus 6%). A greater proportion of RAMQ insured patients had 3 or more ED (16 versus 9%) and hospital visits (8 versus 3%) one year prior to the index date, and a diagnostic code for anxiety (11 compared to 7%) or depression (8 compared to 5%).

**Table 1: Characteristics of Study Participants with and without provincial health coverage (RAMQ) on index day 2***

| | | RAMQ Coverage | No RAMQ Coverage |
|---|---|---|---|
| | | n=18 013 | n=33 293 |
| **Age mean (sd)** | | 38,3 (21,8) | 30,81 (17,5) |
| **Age n (%)** | | | |
| | ≤ 17 | 3 963 (22,0 ) | 10 273 (30,9) |
| | 18-39 | 5 129 (28,6 ) | 9 926 (29,8) |
| | 40-59 | 5 254 (29,2) | 11 277 (33,9) |
| | ≥ 60 | 3 637 (20,2) | 1 817 (5,5) |
| **Sex n (% female)** | | 11 035 (61,3) | 18 665 (56,1) |
| **Income n (%) *** | | | |
| | Low SES | 3 490 (19,4) | 2 665 (8,0) |
| | Middle SES | 13 148 (73.0) | 25 947 (78,0) |
| | High SES | 1 230 (6,8 ) | 4 298 (13,0) |
| **Healthcare Utilization over 1 year prior to March 15, 2008** | | | |
| **Medical *Physician* Visits** n (%)** | | | |
| | 0 visit | 1 736 (9,6 ) | 3 855 (11,6) |
| | 1 visit | 1 998 (11,1) | 4 453 (13,4) |

| | | |
|---|---|---|
| 2 visits | 1 895 (10,5) | 4 154 (12,5) |
| 3 or more visits | 12,384 (68,8) | 20 831 (62,6) |
| **Emergency Department Visits n (%)** | | |
| 0 visit | 10 435 (57,9) | 22 738 (68,0 ) |
| 1 visit | 3 139 (17,4) | 5 445 (16,4) |
| 2 visits | 1 698 (9,4) | 2 416 (7,3) |
| 3 or more visits | 2 741 (15,2) | 2 694 (8,1) |
| **Emergency Department Visits for asthma n (%)** | 1 313 (7,3) | 1 644 (4,9) |
| **Hospitalization** | | |
| 0 day | 14 890 (82,7) | 29 445 (88,4) |
| 1 day | 1 340 (7,4) | 2 072 (6,2) |
| 2 days | 445 (2,5) | 658 (2,0) |
| 3 or more days | 1 338 (7,4) | 1 118 (3,4) |
| **Co-Morbidity n (%)** | | |
| Depression | 1 400 (7,77) | 1 724 (5,2) |
| Anxiety | 1 913 (10,62) | 2 361 (7,1) |

* Around 1 % of missing values for each category; All differences between RAMQ and Non-RAMQ insured are significant, p<0.01

** Ambulatory and specialty care

*Control Status and Recommendation Categories*

Among the 18 013 individuals who were RAMQ insured for prescription drugs, 93% were classified as well controlled and 7% as not well controlled over 3 months prior to the index date (Figure 1).

63 % of individuals who were not well controlled were in the ≥ 40 age group and 26% in the low SES category compared to 49% and 19%, respectively, in the well controlled group. These individuals also had a higher Charlson Co-morbidity Index of 2.11 as compared to 1.6 among those well controlled. A larger proportion of individuals among those not well controlled had a diagnostic code for depression, anxiety, mental illness, and a cardiac related condition. Among those not well controlled 69% (n=667) had at least 1 ED visit , and 74% a medical visit associated with a respiratory problem (in the past year). In comparison 13% (n=2,039) of those well controlled had at least one ED visit and 52% medical visit related to a respiratory problem in the past year.

53% of patients in the not well controlled group had an active prescription for an ICS, 20% a combination therapy, and 14% as compared to 36%, 10%, and 6% in the well controlled group. 63% and 42% of not well and well controlled, respectively, had an active prescription for a fast-acting beta agonist (FABA). At index date 1, all individuals not well controlled had asthma drugs as compared to 9.2 % of those well controlled who had no asthma drugs dispensed.

Table 2 presents the incremental regression coefficients for the demographic, healthcare utilization, and co-morbidity variables hypothesized to be associated with control status. Healthcare utilization including, ≥ 3 days of hospitalization (OR=4.58), and ≥ 3 visits to the ED (for reasons other than a respiratory problem) (OR=2.32), was found to be most strongly associated with control status. Being male (OR=.85), from a low SES (OR= 1.9), and in the 40-59 age group increased the odds of having asthma that was not well controlled.

**Table 2: Multivariable Logistic Regression Models for Identifying Individuals Controlled and Not Well Controlled**

| Variable | OR (95%CI) Control Status |
|---|---|
| **Age mean (sd)** | |
| ≤ 17 | Reference |
| 18-39 | 0.56 (0.44, 0.72) |
| 40-59 | 2.19(1.73, 2.77) |
| ≥ 60 | 1.19 (1, 1.42) |
| **Sex n (% female)** | . |
| Male | Reference |
| Female | 85 (.74, .98) |
| **Income n (%) *** | |
| High SES | Reference |
| Middle SES | 1.44 (1.04, 1.98) |
| Low SES | 1.90 (1.35, 2.68) |
| **Healthcare Utilization over 1 year prior to March 15, 2008** | |
| Medical *Physician* *Visits n (%) | |
| 0 visit | Reference |
| 1 visit | .73 (.47,1.2) |
| 2 visits | .82 (.53,1.28) |
| ≥ 3 visits | 1.62 (1.162.27) |
| **Emergency Department Visits (other than resp)n (%)** | |
| 0 visit | Reference |

| | Ahmed, Tamblyn,Winslade |
|---|---|
| 1 visit | 1.38(1.14,1.66) |
| 2 visits | 1.46(1.16,1.84) |
| ≥3 visits | 2.32(1.94,2.8) |
| **Hospitalisation** | |
| 0 day | Reference |
| 1 day | 2.24(1.55,3.27) |
| 2 days | 2.88(1.79,4.6) |
| 3 or more days | 4.58 (3.36,6.22) |
| **Co-Morbidity n (%)** | |
| Charlson co-morbidity index | 1.04 (1.01, 1.08) |
| Anxiety No | Reference |
| Yes | 1.26 (1.05,1.52 ) |

* General practitioner and specialist

***Recommendation category by control group***

The distribution of individuals across recommendation categories is presented in Table 3.

For 8% (1198/15843) in control, and 21% (201/960) of those not well controlled, a recommendation could not be determined by the ADSS either because the patient 1) had dispensed prescriptions for an inappropriate combination of medications that the ADSS could not reconcile to provide an appropriate recommendation (e.g. a LABA with two prescriptions for combination therapy) or, 2) dispensed two medications that resulted in a duplication of therapy. For those not well controlled, those in the

*duplicate/inappropriate* category had a larger proportion in the lower SES, a higher co-morbidity index and more frequent ambulatory and hospital visits.

Among individuals well controlled, the largest proportion of individuals were in the *maintain treatment* category (50.6%), followed by *maintain/decrease treatment* (28.2%), and *decrease treatment* (2.7%). Almost all individuals not well controlled had the recommendation to *increase treatment* (88%) with a small proportion in the *refer* category (1%). Reasons for the low referral to specialty care needs to be closely examined, and may be related to uncertainty of primary care physicians of when to refer patients, and/or patients may not go see specialists once referred. [23] Regardless of the recommendation category, the largest proportion of individuals was in the 40-59 age group; except for *maintain treatment* that had a larger proportion of individuals in the 18-39 age group. The middle SES was the largest for all recommendation groups and the proportion of females was the same across all categories. Individuals in the *refer* category were on average older than those in the other categories, but comparable on many of the other characteristics.

**Table 3: Comparison of characteristics of individuals in each recommendation category (based on primary recommendation).**

| | In Control N=14989 | | | | Not Well Controlled N=1245 | | |
|---|---|---|---|---|---|---|---|
| | **Maintain n=9564** | **Maintain/Decrease n=4349** | **Decrease n=474** | **Duplicate/ Inappropriate n=602** | **Increase n=1 090** | **Refer n=17** | **Duplicate/ Inappropriate n=138** |
| **Age mean (sd)** | 41,8 (19,2) | 38,2 (22,7) | 44,8 (21,6) | 45,9 (20,3) | 40,4 (21,5) | 57,1 (9,3) | 46,6 (16,0) |
| **Age n (%)** | | | | | | | |
| ≤ 17 | 919 (9,6) | 1 115 (25,6) | 74 (15,6) | 68 (11,3) | 189 (17,3) | 0 | 6 (4,4) |
| 18-39 | 3 561 (37,2) | 996 (22,9) | 86 (18,1) | 123 (20,4) | 310 (28,4) | 0 | 33 (23,9) |
| 40-59 | 2 987 (31,2) | 1 269 (29,2) | 195 (41,1) | 260 (43,2) | 372 (34,1) | 10 (58,8) | 79 (57,2) |
| ≥ 60 | 2 097 (21,9) | 969 (22,3) | 119 (25,1) | 151 (25,1) | 219 (20,1) | 7 (41,2) | 20 (14,5) |
| **Sex n (% F)** | 6 073 (63,5) | 2 659 (61,1) | 303 (63,9) | 381 (63,3) | 709 (65,0) | 12 (70,6) | 101 (73,2) |
| **Income n (%) *** | | | | | | | |
| Low SES | 1 684 (17,6) | 923 (21,2) | 117 (24,7) | 156 (25,9) | 237 (21,7) | 4 (23,5) | 43 (31,2) |
| Middle SES | 7 028 (73,5) | 3 161 (72,7) | 330 (69,6) | 420 (69,8) | 802 (73,6) | 13 (76,5) | 90 (65,2) |
| High SES | 763 (8,0) | 228 (5,2) | 25 (5,3) | 22 (3,6) | 47 (4,3) | 0 | 5 (3,6) |
| **Medical Visits mean (sd) past year** | | | | | | | |
| *All* | 8,78 (13,1) | 9,68 (13,8) | 12,62(13,3) | 12,87(13,4) | 16,52 (22,2) | 29,29 (21,3) | 24,99 (26,1) |
| *Ambulatory* | 7,72 (9,6) | 8,31 (9,2) | 10,89 (9,5) | 11,13 (9,5) | 13,53(15,0) | 19,94 (10,0) | 20,01 (18,1) |
| *Hospitalized* | 1,07 (6,8) | 1,37 (7,7) | 1,73 (7,4) | 1,73 (7,6) | 2,99 (11,6) | 9,35 (16,4) | 4,98 (13,3) |

| | In Control N=14989 | | | | Not Well Controlled N=1245 | | |
|---|---|---|---|---|---|---|---|
| | Maintain n=9564 | Maintain/Decrease n=4349 | Decrease n=474 | Duplicate/ Inappropriate n=602 | Increase n=1 090 | Refer n=17 | Duplicate/ Inappropriate n=138 |
| **Medical Visits n (%) past year** | | | | | | | |
| ***Physician*** | | | | | | | |
| 0 visit | 1 036 (10,8) | 265 (6,1) | 14 (3,0) | 22 (3,6) | 62 (5,7) | 0 | 7 (5,1) |
| 1 visit | 1048 (10,96) | 451 (10,4) | 31 (6,5) | 40 (6,6) | 76 (7,0) | 0 | 5 (3,6) |
| 2 visits | 1000 (10,5) | 486 (11,2) | 41 (8,6) | 26 (4,3) | 81 (7,4) | 0 | 2 (1,4) |
| 3 or more visits | 6 480 (67,8) | 3 147 (72,4) | 388 (81,9) | 514 (85,4) | 871 (79,9) | 17 (100) | 124 (89,9) |
| ***ER*** | | | | | | | |
| 0 visit | 5 995 (62,7) | 2 501 (57,5) | 240 (50,6) | 289 (48,0) | 200 (18,4) | 1 (5,9) | 25 (18,1) |
| 1 visit | 1 565 (16,4) | 790 (18,2) | 89 (18,8) | 118 (19,6) | 221 (20,3) | 3 (17,6) | 21 (15,2) |
| 2 visits | 846 (8,8) | 414 (9,5) | 59 (12,4) | 63 (10,5) | 172 (15,8) | 1 (5,9) | 9 (6,5) |
| 3 or more visits | 1 158 (12,1) | 644 (14,8) | 86 (18,1) | 132 (21,9) | 497 (45,6) | 12 (70,6) | 83 (60,2) |
| **ED- for respiratory problems** | | | | | | | |
| 0 visit | 8 781 (91,8) | 3 792 (87,2) | 394 (83,1) | 491 (81,6) | 294 (27,0) | 4 (23,5) | 38 (27,5) |
| 1 visit | 593 (6,2) | 402 (9,2) | 52 (11,0) | 64 (10,6) | 450 (41,3) | 4 (23,5) | 27 (19,6) |
| 2 visits | 142 (1,5) | 105 (2,4) | 15 (3,2) | 25 (4,2) | 188 (17,2) | 3 (17,65) | 22 (15,9) |
| 3 or more visits | 48 (0,5) | 50 (1,2) | 13 (2,7) | 22 (3,7) | 158 (14,5) | 6 (35,3) | 51 (37,0) |
| **ED- NOT for respiratory problems** | | | | | | | |
| 0 visit | 6 268 (65,5) | 2 712 (62,4) | 265 (55,9) | 326 (54,2) | 456 | 4 (23,5) | 45 (32,6) |

| | In Control N=14989 | | | | Not Well Controlled N=1245 | | |
|---|---|---|---|---|---|---|---|
| | Maintain n=9564 | Maintain/Decrease n=4349 | Decrease n=474 | Duplicate/ Inappropriate n=602 | Increase n=1 090 | Refer n=17 | Duplicate/ Inappropriate n=138 |
| | | | | | (41,8) | | |
| 1 visit | 1 535 (16,1) | 742 (17,1) | 94 (19,8) | 118 (19,6) | 205 (18,8) | 3 (17,6) | 29 (21,0) |
| 2 visits | 746 (7,8) | 370(8,5) | 49 (10,3) | 58 (9,6) | 117 (10,7) | 3 (17,6) | 14 (10,1) |
| 3 or more visits | 1 015 (10,6) | 525 (12,1) | 66 (13,9) | 100 (16,6) | 312 (28,6) | 7 (41,2) | 50 (36,2) |
| **Hospitalization** | | | | | | | |
| 0 day | 8 046 (84,1) | 3 581 (82,3) | 356 (75,1) | 449 (74,6) | 774 (71,0) | 5 (29,4) | 78 (56,5) |
| 1 day | 697 (7,3) | 318 (7,3) | 39 (8,2) | 62 (10,3) | 100 (9,2) | 3 (17,6) | 17 (12,3) |
| 2 days | 215 (2,2) | 107 (2,5) | 20 (4,2) | 23 (3,8) | 44 (4,0) | 1 (5,9) | 3 (2,2) |
| 3 or more days | 606 (6,3) | 343 (7,9) | 59 (12,4) | 68 (11,3) | 172 (15,8) | 8 (47,1) | 40 (29,0) |
| **Hospitalization- for respiratory problems** | | | | | | | |
| 0 day | 9 370 (98,0) | 4 210 (96,8) | 447 (94,3) | 563 (93,5) | 990 (90,8) | 14 (82,4) | 109 (79,0) |
| 1 day | 100 (1,0) | 60 (1,4) | 7 (1,5) | 20 (3,3) | 33 (3,0) | 0 | 7 (5,1) |
| 2 days | 32 (0,3) | 32 (0,74) | 4 (0,8) | 5 (0,8) | 14 (1,3) | 0 | 3 (2,2) |
| 3 or more days | 62 (0,6) | 47 (1,1) | 16 (3,4) | 14 (2,3) | 53 (4,9) | 3 (17,6) | 19 (13,8) |
| **Asthma Medications mean (sd) range past year** | | | | | | | |
| FABA | 0,61 (1,7) | 2,93 (3,8) | 4,32 (5,2) | 4,95 (5,1) | 2,50 (4,4) | 5,00 (5,2) | 6,82 (6,8) |
| ICS | 0,2 (0,7) | 2,3(2,9) | 1,4(2,6) | 3,6(3,8) | 1,4(2,4) | 0,9 (1,7) | 3,5(3,9) |
| Leukotrienes | 0,1 (1,4) | 0,4(3,0) | 6,7(10,0) | 1,5 (4,8) | 0,8(4,4) | 3,3(5,1) | 3,9 (11,5) |
| Combination Therapy | 0,0 (0,4) | 1,2 (2,9) | 5,1(4,9) | 2,18 (3,9) | 1,0 (2,7) | 7,7 (4,5) | 3,0 (4,3) |

| | In Control N=14989 | | | | Not Well Controlled N=1245 | | |
|---|---|---|---|---|---|---|---|
| | **Maintain n=9564** | **Maintain/Decrease n=4349** | **Decrease n=474** | **Duplicate/ Inappropriate n=602** | **Increase n=1 090** | **Refer n=17** | **Duplicate/ Inappropriate n=138** |
| Other | 0,2(1,8) | 0,8(3,4) | 2,9(6,8) | 2,36 (3,9) | 1,8(17,0) | 2,1 (2,5) | 4,45 (6,6) |
| **Control Status n (%)** | | | | | | | |
| Overuse FABA | 0 | 0 | 0 | 0 | 1 (0,1) | 0 | 0 |
| ER visits for Asthma | 0 | 0 | 0 | 0 | 1 076 (98,7) | 17 (100) | 135 (97,8) |
| ER or FABA | 0 | 0 | 0 | 0 | 1 076 (98,7) | 17 (100) | 135 (97,8) |
| **Co-Morbidity Index** | 1,6 (1,5) | 1,6 (1,5) | 1,8 (1,6) | 1,9 (1,9) | 1,8(2,0) | 2,2 (1,4) | 2,6 (2,5) |

- Less than 1 % of missing values for each category
- ED=emergency department

**DISCUSSION**

The purpose of this study was to evaluate the discrepancy between current asthma management and recommended guidelines using the provincial administrative databases and an ADSS. The present study represents an example of how decision support systems can be used to monitor guideline adherence, and to identify individuals at risk of poor outcomes to provide targeted interventions. To our knowledge this is the first time that a decision support system has been used to evaluate disease management at a population level.

As expected, individuals who were provincially insured were on average older, from a lower SES, and a higher proportion used healthcare services. A larger proportion compared to those non-provincially insured also had a diagnosis code for anxiety and depression.

The algorithms used to identify individuals with asthma and evaluate control status were validated in previous work. [24, 25] The majority of individuals well controlled were on an appropriate quantity of asthma treatment. We found, however, that ~ 31% of those well controlled could benefit from a medication review and potentially lower doses of asthma medications.

The majority of individuals not well controlled had the recommendation to increase treatment and for these individuals there was an opportunity to change therapy according to the existing guidelines. [26] The SMART inhaler helps address needs for increase in therapy, as it allows patients to use their as-needed

medication because of declining asthma control—as is very often the case—evolving exacerbations will possibly be treated at an early stage and a further worsening of asthma may possibly be prevented. The SMART inhaler is not a recommended yet part of Canadian guidelines, however, with emerging evidence of its benefits for marinating control compared to other alternatives, [27, 28] it will be included in the next version of guidelines and become more commonly prescribed for Canadian patients. Individuals who were not well controlled were in the 40-59 age range, and had a more complex health profile with greater co-morbidity, including a higher proportion with a diagnosis of anxiety or depression as compared to those well-controlled. The logistic regression analysis in our study also supported these conclusions. These individuals represent a more vulnerable sub-group of the asthma population, and place a greater burden on the healthcare system given the higher proportion that had an ED visit or hospitalization. As such, they require closer monitoring and review of medication to reach doses sufficient to maintain asthma control, or to review reasons for failed treatment.

In this study we were not able to generate a recommendation for a larger proportion of individuals not well controlled compared to controlled either because they were dispensed prescriptions for an inappropriate combination of medications that the ADSS could not reconcile to provide an appropriate recommendation, or they were dispensed two medications that resulted in a duplication of therapy. These cases in themselves represent a segment of the asthma population that requires closer review of their prescribed medication.

The generation of asthma recommendations at a population level using an administrative database allows individuals not receiving treatment based on guidelines to be identified. We found that many individuals

with non-controlled asthma visit a physician 3 or more times per year, and potentially represent missed opportunities to optimize treatment. Possible reasons for our findings may include the lack of knowledge of PCPs of guidelines in general, especially for more complicated cases. It may also be, however, that patients are not going to see the same physician, or are switching physicians to ensure access to SABAs. In such situations, physicians may be reluctant to conduct a complete medication review if they do not perceive themselves as the primary provider for the patient.

Other physician concerns may be the reluctance to prescribe ICS and/or concern regarding polypharmacy with multiple inhalers. [29] This is where the role of pharmacists is important as they can see individuals' entire medication dispensing history and have been shown to be effective in managing asthma patients in particular if supported by an ADSS. [30]

Previous studies have also found that physicians do not adopt guidelines in their practice because of perceived appropriateness of the guidelines. [13, 31] Surveys have shown that they believe that guidelines do not take into account the heterogeneity of asthma and do not account for individual patient variations in response to treatment, [32] and other factors that impact response to asthma therapy such as age and co-morbidities.

Further, patient non-adherence to prescribed therapy and not having prescribed medications filled may also explain the findings from our study. Patient beliefs about the negative impact and benefits of their

medications, [33] their confidence to manage their asthma, and not seeking care early enough to prevent exacerbations have all been identified as contributors to poor outcomes for asthma. [34]

Mechanisms to identify patients who need closer follow-up and evaluation have been identified as an important need for primary healthcare. [3, 34, 35] Future initiatives can include linking administrative databases to decision support systems that can help identify individuals who need closer monitoring and follow-up and allow for targeted services such as visit reminders sent to patients or to their care provider. The ongoing implementation of electronic health records and patient health portals will facilitate this approach. Information can be fed back to physicians and pharmacists to improve patient management, and initiate care early on, before individuals experience deteriorations in health.

**Conclusions**

This study demonstrated how a decision support system linked to an administrative database could be used to identify individuals in the population that require a review of asthma treatment. Such an approach can help identify individuals with uncontrolled asthma or prescriptions that deviate from recommended treatment to intervene early. This study provides a model for monitoring adherence to guidelines for other chronic conditions such as hypertension and diabetes.

**Limitations**

Our approach for identifying individuals with asthma and assessing asthma status may have underestimated the percentage out of control in our study. We examined asthma control on two index dates, and went back 3 months prior to the index date to assess control status. A more sensitive algorithm that treats control as a time varying covariate would likely provide a more accurate evaluation of control status.

Also, our estimation of the percentage of well-controlled individuals may be an overestimate compared to previous studies because of our method of defining asthma control. A previous study conducted in the UK, [36] and another using a US administrative database [37] assumed 2 puffs of a SABA per day, the equivalent of 180 puffs over 3 months, would be the threshold for asthma control. With this measure of asthma control the authors reported 72% of patients were well controlled in the UK study and 56% in the US study. This estimate is substantially below the measure of 250 puffs we used in this study, and likely explains why we found a larger proportion of individuals who were well controlled.

Also, because we used administrative data and not clinical information from an electronic medical record to generate recommendations, we were not able to use asthma severity and relapse as part of the asthma control algorithm. Two previous studies used composite measures of asthma control including (1) no recorded hospital attendance for asthma (including admission or emergency department visit, out of hours, or outpatient department attendance); (2) no prescription for oral corticosteroid; and (3) no consultation, hospital admission, or emergency department attendance for lower respiratory tract infection requiring antibiotics. [36, 37] With this more stringent definition of asthma control they found proportions of well-controlled asthma control to be 72% [36], and 56% [37]which are lower compared the 94% were found to be well-controlled in our study.

In addition, at the time that the ADSS was being developed, the SMART treatments, that allow for the same inhaler to be used as a preventative and rescue inhaler were not commonly used or part of the guidelines. Therefore, they were not programmed as part of the ADSS and not included in the recommendations.

Further, the ADSS does not distinguish between SABA nebulizer and MDI. Finally, use of decision support during clinical encounters allow for a patient-reported assessment of symptoms at the time when recommendations are generated, and allow for a more accurate assessment of asthma control. We were also limited to generating recommendations for those provincially insured that represent a more vulnerable segment of the population.

**Funding Support**

Health Canada and the Canadian Institute of Health Research supported the development of the asthma decision support system. S Ahmed is supported by a Fonds de la Recherche en Santé du Quebec (FRSQ) research career award.

**Contributorship Statement**

SA RT and NW were involved in:

- the conception and design, analysis and interpretation of data,
- drafting the article and revising it critically for important intellectual content,
- final approval of the version to be published.

**Competing Interests**

No competing interests

**Data Sharing Statement**

Additional data regarding the study sample characteristics and guidelines generated from the decision support system can be provided upon request from the corresponding author.

**References**

1. Shenolikar R, Song X, Anderson JA, et al. Costs of asthma among US working adults. *Am J Manag Care* 2011;17:409-16.

2. Schatz M, Zeiger RS, Yang SJ, et al. The relationship of asthma impairment determined by psychometric tools to future asthma exacerbations. *Chest* 2012;141:66-72.

3. Urrutia I, Aguirre U, Pascual S, et al. Impact of anxiety and depression on disease control and quality of life in asthma patients. *J Asthma* 2012;49:201-8.

4. Colice GL, Ostrom NK, Geller DE, et al. The CHOICE survey: high rates of persistent and uncontrolled asthma in the United States. *Ann Allergy Asthma Immunol* 2012;108:157-62.

5. Glaxo Wellcome I. 2000:1-31.

6. Bousquet J, Mantzouranis E, Cruz AA, et al. Uniform definition of asthma severity, control, and exacerbations: document presented for the World Health Organization Consultation on Severe Asthma. *J Allergy Clin Immunol* 2010;126:926-38.

7. Krahn MD, Berka C, Langlois P,et al. Direct and Indirect Costs of Asthma in Canada, 1990 3465. *CMAJ* 1996;154:821-31.

8. US Department of Health and Human Services OoDPaHP. Healthy People 2020 Washington,DC, 2010.

9. Maciejewski ML, Chen SY, Au DH. Adult asthma disease management: an analysis of studies, approaches, outcomes, and methods. *Respir Care* 2009;54:878-86.

10. Legorreta AP, Christian-Herman J, O'Connor RD,et al. Compliance with National Asthma Management Guidelines and Specialty Care: A Health Mantenance Organization Experience. *Arch Intern Med* 1998;158:457-64.

11. Adams RJ, Fuhlbrigge A, Guilbert T, et al. Inadequate use of asthma medication in the United States: results of the asthma in America national population survey. *J Allergy Clin Immunol* 2002;110:58-64.

12. Flor-Escriche X, Rodriguez-Mas M, Espiau M, et al. Compliance with guidelines in the treatment of asthma exacerbations in primary care. *Ther Adv Respir Dis* 2011;5:369-75.

13. Rank MA, Liesinger JT, Ziegenfuss JY, et al. The impact of asthma medication guidelines on asthma controller use and on asthma exacerbation rates comparing 1997-1998 and 2004-2005. *Ann Allergy Asthma Immunol* 2012;108:9-13.

14. Cazzola M, Segreti A, Bettoncelli G, et al. Change in asthma and COPD prescribing by Italian general practitioners between 2006 and 2008. *Prim Care Respir J* 2011;20:291-8.

15. Arnlind MH, Wettermark B, Nokela M, et al. Regional variation and adherence to guidelines for drug treatment of asthma. *Eur J Clin Pharmacol* 2010;66:187-98.

16. Lougheed MD, Olajos-Clow J, Szpiro K, et al. Multicentre evaluation of an emergency department asthma care pathway for adults. *CJEM* 2009;11:215-29.

17. Roshanov PS, Misra S, Gerstein HC, et al. Computerized clinical decision support systems for chronic disease management: a decision-maker-researcher partnership systematic review. *Implement Sci* 2011;6:92.

18. Tamblyn R, Huang A, Perreault R, et al. The medical office of the twenty-first century (MOXXI): evaluation of the effectiveness of computerised decision support in reducing inappropriate prescribing in primary care. *CMAJ* 2003;169:549-56.

19. Kawasumi Y, Abrahamowicz M, Ernst P, et al. Development and validation of a predictive algorithm to identify adult asthmatics from medical services and pharmacy claims databases. *Health Serv Res* 201;46:939-63.

20. Tamblyn RM, Laprise R, Hanley JA, et al. Adverse events associated with prescription drug cost-sharing among poor and elderly persons. *JAMA* 2001;285:421-9.

21. Schatz M, Zeiger RS, Vollmer WM, et al. Validation of a beta-agonist long-term asthma control scale derived from computerized pharmacy data. *J Allergy ClinImmunol* 2006;117:995-1000.

22. Lemiere C, Bai T, Balter M, et al. Adult Asthma Consensus Guidelines update 2003. *Can Respir J* 2004;11 (Suppl A):9A-18A.

23. Archives of Internal Medicine. *JAMA*. 2001;161.

24. Spitzer WO, Suissa S, Ernst P, et al. The use of beta-agonists and the risk of death and near death from asthma. *N Engl J Med* 1992;326:501-6.

25. Wilchesky M, Tamblyn RM, Huang A. Validation of Diagnostic Codes in Medical Services Claims Data. *Can J Clin Pharmacol* 2001;8:39-39.

26. Becker A, Lemiere C, Berube D, et al. Summary of recommendations from the Canadian Asthma Consensus guidelines, 2003. *CMAJ* 2005;173(Suppl 6):S3-11.

27. Boursquet J, Boulet LP, Peters MJ, et al. Budesonide/formoterol for maintenance and relief in uncontrolled asthma vs. high-dose salmeterol/fluticasone. *Respir Med* 2007;101:2437-46.

28. Kuna P, Peters M, Manjra A, et al. Effect of budesonide/formoterol maintenance and reliever therapy on asthma exacerbations. *Int J Clin Pract* 2007;61:725-36.

29. Navaratnam P, Jayawant SS, Pedersen CA, et al. Asthma pharmacotherapy prescribing in the ambulatory population of the United States: evidence of nonadherence to national guidelines and implications for elderly people. *J Am Geriatr Soc* 2008;56:1312-7.

30. Armour C, Bosnic-Anticevich S, Brillant M, et al. Pharmacy Asthma Care Program (PACP) improves outcomes for patients in the community. *Thorax* 2007;62:496-502.

31. Bracha Y, Brottman G, Carlson A. Physicians, guidelines, and cognitive tasks. *Eval Health Prof* 2011;34:309-35.

32. Yeh KW, Chen SH, Chiang LC, et al. Survey of asthma care in Taiwan: a comparison of asthma specialists and general practitioners. *Ann Allergy Asthma Immunol* 2006;96:593-9.

33. Brunton SA, Graham LM, Stoloff SW. Primary care management of patients with asthma. *J Fam Pract* 2011;60(Suppl 5):S1-8.

34. Razykov I, Newton EG, Lober J, et al. Daily SMS reminders for asthma treatment adherence: A comment on Strandbygaard et al. *Respir Med* 2010;104:1234-5; author reply1236.

35 Martens JD, van der Weijden T, Winkens RA, et al. Feasibility and acceptability of a computerised system with automated reminders for prescribing behaviour in primary care. *Int J Med Inform* 2008;77:199-207.

36 Price D, Martin RJ, Barnes N, et al. Prescribing practices and asthma control with hydrofluroroalkane-beclomethasone and fluticasone: a real-world observational study. *J allergy Clin Immunol* 2010;126:511-8

37 Colice G, Martin RJ, Israel E, et al. Asthma outcomes and costs of therapy with extrafine beclomethasone and fluticason. *J Allergy Clin Immunol* 2013; 132:45-54.

**Using decision support for population tracking of adherence to recommended asthma guidelines**

**Sara Ahmed [1,3,4], Robyn Tamblyn [2,3], Nancy Winslade [2,3]**

[1]Faculty of Medicine, School of Physical and Occupational Therapy, McGill University
3654 Prom. Sir William Osler, Montreal, QC, H3G 1Y5, Canada

[2]Faculty of Medicine, Clinical and Health Informatics, McGill University

1140 Pine avenue west, Montreal, QC, H3A 1A3, Canada

[3] McGill University Health Center, Clinical Epidemiology

[4] **Centre de Recherche Interdisciplinaire en Réadaptation** du Montréal Métropolitain

**Corresponding author**

Sara Ahmed

Faculty of Medicine, McGill University
3654 Prom. Sir William Osler, Montreal, QC, H3G 1Y5, Canada
E-mail: sara.ahmed@mcgill.ca

**Word Count:** 3092

**Figures:** 2

**Tables**: 3

**Keywords**: Asthma, clinical practice guidelines, disease management, decision support, administrative database

**What is the key question?** What is the discrepancy between actual asthma treatments individuals' receive as recorded in the provincial administrative database as compared to those recommended by evidence-based guidelines as defined within an asthma decision support system.

**What is the bottom line; and why read on?** Decision support systems that define evidence-based guidelines, linked to an administrative database, can be used to identify individuals with uncontrolled asthma or prescriptions that deviate from recommended treatment at a population level.

**Why read on?** The methods and approach from the current study can provide an opportunity for physicians to intervene early and can be used to evaluate adherence to evidence-based guidelines and indicators of disease management for other patient populations.

**Abstract**

Objective: Decision support systems linked to administrative databases provide a unique opportunity to monitor adherence to guidelines and target disease management strategies to patients not receiving guideline-based therapy. The objective of this study was to evaluate the discrepancy between actual asthma treatments prescribed by primary care physicians compared to those recommended by evidence-based guidelines using a decision support tool linked to a provincial health administrative database.

Design: The drug and medical services information of individuals with asthma were identified from the provincial health database and were pushed through an asthma decision support system (ADSS). Recommendations aimed at optimizing asthma treatment were generated on two index dates, September 15 2007 (index date 1) and March 15 2008 (index date 2).

Setting: Primary care settings in a large Canadian metropolitan area.

Participants: Individuals with asthma and provincial health insurance

Primary and secondary outcome measures: well controlled asthma

Results: 16, 803 eligible individuals were identified on index date 1, and 18, 103 on index date 2. The distribution of recommendation categories were similar on both index dates. 94% were classified as well controlled and 7% as not well controlled. Among individuals well controlled, the largest proportion of individuals were in the maintain treatment category (50.6%), followed by maintain/decrease treatment (28.2%), and decrease treatment (2.7%). Almost all individuals not well controlled had the recommendation to increase treatment (88%) with a small proportion in the refer category (1%).

Conclusions: The ADSS was able to identify sub-groups of patients from an administrative database that could benefit from a medication review and possible change. Decision support systems linked to an administrative database can be used to identify individuals with uncontrolled asthma or prescriptions that

deviate from recommended treatment. When connected to the point of care, this can provide an opportunity for physicians to intervene early.

**Article Summary**

1) Article Focus –

- The objective of this study was to evaluate the discrepancy between actual asthma treatments prescribed by primary care physicians ~~compared~~ to those recommended by evidence-based guidelines using a decision support tool linked to a provincial health administrative database.

2) Key Messages - up to three bullet points outlining the key messages and significance of the study.

- Decision support systems that define evidence-based guidelines, linked to an administrative database, can be used to identify individuals with uncontrolled asthma or prescriptions that deviate from recommended treatment at a population level.
- When connected to the point of care, discrepancies between decision support and actual care can provide an opportunity for physicians to intervene early.
- The methods ~~and approach from the current~~in this study can be applied in future work~~used~~ to evaluate adherence to~~e~~ evidence-based guidelines ~~and indicators of disease management for other patient populations,~~ at a population level if administrative databases are available, or at the point of care if linked to an electronic health record.

3) Strengths and Limitations

- The availability of a provincial administrative database and decision support system allowed us to assess guideline adherence, and to identify sub-groups of individuals at risk

of poor outcomes.

- The administrative database only includes individuals who are provincially insured and therefore discrepancies could not be examined for individuals with private insurance.

- The proportion of individuals with poor asthma control may have been underestimated as control status was evaluated over a 3-month period.

**Introduction**

Asthma poses a significant burden on healthcare resources and costs, [1] and results in reduced individual functioning and quality of life. [2, 3] Over the past 10 years there have been tremendous improvements in the scientific understanding of asthma and its treatment, and these findings have been made available to clinicians through the development of clinical practice guidelines. Despite achieving such sentinel milestones in asthma care, over 50% [4, 5] of individuals remain poorly controlled in the U.S. and Canada, with similar estimates worldwide. [6] This has translated into direct and indirect costs of 654 million and 7.2 billion dollars (equivalent to US dollars in 2008) in Canada and the US, respectively ~~This has translated into $306 million per year in direct costs for providing health management for approximately 2.2 million Canadians diagnosed with asthma. With appropriate disease management over $135 million in costs and reductions in physical and mental health can be prevented.~~ [7]

Healthcare organizations worldwide have been charged with improving asthma outcomes over the next 2-3 years, with the aim of reducing hospitalizations and deaths related to asthma. [8] Several barriers for optimal management result in poor outcomes for asthma, [9] including clinician-related (non-adherence to guidelines), patient-related (non-adherence to treatment), and treatment- related barriers (cost, complexity of treatment). In moving towards improving clinical outcomes potentially modifiable barriers must be identified and targeted through appropriate interventions. A mechanism is needed to identify problematic asthma management so that gaps in care and barriers can be further evaluated and managed.

One potentially modifiable barrier is the gap between optimal versus actual asthma management as reflected by the lack of adoption of guidelines by clinicians or non-adherence of patients to recommended care. [10, 11] Much of the costs of asthma care are related to poor disease control due to under-use of effective prophylactic therapies, and inadequate monitoring of disease control.[7] At a population level there are few mechanisms available for tracking disease-management indicators for asthma to evaluate the current application of guidelines. Several studies have evaluated divergence from asthma guidelines, [12, 13] but have not been able to accurately estimate non-adherence to guidelines among a representative sample of individuals. Evaluations of adherence have mostly relied on chart reviews and clinician or patient reports which are difficult to complete for a large number of patients across several healthcare settings. [14-16]

Decision support systems are designed to facilitate uptake of evidence- based guidelines with the expectation that adherence to such guidelines will improve health outcomes. [17] Typically, decision support systems are used at the point of care. Such systems, however, may also have an alternate benefit of allowing population monitoring of adherence to disease management guidelines when the decision support algorithms are linked to administrative databases. By pushing through administrative health data including diagnoses, healthcare utilization and medication information, algorithms can be used to generate recommendations for optimizing treatment. In turn, patterns of under-optimization of treatment can be identified to monitor adherence to guidelines and target specific physician and patient sub-groups with disease management interventions.

The implementation of an asthma decision support system linked to provincial health insurance information represents a novel approach and facilitates the evaluation of the gap between recommended and actual treatment. We have developed a new methodology for assessing the quality of asthma management and asthma control in the population. Using evidence based decision-support systems developed to guide physicians using computerized physician order entry and electronic medical record systems, we developed a program for sequentially entering, assessing and extracting individual and summarized population level quality monitoring and control status indicators. Using population level administrative data for over 16,000 asthma patients, we then used this program to evaluate asthma status and quality of adherence to national guidelines in a Quebec population on two randomly selected days in fall 2007~~the spring~~ and ~~fall~~spring 2008. This information is needed for asthma management, and can be used for identifying opportunities to target interventions and improve asthma outcomes.

In this study we examined the discrepancy between actual asthma treatments as recorded in the provincial administrative database compared to those recommended by evidence-based guidelines as defined in the asthma decision support system on two index dates.

## METHODS

### Study population

The drug and medical services information of patients cared for by primary care physicians (PCP) participating in the Medical Office of the 21st Century(MOXXI) study [18] in a large metropolitan area was used to evaluate adherence to asthma treatment guidelines. PCPs were identified by professional

association master lists and contacted by letter and telephone to determine their interest in participating in the MOXXI project. Patients of these physicians were identified from the Quebec provincial health data base (RAMQ) medical service claims, physician, and beneficiary files. McGill University IRB approval was obtained for this study and PCPs who accepted provided consent for the research team to receive patient anonymised administrative data.

All patients with an ICD-9 code for asthma, with no prior diagnosis for Chronic Obstructive Pulmonary Disease (COPD), and who were ≥ 5 years old were identified from RAMQ based on algorithms validated in prior research. [19] For the purposes of this study, only patients with ~~full~~ drug coverage by RAMQ for 75% of the year were included to ensure that all drugs dispensed were captured.

**The provincial drug and administrative database (RAMQ)**

The RAMQ beneficiary demographic database provided data on individual age, gender, and mortality, and census data provided income and education. [20] Information on each drug dispensed was obtained from the prescription claims database and included the drug name, quantity, date, and duration for each prescription. The medical services claims database provided information on the beneficiary, date, type, provider, and location of service delivery (e.g., inpatient, emergency, clinic) for all medical services remunerated on a fee-for-service basis.

**Study Procedure: Evaluating the gap between actual and recommended asthma treatment using the Asthma Decision Support System (ADSS)**

The ADSS is integrated into the MOXXI electronic prescribing drug management application with patient information retrieved by real-time integration with the beneficiary, prescription and medical services claims files of the RAMQ. Using information from the prescription drug management platform, the ADSS uses the profile of existing drugs and health problems to customize recommended changes in asthma drug therapy. For this study, recommendations aimed at optimizing asthma treatment were generated on two index dates, September 15 2007 (index date 1) and March 15 2008 (index date 2), representing peak times for asthma symptoms.

In the ADSS, asthma control is determined based on overuse of short acting beta agonists (SABA) and visits to the Emergency Department (ED) for a respiratory problem over a 3 month period before the index date. Based on a previously validated algorithm, a patient is considered to be not well controlled if the sum of the quantity of all SABA medications dispensed to the patient within the last 3 months exceeds 250 doses1, [21] and/or they visited an ED for a respiratory related problem in the last 3 months. Only asthma drugs that were 1) prescribed and dispensed within one year of the index date, and 2) active (i.e. based on prescription algorithms it is likely that the person has a supply of the medication) or expired within 30 days prior to the index date were considered when generating the recommendations.

Patient-specific recommendations related to drug therapy are translated into pre-formatted prescriptions in the drug management platform. The ADSS is structured to support the Canadian Consensus guidelines for Asthma Management. [22] Recommendations are categorised based on control status. For individuals in

[1] 250 doses is based on the most commonly prescribed SABA salbutamol 100mcg, 2 inhalations at a time, or the equivalent for other fast acting bronchodilators in the last three months.

control, recommendations generated are one of three categories: maintain treatment, decrease treatment, or maintain or decrease treatment. Recommendations also include options for action plan prescriptions for patients who are in control. For individuals not well controlled recommendations are either to increase treatment or to refer to a specialist. Within each recommendation category, physicians are presented with specific recommendations for medications and doses to achieve the desired level of drug treatment.

**Data Analysis**

Results were calculated for each index date. Descriptive statistics were used to characterize the study population and to evaluate differences between individuals with and without RAMQ coverage for prescription drugs. For individuals with RAMQ coverage, the proportion of individuals under each recommendation category was evaluated among individuals classified as 'well controlled' and 'not well controlled', and descriptive statistics were used to compare the characteristics of patients across categories. Multivariable logistic regression was used to estimate the probability of being classified in control or not well controlled as a function of sociodemographic characteristics and healthcare utilization.

**Results**

*Study Population and Insured Compared to Non-Insured*

A total of 47, 614 individuals with an asthma diagnosis were identified on index date 1, after removing individuals with a prior diagnosis of COPD (6018) and those ≤ 5 years old (Figure 1). Thirty five percent of individuals were RAMQ insured for prescription drugs at least 75% of the year prior to the index date, for both dates. On index date 2, 51 306 individuals with an asthma diagnosis were identified (Figure 2).

Approximately the same proportion of individuals was classified as well controlled on index date 1 (93 %) and index date 2 (94%). As the distribution of individual characteristics, control status, and recommendation categories were similar on both index dates, we only report the results from index date 2 from this point on (Table 1).

Individuals who were RAMQ insured were on average older (mean=38±22) as compared to non-RAMQ insured individuals (mean=31±18) and had a greater percentage of individuals ≥ 60 years old, a larger proportion was female (61% versus 56%), and in the lower socioeconiomic status (-SES) category (21% versus 6%). A greater proportion of RAMQ insured patients had 3 or more ED (16 versus 9%) and hospital visits (8 versus 3%) one year prior to the index date, and a diagnostic code for anxiety (11 compared to 7%) or depression (8 compared to 5%).

**Table 1: Characteristics of Study Participants with and without provincial health coverage (RAMQ) on index day 2***

| | RAMQ Coverage | No RAMQ Coverage |
|---|---|---|
| | | |
| | | |

| | n=18 013 | n=33 293 |
|---|---|---|
| **Age mean (sd)** | 38,3 (21,8) | 30,81 (17,5) |
| **Age n (%)** | | |
| ≤ 17 | 3 963 (22,0 ) | 10 273 (30,9) |
| 18-39 | 5 129 (28,6 ) | 9 926 (29,8) |
| 40-59 | 5 254 (29,2) | 11 277 (33,9) |
| ≥ 60 | 3 637 (20,2) | 1 817 (5,5) |
| **Sex n (% female)** | 11 035 (61,3) | 18 665 (56,1) |
| **Income n (%) *** | | |
| Low SES | 3 490 (19,4) | 2 665 (8,0) |
| Middle SES | 13 148 (73.0) | 25 947 (78,0) |
| High SES | 1 230 (6,8 ) | 4 298 (13,0) |
| **Healthcare Utilization over 1 year prior to March 15, 2008** | | |
| **Medical ~~Phycisian~~Physician Visits** n (%)** | | |
| 0 visit | 1 736 (9,6 ) | 3 855 (11,6) |
| 1 visit | 1 998 (11,1) | 4 453 (13,4) |
| 2 visits | 1 895 (10,5) | 4 154 (12,5) |
| 3 or more visits | 12,384 (68,8) | 20 831 (62,6) |
| **Emergency Department Visits n (%)** | | |
| 0 visit | 10 435 (57,9) | 22 738 (68,0 ) |
| 1 visit | 3 139 (17,4) | 5 445 (16,4) |
| 2 visits | 1 698 (9,4) | 2 416 (7,3) |

| | | |
|---|---|---|
| 3 or more visits | 2 741 (15,2) | 2 694 (8,1) |
| **Emergency Department Visits for asthma n (%)** | 1 313 (7,3) | 1 644 (4,9) |
| **Hospitalization** | | |
| 0 day | 14 890 (82,7) | 29 445 (88,4) |
| 1 day | 1 340 (7,4) | 2 072 (6,2) |
| 2 days | 445 (2,5) | 658 (2,0) |
| 3 or more days | 1 338 (7,4) | 1 118 (3,4) |
| **Co-Morbidity n (%)** | | |
| Depression | 1 400 (7,77) | 1 724 (5,2) |
| Anxiety | 1 913 (10,62) | 2 361 (7,1) |

* Around 1 % of missing values for each category; All differences between RAMQ and Non-RAMQ insured are significant, p<0.01

** Ambulatory and specialty care

*Control Status and Recommendation Categories*

Among the 18 013 individuals who were RAMQ insured for prescription drugs, 934% were classified as well controlled and 7% as not well controlled over 3 months prior to the index date (Figure 1).

63 % of individuals who were not well controlled were in the ≥ 40 age group and 26% in the low SES category compared to 49% and 19%, respectively, in the well controlled group. These individuals also had a higher Charlson Co-morbidity Index of 2.11 as compared to 1.6 among those well controlled. A larger proportion of individuals among those not well controlled had a diagnostic code for depression, anxiety, mental illness, and a cardiac related condition. Among those not well controlled 69% (n=667) had at least 1

ED visit ~~(past 3 months)~~, and 74% a medical visit associated with a respiratory problem (in the past year). In comparison 13% (n=2,039) of those well controlled had at least one ED visit and 52% medical visit related to a respiratory problem in the past year.

53% of patients in the not well controlled group had an active prescription for an ICS, 20% a combination therapy, and 14% as compared to 36%, 10%, and 6% in the well controlled group. 63% and 42% of not well and well controlled, respectively, had an active prescription for a fast-acting beta agonist (FABA). At index date 1, all individuals not well controlled had asthma drugs as compared to 9.2 % of those well controlled who had no asthma drugs dispensed.

Table 2 presents the incremental regression coefficients for the demographic, healthcare utilization, and co-morbidity variables hypothesized to be associated with control status. Healthcare utilization including, ≥ 3 days of hospitalization (OR=4.58), and ≥ 3 visits to the ED (for reasons other than a respiratory problem) (OR=2.32), was found to be most strongly associated with control status. Being male (OR=.85), from a low SES (OR= 1.9), and in the 40-59 age group increased the odds of having asthma that was not well controlled.

**Table 2: Multivariable Logistic Regression Models for Identifying Individuals Controlled and Not Well Controlled**

| Variable | OR (95%CI) Control Status |
|---|---|
| **Age mean (sd)** | |
| ≤ 17 | Reference |

17

Ahmed, Tamblyn,Winslade

| | |
|---|---|
| 18-39 | 0.56 (0.44, 0.72) |
| 40-59 | 2.19(1.73, 2.77) |
| ≥ 60 | 1.19 (1, 1.42) |
| **Sex n (% female)** | . |
| Male | Reference |
| Female | 85 (.74, .98) |
| **Income n (%) *** | |
| High SES | Reference |
| Middle SES | 1.44 (1.04, 1.98) |
| Low SES | 1.90 (1.35, 2.68) |
| **Healthcare Utilization over 1 year prior to March 15, 2008** | |
| Medical *Physician* *Visits n (%) | |
| 0 visit | Reference |
| 1 visit | .73 (.47,1.2) |
| 2 visits | .82 (.53,1.28) |
| ≥ 3 visits | 1.62 (1.162.27) |
| **Emergency Department Visits (other than resp)n (%)** | |
| 0 visit | Reference |
| 1 visit | 1.38(1.14,1.66) |
| 2 visits | 1.46(1.16,1.84) |
| ≥3 visits | 2.32(1.94,2.8) |
| **Hospitalisation** | |

| | Ahmed, Tamblyn,Winslade |
|---|---|
| 0 day | Reference |
| 1 day | 2.24(1.55,3.27) |
| 2 days | 2.88(1.79,4.6) |
| 3 or more days | 4.58 (3.36,6.22) |
| **Co-Morbidity n (%)** | |
| Charlson co-morbidity index | 1.04 (1.01, 1.08) |
| Anxiety No | Reference |
| Yes | 1.26 (1.05,1.52 ) |

* General practitioner and specialist

***Recommendation category by control group***

The distribution of individuals across recommendation categories is presented in Table 3.

For 8% (1198/15843) in control, and 21% (201/960) of those not well controlled, a recommendation could not be determined by the ADSS either because the patient 1) had dispensed prescriptions for an inappropriate combination of medications that the ADSS could not reconcile to provide an appropriate recommendation (e.g. a LABA with two prescriptions for combination therapy) or, 2) dispensed two medications that resulted in a duplication of therapy. For those not well controlled, those in the *duplicate/inappropriate* category had a larger proportion in the lower SES, a higher co-~~morbidity~~morbidity index and more frequent ambulatory and hospital visits.

Among individuals well controlled, the largest proportion of individuals were in the *maintain treatment* category (50.6%), followed by *maintain/decrease treatment* (28.2%), and *decrease treatment* (2.7%).

Almost all individuals not well controlled had the recommendation to *increase treatment* (88%) with a small proportion in the *refer* category (1%). Reasons for the low referral to specialty care needs to be closely examined, and may be related to uncertainty of primary care physicians of when to refer patients, and/or patients may not go see specialists once referred. [23] Regardless of the recommendation category, the largest proportion of individuals was in the 40-59 age group; except for *maintain treatment* that had a larger proportion of individuals in the 18-39 age group. The middle SES was the largest for all recommendation groups and the proportion of females was the same across all categories. Individuals in the *refer* category were on average older than those in the other categories, but comparable on many of the other characteristics.

**Table 3: Comparison of characteristics of individuals in each recommendation category (based on primary recommendation).**

| | In Control N=14989 | | | | Not Well Controlled N=1245 | | |
|---|---|---|---|---|---|---|---|
| | Maintain n=9564 | Maintain/Decrease n=4349 | Decrease n=474 | Duplicate/ Inappropriate n=602 | Increase n=1 090 | Refer n=17 | Duplicate/ Inappropriate n=138 |
| **Age mean (sd)** | 41,8 (19,2) | 38,2 (22,7) | 44,8 (21,6) | 45,9 (20,3) | 40,4 (21,5) | 57,1 (9,3) | 46,6 (16,0) |
| **Age n (%)** | | | | | | | |
| ≤ 17 | 919 (9,6) | 1 115 (25,6) | 74 (15,6) | 68 (11,3) | 189 (17,3) | 0 | 6 (4,4) |
| 18-39 | 3 561 (37,2) | 996 (22,9) | 86 (18,1) | 123 (20,4) | 310 (28,4) | 0 | 33 (23,9) |
| 40-59 | 2 987 (31,2) | 1 269 (29,2) | 195 (41,1) | 260 (43,2) | 372 (34,1) | 10 (58,8) | 79 (57,2) |
| ≥ 60 | 2 097 (21,9) | 969 (22,3) | 119 (25,1) | 151 (25,1) | 219 (20,1) | 7 (41,2) | 20 (14,5) |
| **Sex n (% F)** | 6 073 (63,5) | 2 659 (61,1) | 303 (63,9) | 381 (63,3) | 709 (65,0) | 12 (70,6) | 101 (73,2) |
| **Income n (%) *** | | | | | | | |
| Low SES | 1 684 (17,6) | 923 (21,2) | 117 (24,7) | 156 (25,9) | 237 (21,7) | 4 (23,5) | 43 (31,2) |
| Middle SES | 7 028 (73,5) | 3 161 (72,7) | 330 (69,6) | 420 (69,8) | 802 (73,6) | 13 (76,5) | 90 (65,2) |
| High SES | 763 (8,0) | 228 (5,2) | 25 (5,3) | 22 (3,6) | 47 (4,3) | 0 | 5 (3,6) |
| **Medical Visits mean (sd) past year** | | | | | | | |
| *All* | 8,78 (13,1) | 9,68 (13,8) | 12,62(13,3) | 12,87(13,4) | 16,52 (22,2) | 29,29 (21,3) | 24,99 (26,1) |
| *Ambulatory* | 7,72 (9,6) | 8,31 (9,2) | 10,89 (9,5) | 11,13 (9,5) | 13,53(15,0) | 19,94 (10,0) | 20,01 (18,1) |
| *Hospitalized* | 1,07 (6,8) | 1,37 (7,7) | 1,73 (7,4) | 1,73 (7,6) | 2,99 (11,6) | 9,35 (16,4) | 4,98 (13,3) |

| | In Control N=14989 | | | | Not Well Controlled N=1245 | | |
|---|---|---|---|---|---|---|---|
| | Maintain n=9564 | Maintain/Decrease n=4349 | Decrease n=474 | Duplicate/ Inappropriate n=602 | Increase n=1 090 | Refer n=17 | Duplicate/ Inappropriate n=138 |
| **Medical Visits n (%) past year** | | | | | | | |
| ~~Physician~~Physician | | | | | | | |
| 0 visit | 1 036 (10,8) | 265 (6,1) | 14 (3,0) | 22 (3,6) | 62 (5,7) | 0 | 7 (5,1) |
| 1 visit | 1048 (10,96) | 451 (10,4) | 31 (6,5) | 40 (6,6) | 76 (7,0) | 0 | 5 (3,6) |
| 2 visits | 1000 (10,5) | 486 (11,2) | 41 (8,6) | 26 (4,3) | 81 (7,4) | 0 | 2 (1,4) |
| 3 or more visits | 6 480 (67,8) | 3 147 (72,4) | 388 (81,9) | 514 (85,4) | 871 (79,9) | 17 (100) | 124 (89,9) |
| ***ER*** | | | | | | | |
| 0 visit | 5 995 (62,7) | 2 501 (57,5) | 240 (50,6) | 289 (48,0) | 200 (18,4) | 1 (5,9) | 25 (18,1) |
| 1 visit | 1 565 (16,4) | 790 (18,2) | 89 (18,8) | 118 (19,6) | 221 (20,3) | 3 (17,6) | 21 (15,2) |
| 2 visits | 846 (8,8) | 414 (9,5) | 59 (12,4) | 63 (10,5) | 172 (15,8) | 1 (5,9) | 9 (6,5) |
| 3 or more visits | 1 158 (12,1) | 644 (14,8) | 86 (18,1) | 132 (21,9) | 497 (45,6) | 12 (70,6) | 83 (60,2) |
| **ED- for respiratory problems** | | | | | | | |
| 0 visit | 8 781 (91,8) | 3 792 (87,2) | 394 (83,1) | 491 (81,6) | 294 (27,0) | 4 (23,5) | 38 (27,5) |
| 1 visit | 593 (6,2) | 402 (9,2) | 52 (11,0) | 64 (10,6) | 450 (41,3) | 4 (23,5) | 27 (19,6) |
| 2 visits | 142 (1,5) | 105 (2,4) | 15 (3,2) | 25 (4,2) | 188 (17,2) | 3 (17,65) | 22 (15,9) |
| 3 or more visits | 48 (0,5) | 50 (1,2) | 13 (2,7) | 22 (3,7) | 158 (14,5) | 6 (35,3) | 51 (37,0) |
| **ED- NOT for respiratory problems** | | | | | | | |
| 0 visit | 6 268 (65,5) | 2 712 (62,4) | 265 (55,9) | 326 (54,2) | 456 | 4 (23,5) | 45 (32,6) |

| | In Control N=14989 | | | | Not Well Controlled N=1245 | | |
|---|---|---|---|---|---|---|---|
| | Maintain n=9564 | Maintain/Decrease n=4349 | Decrease n=474 | Duplicate/ Inappropriate n=602 | Increase n=1 090 | Refer n=17 | Duplicate/ Inappropriate n=138 |
| | | | | | (41,8) | | |
| 1 visit | 1 535 (16,1) | 742 (17,1) | 94 (19,8) | 118 (19,6) | 205 (18,8) | 3 (17,6) | 29 (21,0) |
| 2 visits | 746 (7,8) | 370(8,5) | 49 (10,3) | 58 (9,6) | 117 (10,7) | 3 (17,6) | 14 (10,1) |
| 3 or more visits | 1 015 (10,6) | 525 (12,1) | 66 (13,9) | 100 (16,6) | 312 (28,6) | 7 (41,2) | 50 (36,2) |
| **Hospitalization** | | | | | | | |
| 0 day | 8 046 (84,1) | 3 581 (82,3) | 356 (75,1) | 449 (74,6) | 774 (71,0) | 5 (29,4) | 78 (56,5) |
| 1 day | 697 (7,3) | 318 (7,3) | 39 (8,2) | 62 (10,3) | 100 (9,2) | 3 (17,6) | 17 (12,3) |
| 2 days | 215 (2,2) | 107 (2,5) | 20 (4,2) | 23 (3,8) | 44 (4,0) | 1 (5,9) | 3 (2,2) |
| 3 or more days | 606 (6,3) | 343 (7,9) | 59 (12,4) | 68 (11,3) | 172 (15,8) | 8 (47,1) | 40 (29,0) |
| **Hospitalization- for respiratory problems** | | | | | | | |
| 0 day | 9 370 (98,0) | 4 210 (96,8) | 447 (94,3) | 563 (93,5) | 990 (90,8) | 14 (82,4) | 109 (79,0) |
| 1 day | 100 (1,0) | 60 (1,4) | 7 (1,5) | 20 (3,3) | 33 (3,0) | 0 | 7 (5,1) |
| 2 days | 32 (0,3) | 32 (0,74) | 4 (0,8) | 5 (0,8) | 14 (1,3) | 0 | 3 (2,2) |
| 3 or more days | 62 (0,6) | 47 (1,1) | 16 (3,4) | 14 (2,3) | 53 (4,9) | 3 (17,6) | 19 (13,8) |
| **Asthma Medications mean (sd) range past year** | | | | | | | |
| FABA | 0,61 (1,7) | 2,93 (3,8) | 4,32 (5,2) | 4,95 (5,1) | 2,50 (4,4) | 5,00 (5,2) | 6,82 (6,8) |
| ICS | 0,2 (0,7) | 2,3(2,9) | 1,4(2,6) | 3,6(3,8) | 1,4(2,4) | 0,9 (1,7) | 3,5(3,9) |
| Leukotrienes | 0,1 (1,4) | 0,4(3,0) | 6,7(10,0) | 1,5 (4,8) | 0,8(4,4) | 3,3(5,1) | 3,9 (11,5) |
| Combination Therapy | 0,0 (0,4) | 1,2 (2,9) | 5,1(4,9) | 2,18 (3,9) | 1,0 (2,7) | 7,7 (4,5) | 3,0 (4,3) |

| | In Control N=14989 | | | | Not Well Controlled N=1245 | | |
|---|---|---|---|---|---|---|---|
| | **Maintain n=9564** | **Maintain/Decrease n=4349** | **Decrease n=474** | **Duplicate/ Inappropriate n=602** | **Increase n=1 090** | **Refer n=17** | **Duplicate/ Inappropriate n=138** |
| Other | 0,2(1,8) | 0,8(3,4) | 2,9(6,8) | 2,36 (3,9) | 1,8(17,0) | 2,1 (2,5) | 4,45 (6,6) |
| **Control Status n (%)** | | | | | | | |
| Overuse FABA | 0 | 0 | 0 | 0 | 1 (0,1) | 0 | 0 |
| ER visits for Asthma | 0 | 0 | 0 | 0 | 1 076 (98,7) | 17 (100) | 135 (97,8) |
| ER or FABA | 0 | 0 | 0 | 0 | 1 076 (98,7) | 17 (100) | 135 (97,8) |
| **Co-Morbidity Index** | 1,6 (1,5) | 1,6 (1,5) | 1,8 (1,6) | 1,9 (1,9) | 1,8(2,0) | 2,2 (1,4) | 2,6 (2,5) |

- Less than 1 % of missing values for each category
- ED=emergency department

**DISCUSSION**

The purpose of this study was to evaluate the discrepancy between current asthma management and recommended guidelines using the provincial administrative databases and an ADSS. The present study represents an example of how decision support systems can be used to monitor guideline adherence, and to identify individuals at risk of poor outcomes to provide targeted interventions. To our knowledge this is the first time that a decision support system has been used to evaluate disease management at a population level.

As expected, individuals who were provincially insured were on average older, from a lower SES, and a higher proportion used healthcare services. A larger proportion compared to those non-provincially insured also had a diagnosis code for anxiety and depression.

The algorithms used to identify individuals with asthma and evaluate control status were validated in previous work. [24, 25] The majority of individuals well controlled were on an appropriate quantity of asthma treatment. We found, however, that ~ 31% of those well controlled could benefit from a medication review and potentially lower doses of asthma medications.

The majority of individuals not well controlled had the recommendation to increase treatment and for these individuals there was an opportunity to change therapy according to the existing guidelines. [26] The SMART inhaler helps address needs for increase in therapy, as it allows patients to use their as-needed

medication because of declining asthma control—as is very often the case—evolving exacerbations will possibly be treated at an early stage and a further worsening of asthma may possibly be prevented. The SMART inhaler is not a recommended yet part of Canadian guidelines, however, with emerging evidence of its benefits for marinating control compared to other alternatives, [27, 28] it will be included in the next version of guidelines and become more commonly prescribed for Canadian patients. Individuals who were not well controlled were in the 40-59 age range, and had a more complex health profile with greater co-morbidity, including a higher proportion with a diagnosis of anxiety or depression as compared to those well-controlled. The logistic regression analysis in our study also supported these conclusions. These individuals represent a more vulnerable sub-group of the asthma population, and place a greater burden on the healthcare system given the higher proportion that had an ED visit or hospitalization. As such, they require closer monitoring and review of medication to reach doses sufficient to maintain asthma control, or to review reasons for failed treatment.

In this study we were not able to generate a recommendation for a larger proportion of individuals not well controlled compared to controlled either because they were dispensed prescriptions for an inappropriate combination of medications that the ADSS could not reconcile to provide an appropriate recommendation, or they were dispensed two medications that resulted in a duplication of therapy. These cases in themselves represent a segment of the asthma population that requires closer review of their prescribed medication.

The generation of asthma recommendations at a population level using an administrative database allows individuals not receiving treatment based on guidelines to be identified. We found that many individuals

with non-controlled asthma visit a physician 3 or more times per year, and potentially represent missed opportunities to optimize treatment. Possible reasons for our findings may include the lack of knowledge of PCPs of guidelines in general, especially for more complicated cases. It may also be, however, that patients are not going to see the same physician, or are switching physicians to ensure access to SABAs. In such situations, physicians may be reluctant to conduct a complete medication review if they do not perceive themselves as the primary provider for the patient.

Other physician concerns may be the reluctance to prescribe ICS and/or concern regarding polypharmacy with multiple inhalers. [29] This is where the role of pharmacists is important as they can see individuals' entire medication dispensing history and have been shown to be effective in managing asthma patients in particular if supported by an ADSS. [30]

Previous studies have also found that physicians do not adopt guidelines in their practice because of perceived appropriateness of the guidelines. [13, 31] Surveys have shown that they believe that guidelines do not take into account the heterogeneity of asthma and do not account for individual patient variations in response to treatment, [32] and other factors that impact response to asthma therapy such as age and co-morbidities.

Further, patient non-adherence to prescribed therapy and not having prescribed medications filled may also explain the findings from our study. Patient beliefs about the negative impact and benefits of their

medications, [33] their confidence to manage their asthma, and not seeking care early enough to prevent exacerbations have all been identified as contributors to poor outcomes for asthma. [34]

Mechanisms to identify patients who need closer follow-up and evaluation have been identified as an important need for primary healthcare. [3, 34, 35] Future initiatives can include linking administrative databases to decision support systems that can help identify individuals who need closer monitoring and follow-up and allow for targeted services such as visit reminders sent to patients or to their care provider. The ongoing implementation of electronic health records and patient health portals will facilitate this approach. Information can be fed back to physicians and pharmacists to improve patient management, and initiate care early on, before individuals experience deteriorations in health.

**Conclusions**

This study demonstrated how a decision support system linked to an administrative database could be used to identify individuals in the population that require a review of asthma treatment. Such an approach can help identify individuals with uncontrolled asthma or prescriptions that deviate from recommended treatment to intervene early. This study provides a model for monitoring adherence to guidelines for other chronic conditions such as hypertension and diabetes.

**Limitations**

Our approach for identifying individuals with asthma and assessing asthma status may have underestimated the percentage out of control in our study. We examined asthma control on two index dates, and went back 3 months prior to the index date to assess control status. A more sensitive algorithm that treats control as a time varying covariate would likely provide a more accurate evaluation of control status.

Also, our estimation of the percentage of well-controlled individuals may be an overestimate compared to previous studies because of our method of defining asthma control. A previous study conducted in the UK, [36] and another using a US administrative database [37] assumed 2 puffs of a SABA per day, the equivalent of 180 puffs over 3 months, would be the threshold for asthma control. With this measure of asthma control the authors reported 72% of patients were well controlled in the UK study and 56% in the US study. This estimate is substantially below the measure of 250 puffs we used in this study, and likely explains why we found a larger proportion of individuals who were well controlled.

Also, because we used administrative data and not clinical information from an electronic medical record to generate recommendations, we were not able to use asthma severity and relapse as part of the asthma control algorithm. Two previous studies used composite measures of asthma control including (1) no recorded hospital attendance for asthma (including admission or emergency department visit, out of hours, or outpatient department attendance); (2) no prescription for oral corticosteroid; and (3) no consultation, hospital admission, or emergency department attendance for lower respiratory tract infection requiring antibiotics. [36, 37] With this more stringent definition of asthma control they found proportions of well-controlled asthma control to be 72% [36], and 56% [37]which are lower compared the 94% were found to be well-controlled in our study.

In addition, at the time that the ADSS was being developed, the SMART treatments, that allow for the same inhaler to be used as a preventative and rescue inhaler were not commonly used or part of the guidelines. Therefore, they were not programmed as part of the ADSS and not included in the recommendations.

Further, the ADSS does not distinguish between SABA nebulizer and MDI. Finally, use of decision support during clinical encounters allow for a patient-reported assessment of symptoms at the time when recommendations are generated, and allow for a more accurate assessment of asthma control. We were also limited to generating recommendations for those provincially insured that represent a more vulnerable segment of the population.

**Funding Support**

Health Canada and the Canadian Institute of Health Research supported the development of the asthma decision support system. S Ahmed is supported by a Fonds de la Recherche en Santé du Quebec (FRSQ) research career award.

**Contributorship Statement**

SA RT and NW were involved in:
- the conception and design, analysis and interpretation of data,
- drafting the article and revising it critically for important intellectual content,
- final approval of the version to be published.

**Competing Interests**

No competing interests

**Data Sharing Statement**

Additional data regarding the study sample characteristics and guidelines generated from the decision support system can be provided upon request from the corresponding author.

**References**

1. Shenolikar R, Song X, Anderson JA, et al. Costs of asthma among US working adults. *Am J Manag Care* 2011;17:409-16.

2. Schatz M, Zeiger RS, Yang SJ, et al. The relationship of asthma impairment determined by psychometric tools to future asthma exacerbations. *Chest* 2012;141:66-72.

3. Urrutia I, Aguirre U, Pascual S, et al. Impact of anxiety and depression on disease control and quality of life in asthma patients. *J Asthma* 2012;49:201-8.

4. Colice GL, Ostrom NK, Geller DE, et al. The CHOICE survey: high rates of persistent and uncontrolled asthma in the United States. *Ann Allergy Asthma Immunol* 2012;108:157-62.

5. Glaxo Wellcome I. 2000:1-31.

6. Bousquet J, Mantzouranis E, Cruz AA, et al. Uniform definition of asthma severity, control, and exacerbations: document presented for the World Health Organization Consultation on Severe Asthma. *J Allergy Clin Immunol* 2010;126:926-38.

7. Krahn MD, Berka C, Langlois P,et al. Direct and Indirect Costs of Asthma in Canada, 1990 3465. *CMAJ* 1996;154:821-31.

8. US Department of Health and Human Services OoDPaHP. Healthy People 2020 Washington,DC, 2010.

9. Maciejewski ML, Chen SY, Au DH. Adult asthma disease management: an analysis of studies, approaches, outcomes, and methods. *Respir Care* 2009;54:878-86.

10. Legorreta AP, Christian-Herman J, O'Connor RD,et al. Compliance with National Asthma Management Guidelines and Specialty Care: A Health Mantenance Organization Experience. *Arch Intern Med* 1998;158:457-64.

11. Adams RJ, Fuhlbrigge A, Guilbert T, et al. Inadequate use of asthma medication in the United States: results of the asthma in America national population survey. *J Allergy Clin Immunol* 2002;110:58-64.

12. Flor-Escriche X, Rodriguez-Mas M, Espiau M, et al. Compliance with guidelines in the treatment of asthma exacerbations in primary care. *Ther Adv Respir Dis* 2011;5:369-75.

13. Rank MA, Liesinger JT, Ziegenfuss JY, et al. The impact of asthma medication guidelines on asthma controller use and on asthma exacerbation rates comparing 1997-1998 and 2004-2005. *Ann Allergy Asthma Immunol* 2012;108:9-13.

14. Cazzola M, Segreti A, Bettoncelli G, et al. Change in asthma and COPD prescribing by Italian general practitioners between 2006 and 2008. *Prim Care Respir J* 2011;20:291-8.

15. Arnlind MH, Wettermark B, Nokela M, et al. Regional variation and adherence to guidelines for drug treatment of asthma. *Eur J Clin Pharmacol* 2010;66:187-98.

16. Lougheed MD, Olajos-Clow J, Szpiro K, et al. Multicentre evaluation of an emergency department asthma care pathway for adults. *CJEM* 2009;11:215-29.

17. Roshanov PS, Misra S, Gerstein HC, et al. Computerized clinical decision support systems for chronic disease management: a decision-maker-researcher partnership systematic review. *Implement Sci* 2011;6:92.

18. Tamblyn R, Huang A, Perreault R, et al. The medical office of the twenty-first century (MOXXI): evaluation of the effectiveness of computerised decision support in reducing inappropriate prescribing in primary care. *CMAJ* 2003;169:549-56.

19. Kawasumi Y, Abrahamowicz M, Ernst P, et al. Development and validation of a predictive algorithm to identify adult asthmatics from medical services and pharmacy claims databases. *Health Serv Res* 201;46:939-63.

20. Tamblyn RM, Laprise R, Hanley JA, et al. Adverse events associated with prescription drug cost-sharing among poor and elderly persons. *JAMA* 2001;285:421-9.

21. Schatz M, Zeiger RS, Vollmer WM, et al. Validation of a beta-agonist long-term asthma control scale derived from computerized pharmacy data. *J Allergy ClinImmunol* 2006;117:995-1000.

22. Lemiere C, Bai T, Balter M, et al. Adult Asthma Consensus Guidelines update 2003. *Can Respir J* 2004;11 (Suppl A):9A-18A.

23. Archives of Internal Medicine. *JAMA*. 2001;161.

24. Spitzer WO, Suissa S, Ernst P, et al. The use of beta-agonists and the risk of death and near death from asthma. *N Engl J Med* 1992;326:501-6.

25. Wilchesky M, Tamblyn RM, Huang A. Validation of Diagnostic Codes in Medical Services Claims Data. *Can J Clin Pharmacol* 2001;8:39-39.

26. Becker A, Lemiere C, Berube D, et al. Summary of recommendations from the Canadian Asthma Consensus guidelines, 2003. *CMAJ* 2005;173(Suppl 6):S3-11.

27. Boursquet J, Boulet LP, Peters MJ, et al. Budesonide/formoterol for maintenance and relief in uncontrolled asthma vs. high-dose salmeterol/fluticasone. *Respir Med* 2007;101:2437-46.

28. Kuna P, Peters M, Manjra A, et al. Effect of budesonide/formoterol maintenance and reliever therapy on asthma exacerbations. *Int J Clin Pract* 2007;61:725-36.

29. Navaratnam P, Jayawant SS, Pedersen CA, et al. Asthma pharmacotherapy prescribing in the ambulatory population of the United States: evidence of nonadherence to national guidelines and implications for elderly people. *J Am Geriatr Soc* 2008;56:1312-7.

30. Armour C, Bosnic-Anticevich S, Brillant M, et al. Pharmacy Asthma Care Program (PACP) improves outcomes for patients in the community. *Thorax* 2007;62:496-502.

31. Bracha Y, Brottman G, Carlson A. Physicians, guidelines, and cognitive tasks. *Eval Health Prof* 2011;34:309-35.

32. Yeh KW, Chen SH, Chiang LC, et al. Survey of asthma care in Taiwan: a comparison of asthma specialists and general practitioners. *Ann Allergy Asthma Immunol* 2006;96:593-9.

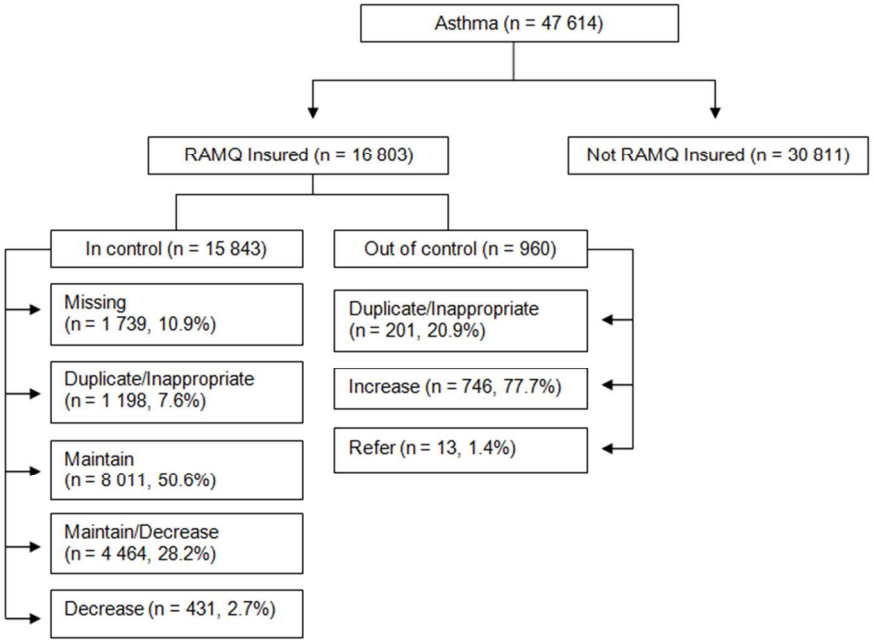
33. Brunton SA, Graham LM, Stoloff SW. Primary care management of patients with asthma. *J Fam Pract* 2011;60(Suppl 5):S1-8.

34. Razykov I, Newton EG, Lober J, et al. Daily SMS reminders for asthma treatment adherence: A comment on Strandbygaard et al. *Respir Med* 2010;104:1234-5; author reply1236.

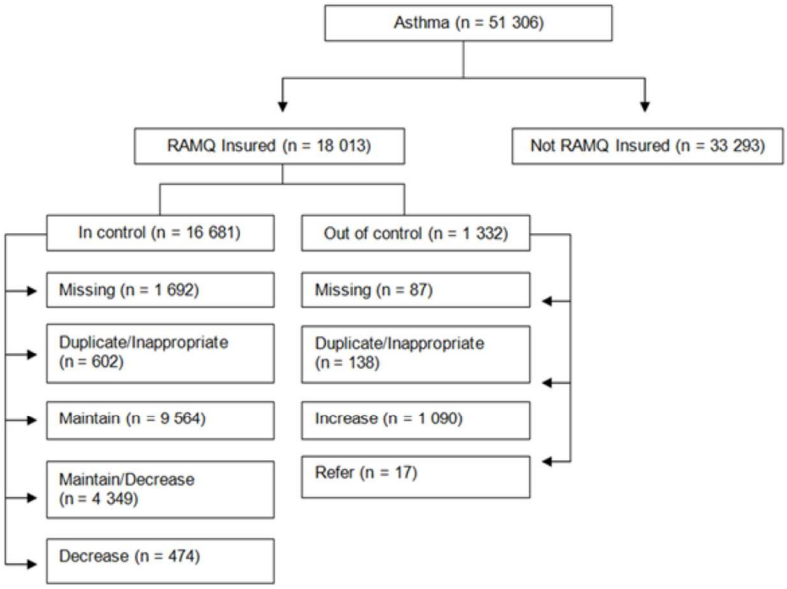
35 Martens JD, van der Weijden T, Winkens RA, et al. Feasibility and acceptability of a computerised system with automated reminders for prescribing behaviour in primary care. *Int J Med Inform* 2008;77:199-207.

36 Price D, Martin RJ, Barnes N, et al. Prescribing practices and asthma control with hydrofluroroalkane-beclomethasone and fluticasone: a real-world observational study. *J allergy Clin Immunol* 2010;126:511-8

37 Colice G, Martin RJ, Israel E, et al. Asthma outcomes and costs of therapy with extrafine beclomethasone and fluticason. *J Allergy Clin Immunol* 2013; 132:45-54.




254x190mm (300 x 300 DPI)




Study Population and recommendation categories for March 15, 2008 (index date 2)
110x71mm (300 x 300 DPI)