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Pulmonary Function Testing in the Diagnosis of Asthma

A Population Study

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Background: Asthma is a common chronic respiratory condition, the diagnosis of which depends on symptoms and objective evidence of variable airflow obstruction or airway hyperresponsiveness. The proportion of people who have had objective pulmonary function testing around the time of diagnosis and factors associated with receiving testing are not well understood.

Methods: A retrospective cohort study was conducted using the health administrative data of all individuals aged 7 years and older with newly physician-diagnosed asthma living in Ontario, Canada between 1996 and 2007. Receipt of pulmonary function testing in the peridiagnostic period was determined and examined across patient sociodemographic and clinical factors.

Results: Only 42.7% (95% CI, 42.6%-42.9%) of the 465,866 Ontarians newly diagnosed with asthma received pulmonary function testing between 1 year prior and 2.5 years following the time of diagnosis. In adjusted analyses, individuals 7 to 9 years old and those 70 years or older were less likely to receive testing than younger adults, individuals in the lowest neighborhood income quintile were less likely to receive testing than those in the highest, and individuals seeing a medical specialist were more likely to receive testing than those seeing only a general practitioner.

Conclusions: Less than one-half of patients with new physician-diagnosed asthma in Ontario, Canada received objective pulmonary function testing around the time of diagnosis. Further study is needed to determine why more pulmonary function testing is not being used to diagnose asthma and how barriers to its appropriate use can be overcome. *CHEST 2012; 141(5):1190-1196*

Abbreviations: IRB = institutional review board; PR = prevalence ratio; SES = socioeconomic status

Asthma is a common chronic respiratory condition characterized by paroxysmal or persistent respiratory symptoms associated with variable airflow limitation and airway hyperresponsiveness to stimuli.¹ Canadian and global asthma guidelines specify that asthma diagnoses should be based on both symptoms and objective physiologic evidence of variable airflow obstruction and/or airway hyperresponsiveness.¹⁻⁴ Pulmonary function testing objectively documents these findings and is the standard diagnostic test for asthma. Pulmonary function testing also has been empirically shown to improve asthma diagnosis and treatment and rule out other diseases, like COPD, that can present like asthma.⁵⁻⁸ Thus, lack of testing increases the chance of misdiagnoses and associated morbidities in the population.

Evidence suggests that pulmonary function testing is not consistently used to confirm asthma diag-

noses. First, studies have suggested that the rate of pulmonary function testing in patients with newly diagnosed asthma is low, and primary care physicians report not using testing for all their asthma patients.⁹⁻¹¹ Second, use of testing for asthma monitoring (where evidence of benefit is not as clear) is low.^{12,13} Finally, both overdiagnosis and underdiagnosis of asthma appear to be common, which would not be expected if objective diagnostic testing was widely used.¹⁴⁻¹⁶ Therefore, we conducted the current study to determine the frequency of clinical asthma diagnoses made without pulmonary function testing. We also identified patient and health-care provider characteristics associated with not receiving testing.

MATERIALS AND METHODS

We conducted a longitudinal cohort study using health administrative data from Ontario, a province of Canada with universal

health-care insurance and a diverse multicultural population of approximately 13 million.

Data Sources

Residents of Ontario have universal public health insurance with the Government of Ontario being the single payer for all medically necessary services across the full spectrum of providers and hospitals. The details of this utilization are captured in large health administrative databases which are linked on an individual level to provide a complete health services use profile for each resident. Three databases were used: (1) The Ontario Health Insurance Plan (OHIP) database contains information on virtually all claims made by Ontario physicians; (2) the Canadian Institute for Health Information (CIHI) Discharge Abstract contains discharge information from every acute hospitalization in Canada; and (3) finally, the Ontario Registered Persons Database (RPDB) captures and maintains demographic information on all individuals living in the province. All databases have information dating back to 1991.

Participants

The Ontario Asthma Surveillance Information System (OASIS) database is a validated registry of all Ontario residents with asthma generated using the databases described previously. Individuals with physician-diagnosed asthma are identified if they have one or more hospital discharges and/or two or more physician visits with a diagnosis of asthma within a 2-year period. About 3% are identified through hospital discharge, 84% through physician visits, and 13% through both criteria. This asthma case definition was previously validated against a clinical reference standard and found to have 89% sensitivity and 72% specificity in children and 84% sensitivity and 76% specificity in adults.^{17,18} The date of the earliest health service was considered the asthma diagnosis date provided no asthma claims occurred within the previous 5 years. If a claim did occur, the subject was not considered newly diagnosed. Children born after April 1, 1991, were exempt from this 5-year rule because data from their entire lifetime was available to indicate previous diagnosis. Individuals prior to 1996 could not be

considered newly diagnosed because they did not have a full 5-year lookback period.

All residents of Ontario 7 years and older newly diagnosed with asthma between April 1, 1996, and March 31, 2007, were included. We excluded children under 7 years because many are not able to effectively carry out pulmonary function testing. In addition, individuals receiving a codiagnosis of COPD, according to a previously validated health administrative case definition, were also excluded.^{19,20}

Outcomes

The primary outcome was pulmonary function testing (performed in physician offices and laboratories), as reported in the health administrative data, between 1 year prior and 2.5 years following a new asthma diagnosis. To ensure that all attempts to confirm asthma diagnoses were captured, most common types of pulmonary function tests were considered: simple spirometry both alone or after a bronchodilator, flow-volume loop testing, body plethysmography, carbon monoxide diffusing capacity testing, and/or bronchoprovocational challenge.

Covariates

Using their residential postal codes, individuals with asthma were characterized in terms of socioeconomic status (SES) based on the average household income of the patients' neighborhood derived from the Canadian Census,^{21,22} rural or urban residence according to Statistics Canada's definition of rural,²¹ and residential provincial health region. Comorbidity was based on health services records in the 2 years prior and was characterized by aggregate diagnostic groups using the Johns Hopkins Adjusted Clinical Group Case-Mix System.²³⁻²⁶ Whether an individual saw a specialist (specifically a physician who specialized in internal medicine, pediatrics, pulmonology, allergy, or geriatrics) during the peridiagnostic period was also considered as, in Canada, most asthma tends to be taken care of by primary care physicians.²⁷

Analyses

Frequencies and proportions were used to report characteristics of the population. The proportions of patients who underwent pulmonary function testing and their 95% CIs were calculated according to different factors. Log-binomial models were used to model the likelihood of pulmonary function testing onto sociodemographic and clinical characteristics and identify factors that, after adjustment, were correlated with its prevalence. These are similar to logistic regression models with the exception that the measure of association produced is the prevalence ratio (PR), or the ratio of two prevalence estimates (in this case of pulmonary function testing), as opposed to the OR.^{28,29} PRs were used rather than ORs as they are more conservative (ie, do not overstate the magnitude of association) and are more intuitive in their interpretation.²⁹ Analyses were performed using SAS, version 9.1 (SAS Institute).

Sensitivity Analysis

To ensure that misclassification of asthma did not bias our results, we repeated the analysis using three additional asthma cohorts derived from the same databases used for the primary analysis. The first cohort was constructed using a second validated case definition of physician-diagnosed asthma shown to have > 84% specificity, but only 80% sensitivity in children and over 87% specificity, but only 74% sensitivity, in adults.^{17,18} The second cohort consisted of those in the original cohort who appeared to require continuing medical attention for asthma

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as indicated by one or more asthma health-care claims at least 2.5 years after their diagnosis was made. Finally, to ensure that only new-onset physician-diagnosed asthma was considered, the third cohort consisted of those who did not have any known previous asthma claims.

Ethics Statement

Research ethics approval was obtained from the institutional review boards (IRBs) at Sunnybrook Health Sciences Centre (IRB approval number 332-2011) and The Hospital for Sick Children, Toronto, ON, Canada (IRB approval number 1000004716).

RESULTS

Participants

There were 465,866 Ontarians aged 7 years and older who were diagnosed with asthma between 1996 and 2007. Characteristics of these individuals are presented in Table 1. The majority were under 40 years, were female, lived in an urban region, had a low to moderate amount of comorbidity, and had a specialist involved in their care.

Pulmonary Function Test Use Around the Time of Asthma Diagnosis

Approximately 42.7% of individuals (95% CI, 42.6, 42.9) underwent pulmonary function testing in the peridiagnostic period. Of these, 17.5% received a bronchoprovocational challenge, 82.4% received spirometry alone, and 0.1% received either plethysmography or diffusing capacity testing. The unadjusted percentage of individuals who received pulmonary function testing differed modestly by age, sex, SES, place of residence, comorbidity, and whether they saw a specialist (Table 2).

Multivariable analysis revealed that younger adulthood, male sex, higher SES, involvement of a specialist, rural residence, and diagnosis during spring and summer were all statistically associated with a greater likelihood of pulmonary function testing (Fig 1). Involvement of a specialist (PR, 2.42; 95% CI, 2.40-2.45); age (adolescents and younger adults were significantly more likely to receive pulmonary function tests than their younger or older peers); and SES (PR, 0.88; 95% CI, 0.87-0.89 for the lowest compared with the highest income quintile) appeared to have the most influence.

Sensitivity Analyses

Repeating the analysis using a highly specific asthma cohort revealed that 50.2% received pulmonary function testing. When the analysis was limited to those who appeared to require ongoing medical attention for asthma, 45.3% received testing. Finally, when the analysis was repeated in individuals who

Table 1—Sociodemographic and Clinical Characteristics of Individuals With Newly Diagnosed Asthma in Ontario, Canada, 1996 to 2007

Characteristic	No. out of 465,866 (%)
Age, y	
7-9	48,316 (10.4)
10-14	56,220 (12.1)
15-19	38,448 (8.3)
20-29	73,872 (15.9)
30-39	87,214 (18.7)
40-49	70,531 (15.1)
50-59	44,565 (9.6)
60-69	26,625 (5.7)
70-79	14,929 (3.2)
80-89	4,546 (1.0)
90-99	600 (0.1)
Sex	
Female	275,253 (59.1)
Male	190,613 (40.9)
Socioeconomic status ^a	
Lowest 1	98,366 (21.1)
2	93,773 (20.1)
3	92,782 (19.9)
4	91,501 (19.6)
Highest 5	88,255 (18.9)
Rural residence ^a	
Yes	50,169 (10.8)
No	415,367 (89.2)
Amount of comorbidity	
Low	193,636 (41.6)
Moderate	213,204 (45.8)
High	59,026 (12.7)
Medical specialist involved in care	
Yes	285,328 (61.2)
No	180,538 (38.8)
Month of diagnosis	
January-March	112,148 (26.8)
April-June	120,639 (25.9)
July-September	108,355 (23.3)
October-December	124,724 (24.1)

^aIncome quintile and rural residence could not be determined for 1,189 and 330 individuals (0.2% and 0.1%), respectively, for whom full residential postal code was unavailable or invalid.

had no known prior asthma claims, 43.1% received testing.

DISCUSSION

We conducted a study of all individuals living in Ontario, Canada with new physician-diagnosed asthma between 1996 and 2007 and found that only 42.7% received objective pulmonary function testing around the time of diagnosis. We also found young children and older adults, those who did not have a specialist involved in their care, and those of lower SES less likely to receive pulmonary function testing. Thus, it appears that most physician-diagnosed asthma in Ontario—a province with universal health care that covers pulmonary function testing—is diagnosed solely by clinical evaluation without objective

Table 2—Unadjusted Rates of Pulmonary Function Testing Around Time of Asthma Diagnosis by Sociodemographic and Clinical Characteristics

Characteristic	Individuals Receiving Pulmonary Function Testing		Prevalence Ratio (95% CI)	P Value for Comparison With Reference Value
	No.	% (95% CI)		
Overall	199,148	42.7 (42.6, 42.9)	...	...
Age group, y				
7-9	15,496	32.1 (31.7, 32.5)	0.74 (0.73, 0.76)	< .001
10-14	22,531	40.1 (39.7, 40.5)	0.93 (0.92, 0.94)	< .001
15-19	15,972	41.5 (41.0, 42.0)	0.96 (0.95, 0.98)	< .001
20-29	31,812	43.1 (42.7, 43.4)	1.00	Ref
30-39	38,608	44.3 (43.9, 44.6)	1.03 (1.02, 1.04)	< .001
40-49	32,892	46.6 (46.3, 47.0)	1.08 (1.07, 1.10)	< .001
50-59	21,784	48.9 (48.4, 49.3)	1.14 (1.12, 1.15)	< .001
60-69	12,494	46.9 (46.3, 47.5)	1.09 (1.07, 1.11)	< .001
70-79	6,203	41.6 (40.8, 42.3)	0.96 (0.94, 0.98)	.001
80-89	1,299	28.6 (27.3, 29.9)	0.66 (0.63, 0.69)	< .001
90-99	57	9.5 (7.2, 11.8)	0.22 (0.17, 0.28)	< .001
Sex				
F	119,885	43.6 (43.4, 43.7)	1.00	Ref
M	79,263	41.6 (41.4, 41.8)	0.95 (0.95, 0.96)	< .001
Socioeconomic status				
Lowest 1	38,566	39.2 (38.9, 39.5)	0.85 (0.84, 0.86)	< .001
2	39,119	41.7 (41.4, 42.0)	0.91 (0.90, 0.92)	< .001
3	39,888	43.0 (42.7, 43.3)	0.93 (0.92, 0.94)	< .001
4	40,531	44.3 (44.0, 44.6)	0.96 (0.95, 0.97)	< .001
Highest 5	40,639	46.1 (45.7, 46.4)	1.00	Ref
Rural residence				
Yes	20,354	40.6 (40.1, 41.0)	0.94 (0.93, 0.95)	< .001
No	178,652	43.0 (42.9, 43.2)	1.00	Ref
Comorbidity				
Low	75,081	38.8 (38.6, 39.0)	1.00	Ref
Moderate	95,418	44.8 (44.5, 45.0)	1.15 (1.15, 1.16)	< .001
High	28,649	48.5 (48.1, 48.9)	1.25 (1.24, 1.26)	< .001
Medical specialist involved in care				
Yes	157,065	55.1 (54.9, 55.2)	2.36 (2.34, 2.38)	< .001
No	42,083	23.3 (23.1, 23.5)	1.00	Ref
Month of diagnosis				
January-March	48,097	24.2 (23.9, 24.5)	0.99 (0.98, 1.00)	.087
April-June	52,664	26.4 (26.2, 26.6)	1.01 (1.00, 1.02)	.050
July-September	46,861	23.5 (23.3, 23.8)	1.00	Ref
October-December	51,526	25.9 (25.7, 26.1)	0.96 (0.95, 0.96)	< .001

F = female; M = male; Ref = reference category.

physiologic findings. This points to a large quality gap in clinical asthma care that might be responsible for the considerable amount of asthma overdiagnosis previously found in Ontario.¹⁴

There are several reasons why patients might not receive pulmonary function testing to diagnose their asthma. Patient factors such as lack of time, lack of education, disinterest in finding out a diagnosis, or inability to perform the tests may play a role.¹¹ Although children and the very old are potential candidates for testing, it may not be feasible or a priority in all situations. Physician factors such as attitudes, beliefs about how asthma should be diagnosed, and lack of knowledge may also be barriers. Primary care physicians can conduct spirometry in their offices but cost of the machine, lack of time, organizational struc-

ture, low remuneration, and need for proper training may be reasons why they do not do so.^{11,30} In addition, evidence linking pulmonary function testing to better long-term outcomes is limited and some physicians may not be convinced they actually make a difference.^{30,31} Finally, system factors such as too few or inconvenient to access laboratories may also play a role.

We observed that individuals who did not have a specialist, young children and older adults, and people of lower SES were less likely to receive pulmonary function testing. Specialists may have better access than primary care practitioners to testing and, in some cases, may be remunerated more for reading tests. They may also be more likely to see individuals with complicated asthma or obscure diagnoses

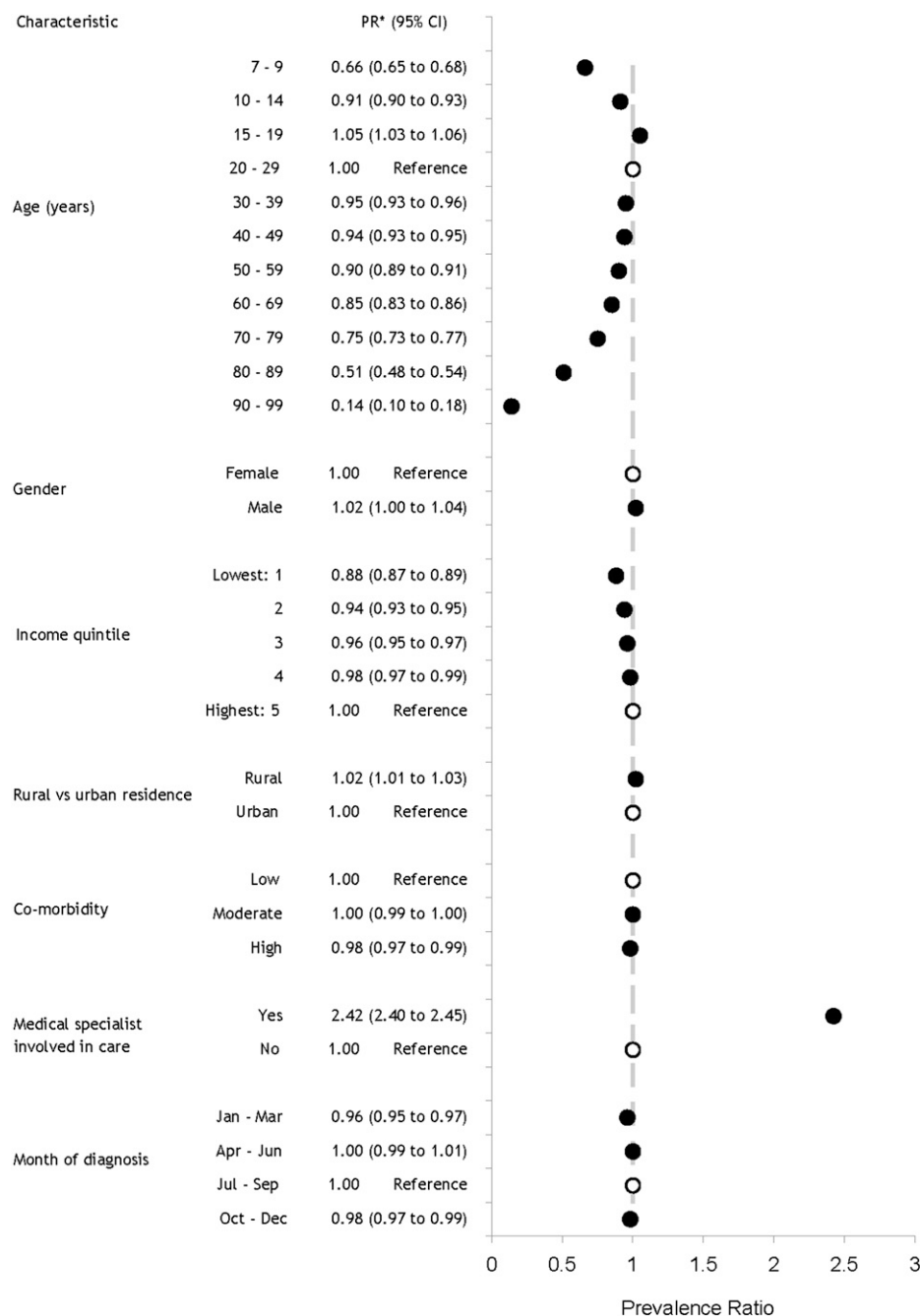


FIGURE 1. Adjusted PRs of receiving pulmonary function testing in individuals with newly diagnosed asthma in Ontario, Canada between 1996 and 2006 according to various socioeconomic and clinical characteristics. Model also adjusted for provincial health region. ○ = reference category for a given variable; ● = PRs adjusted for all variables presented, and geographic region. PR = prevalence ratio.

where testing would play a larger role. Despite this, however, it is interesting to note that specialists' rate of testing was only about 55%. Pulmonary function testing is recommended for children over the age of 5 years¹⁻⁴; however, there may be a misconception that younger children cannot perform testing. Likewise, there might be a misbelief that older patients with limited functional capacity are not appropriate candidates. In other cases, developmental delay,

dementia, or other comorbidity may make it appropriate to forgo testing. Finally, decreased access to pulmonary function testing by individuals of lower SES is consistent with other studies demonstrating decreased access to other diagnostic tests by this group.³²

Our study examined pulmonary function testing for asthma diagnosis and not for monitoring where—because guidelines and the literature are less clear

about its benefit—rates would be expected to be lower. In our cohort, only about 12% of individuals with prevalent asthma had undergone pulmonary function testing in the previous year (data not shown).

The strengths of our study were its ability to examine receipt of pulmonary function testing in an entire, large, real-world population of individuals with newly diagnosed asthma. It also had some limitations that merit emphasis. To begin, our asthma case definition only had 72% to 76% specificity, so misclassification of individuals with asthma could have occurred. However, when we repeated the analysis using a case definition with higher specificity, we found the proportion receiving testing only slightly higher. Likewise, when we repeated the analysis including those who appeared to require ongoing medical attention for asthma, the results were similar. A second limitation was that, without clinical detail, we could not be certain on which physician visit a diagnosis of asthma was made. To accommodate this uncertainty, we defined a very generous peridiagnostic period (3.5 years). A third limitation was that we could not be certain that all subjects had newly diagnosed asthma. For the primary analysis, a common 5-year lookback period for all individuals was used to avoid potential bias from differential lookback periods. Some individuals, however, may have had a claim >5 years before diagnosis in our database and may not truly have been newly diagnosed. Nonetheless, when we excluded all individuals who had an asthma claim since 1991, the results did not differ significantly. Fourth, health administrative data revealed whether pulmonary function testing took place but could not indicate whether it was diagnostic of asthma and in many cases it may not have been. Similarly, the health administrative data could not reveal quality of the testing.³³ Finally, diurnal peak flow variability using a home peak expiratory flowmeter was not captured in our data. This could have resulted in an underestimate of the number of people who have had testing during the peridiagnostic period; however, given the issues regarding reliability of this test and its nonpreferred status as a diagnostic test for asthma, we believe that the number of individuals who were tested that were missed would have been small.^{1,34}

This study identified a large proportion of individuals who had been diagnosed with asthma without pulmonary function testing but were not designed to determine whether their health outcomes differed from those who were diagnosed with pulmonary function testing. As mentioned previously, previous studies have shown that pulmonary function testing alters clinical decision making and positively influences asthma diagnosis and treatment.⁵⁻⁸ Whether pulmonary function testing also has a positive influence on asthma outcomes would be an interesting topic for future study.

In summary, our study confirmed that a large proportion of new asthma diagnoses are made without pulmonary function testing. This gap in quality care increases the chance of misdiagnoses and associated morbidities arising from either missed alternative diagnoses or inappropriate use of asthma medications. We also found that individuals who had not seen a specialist, young children and older adults, and people of lower SES were less likely to receive pulmonary function testing than other members of the population. Clinicians should be encouraged to routinely use pulmonary function testing for the diagnosis of asthma to facilitate more accurate diagnosis and improve management. Further study is needed to determine why more pulmonary function testing is not being used to diagnose asthma and how barriers to its appropriate use can be overcome.

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Dr Gershon: contributed to the conception and design, acquisition of data, analysis and interpretation of data, drafting and critical revision of the manuscript, and approval of the final version.

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Ms Guan: contributed to the design, analysis and interpretation of data, critical revision of the manuscript, and approval of the final version.

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REFERENCES

1. Loughheed MD, Lemièrre C, Dell SD, et al; Canadian Thoracic Society Asthma Committee. Canadian Thoracic Society Asthma Management Continuum—2010 Consensus Summary for children six years of age and over, and adults. *Can Respir J*. 2010; 17(1):15-24.
2. The global strategy for asthma management and prevention, Global Initiative for Asthma (GINA) 2011. Global Initiative for Asthma website. <http://www.ginasthma.org/>. Accessed January 21, 2011.
3. National Heart, Lung and Blood Institute, National Institutes of Health. *National Asthma Education and Prevention Program Expert Panel Report 3: Guidelines for the Diagnosis and Management of Asthma*. Washington, DC: US Department of Health and Human Services; 2007.

4. Reddel HK, Taylor DR, Bateman ED, et al; American Thoracic Society/European Respiratory Society Task Force on Asthma Control and Exacerbations. An official American Thoracic Society/European Respiratory Society statement: asthma control and exacerbations: standardizing endpoints for clinical asthma trials and clinical practice. *Am J Respir Crit Care Med*. 2009;180(1):59-99.
5. Cowie RL, Underwood MF, Field SK. Asthma symptoms do not predict spirometry. *Can Respir J*. 2007;14(6):339-342.
6. Nair SJ, Daigle KL, DeCuir P, Lapin CD, Schramm CM. The influence of pulmonary function testing on the management of asthma in children. *J Pediatr*. 2005;147(6):797-801.
7. Holt EW, Tan J, Hosgood HD. The impact of spirometry on pediatric asthma diagnosis and treatment. *J Asthma*. 2006;43(7):489-493.
8. Yawn BP, Enright PL, Lemanske RF Jr, et al. Spirometry can be done in family physicians' offices and alters clinical decisions in management of asthma and COPD. *Chest*. 2007;132(4):1162-1168.
9. Grant EN, Moy JN, Turner-Roan K, Daugherty SR, Weiss KB; Chicago Asthma Surveillance Initiative Project Team. Asthma care practices, perceptions, and beliefs of Chicago-area primary-care physicians. *Chest*. 1999;116(4)(suppl 1):145S-154S.
10. Dennis SM, Price JF, Vickers MR, Frost CD, Levy ML, Barnes PJ. The management of newly identified asthma in primary care in England. *Prim Care Respir J*. 2002;11(4):120-122.
11. Dennis SM, Zwar NA, Marks GB. Diagnosing asthma in adults in primary care: a qualitative study of Australian GPs' experiences. *Prim Care Respir J*. 2010;19(1):52-56.
12. Finkelstein JA, Lozano P, Shulruff R, et al. Self-reported physician practices for children with asthma: are national guidelines followed? *Pediatrics*. 2000;106(suppl 4):886-896.
13. Chapman KR, Ernst P, Grenville A, Dewland P, Zimmerman S. Control of asthma in Canada: failure to achieve guideline targets. *Can Respir J*. 2001;8(suppl A):35A-40A.
14. Aaron SD, Vandemheen KL, Boulet LP, et al; Canadian Respiratory Clinical Research Consortium. Overdiagnosis of asthma in obese and nonobese adults. *CMAJ*. 2008;179(11):1121-1131.
15. Stupka E, deShazo R. Asthma in seniors: Part 1. Evidence for underdiagnosis, undertreatment, and increasing morbidity and mortality. *Am J Med*. 2009;122(1):6-11.
16. Quinn K, Shalowitz MU, Berry CA, Mijanovich T, Wolf RL. Racial and ethnic disparities in diagnosed and possible undiagnosed asthma among public-school children in Chicago. *Am J Public Health*. 2006;96(9):1599-1603.
17. To T, Dell S, Dick PT, et al. Case verification of children with asthma in Ontario. *Pediatr Allergy Immunol*. 2006;17(1):69-76.
18. Gershon AS, Wang C, Guan J, Vasilevska-Ristovska J, Cicutto L, To T. Identifying patients with physician-diagnosed asthma in health administrative databases. *Can Respir J*. 2009;16(6):183-188.
19. Gershon AS, Wang C, Wilton AS, Raut R, To T. Trends in chronic obstructive pulmonary disease prevalence, incidence, and mortality in Ontario, Canada, 1996 to 2007: a population-based study. *Arch Intern Med*. 2010;170(6):560-565.
20. Gershon AS, Wang C, Guan J, Vasilevska-Ristovska J, Cicutto L, To T. Identifying individuals with physician diagnosed COPD in health administrative databases. *COPD*. 2009;6(5):388-394.
21. PCCF+ Version 4D User's Guide (Geocodes/PCCF). *Automated Geographic Coding Based on the Statistics Canada Postal Code Conversion Files, Including Postal Codes to December 2003*. Ottawa, Canada: Statistics Canada; 2004.
22. *Postal Code Conversion File* [computer program]. Ottawa, Canada: Minister of Industry; 2009.
23. Reid RJ, MacWilliam L, Verhulst L, Roos N, Atkinson M. Performance of the ACG case-mix system in two Canadian provinces. *Med Care*. 2001;39(1):86-99.
24. *The Johns Hopkins University ACG Case-Mix System, Version 8.0* [computer program]. Baltimore, MD: The John Hopkins University; 2006.
25. Starfield B, Lemke KW, Bernhardt T, Foldes SS, Forrest CB, Weiner JP. Comorbidity: implications for the importance of primary care in 'case' management. *Ann Fam Med*. 2003;1(1):8-14.
26. Starfield B, Lemke KW, Herbert R, Pavlovich WD, Anderson G. Comorbidity and the use of primary care and specialist care in the elderly. *Ann Fam Med*. 2005;3(3):215-222.
27. To T, Gershon A, Tassoudji M, et al. The burden of asthma in Ontario. ICES investigative report. Toronto, Canada: Institute for Clinical Evaluative Sciences; 2006:18. ICES website. http://www.ices.on.ca/webpage.cfm?site_id=1&org_id=68. Accessed August 8, 2011.
28. Thompson ML, Myers JE, Kriebel D. Prevalence odds ratio or prevalence ratio in the analysis of cross sectional data: what is to be done? *Occup Environ Med*. 1998;55(4):272-277.
29. McNutt LA, Wu C, Xue X, Hafner JP. Estimating the relative risk in cohort studies and clinical trials of common outcomes. *Am J Epidemiol*. 2003;157(10):940-943.
30. Wiener-Ogilvie SW, Huby G, Pinnock H, Gillies J, Sheikh A. Practice organisational characteristics can impact on compliance with the BTS/SIGN asthma guideline: qualitative comparative case study in primary care. *BMC Fam Pract*. 2008;9:32.
31. O'Dowd LC, Fife D, Tenhave T, Panettieri RA Jr. Attitudes of physicians toward objective measures of airway function in asthma. *Am J Med*. 2003;114(5):391-396.
32. Alter DA, Naylor CD, Austin P, Tu JV. Effects of socioeconomic status on access to invasive cardiac procedures and on mortality after acute myocardial infarction. *N Engl J Med*. 1999;341(18):1359-1367.
33. Haynes JM. Comprehensive quality control for pulmonary function testing: it's time to face the music. *Respir Care*. 2010;55(3):355-357.
34. Reddel H, Jenkins C, Woolcock A. Diurnal variability—time to change asthma guidelines? *BMJ*. 1999;319(7201):45-47.

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