DOI: 10.1111/j.1475-6773.2005.00410.x

The Impact of Allergy and Pulmonary Specialist Care on Emergency Asthma Utilization in a Large Managed Care Organization

Sara Erickson, Irina Tolstykh, Joe V. Selby, Guillermo Mendoza, Carlos Iribarren, and Mark D. Eisner

Objective. To evaluate the longitudinal impact of asthma specialist care on the risk of emergency department (ED) visits and hospitalization for asthma.

Data Sources/Study Setting. A prospective cohort study using both telephone survey and computerized utilization data.

Study Design. We recruited a prospective cohort of 4,742 adult members of a closed panel managed care organization who were hospitalized for asthma (the "baseline hospitalization").

Data Collection/Extraction Methods. Visits to asthma specialists were ascertained from computerized utilization databases. Specialist visits after baseline hospitalization were defined as time-dependent covariates. An alternative analysis defined specialist visits during the year preceding baseline hospitalization. A subcohort of 596 subjects completed telephone interviews.

Principal Findings. Compared with subjects who received no specialist visits after baseline hospitalization, treatment by allergists (hazard ratio (HR) 1.04; 95 percent confidence interval (CI) 0.87–1.26) or pulmonologists (HR 0.92; 95 percent CI 0.71–1.19) was not associated with a reduction in the risk of future ED visits for asthma in the entire cohort, controlling for age, sex, race, recent asthma medication dispensing, and pharmacy benefits status. There was also no association between allergist visits and the risk of subsequent hospitalizations for asthma (HR 0.93; 95 percent CI 0.75–1.14). In contrast, visits to pulmonologists (HR 0.74; 95 percent CI 0.55–0.99) were related to a reduced risk of rehospitalization.

Conclusions. Pulmonary specialist visits appeared to reduce the risk of hospitalization for asthma, whereas asthma specialist visits did not reduce the risk of ED visits. In the context of comprehensive prepaid health care, the benefit of specialist care was modest.

Key Words. Asthma, pulmonary disease (specialty), treatment outcome

During the past 20 years, the U.S. morbidity and mortality from asthma have been increasing (Mannino et al. 1998, 2002). In an effort to improve asthma care, the National Asthma Education and Prevention Program (NAEPP) published guidelines for the diagnosis and management of asthma in 1991 (NAEPP 1991). In general, physicians' compliance with these national guidelines appears to be poor (Legorreta et al. 1998; Meng et al. 1999). However, asthma specialists (allergists and pulmonologists) appear to follow the clinical practice guidelines more closely than primary care physicians (Legorreta et al. 1998; Meng et al. 1999; Diette et al. 2001; Frieri et al. 2002). In addition, a substantial body of literature suggests that patients who are managed by asthma specialists have better outcomes than patients managed by primary care physicians (Engel et al. 1989; Mayo, Richman, and Harris 1990; Zeiger et al. 1991; Mahr and Evans 1993; Sperber et al. 1995; Storms et al. 1995; Legorreta et al. 1998; Brunner, Wunsch, and Marmot 2001). These improved outcomes included fewer asthma symptoms, improved quality of life, and fewer emergency department (ED) visits and hospitalizations (Engel et al. 1989; Mayo et al. 1990; Zeiger et al. 1991; Mahr and Evans 1993; Sperber et al. 1995; Storms et al. 1995; Legorreta et al. 1998; Brunner et al. 2001).

On a conceptual basis, asthma specialist care could improve asthma outcomes, including exacerbations and hospitalizations, through a variety of mechanisms. Specialty care might improve identification and remediation of factors that exacerbate asthma, such as workplace exposures to allergens or irritants, dust mites, mold, secondhand tobacco smoke, or comorbid medical conditions (e.g., rhinitis, sinusitis, or gastroesphageal reflux disease). Specialist care could also increase the use of objective assessment and monitoring of asthma using spirometry and peak expiratory flow measurement. Specialists may provide enhanced education about asthma and the use of self-management plans (i.e., "action plans") for handling exacerbations. And specialist visits could result in greater appropriate use of inhaled anti-inflammatory

---

Address correspondence to Mark D. Eisner, M.D., M.P.H., Department of Medicine, University of California, San Fransisco, 350 Parnassus Avenue, Ste 609, San Francisco, CA 94117. Sara Erickson, M.D., is with the Department of Medicine, University of California, San Francisco, CA. Irina Tolstykh, M.S., Joe V. Selby, M.D., M.P.H., Guillermo Mendoza, M.D., Carlos Iribarren, M.D., Ph.D., M.P.H., and Mark D. Eisner are with the Division of Research, Kaiser Permanente, Oakland, CA. Mark D. Eisner is also with the Division of Occupational and Environmental Medicine and Division of Pulmonary and Critical Care Medicine, Department of Medicine, University of California, San Francisco.

medications and inhaled β-agonists. Some of these putative benefits would be likely to yield short-term improvements, such as inhaled anti-inflammatory medications; other interventions, such as asthma education, would likely result in longer-term behavior change. In both cases, the impacts should be detectable within a period of our study.

Two of the seminal randomized trials of asthma specialist care both facilitated health care access and provided more intense treatment and education to the intervention/specialist group (Mayo et al. 1990; Zeiger et al. 1991). It is therefore difficult to determine which component of the intervention—specialist expertise, improved access to care, or formalized patient education—accounted for the improved outcomes. Notably, all of the studies comparing asthma specialist care to primary care were conducted more than 7 years ago. Since that time, inhaled corticosteroids have become more widely available and additional controller medications have been developed including long-acting β-agonists and leukotriene modifiers. In addition, 12 years have passed since the initial publication of the NAEPP guidelines and since then, two subsequent updates have been released, in 1997 and 2002 (NAEPP 1997, 2002). Many of the studies comparing specialist to generalist care were conducted before the publication of the initial guidelines or shortly thereafter (Engel et al. 1989; Mayo et al. 1990; Zeiger et al. 1991; Sperber et al. 1995; Storms et al. 1995; Mahr and Evans 1993). Now that more time has elapsed, allowing for the dissemination of this important information, outcomes may have improved among patients treated by primary care physicians. Given that two-thirds of patients with asthma receive their care from primary care physicians (Carr, Zeitel, and Weiss 1992) and also given the evolving state of asthma management, a current investigation comparing specialist and generalist asthma care is warranted.

In a prospective cohort study, we evaluated the impact of specialist care on the utilization outcomes of asthma patients enrolled in a large integrated health care delivery system in Northern California. Our study sought to determine whether there was a difference in asthma-related emergency health care utilization among patients treated by asthma specialists (allergists or pulmonologists) compared with primary care physicians. Because this study was conducted within a managed care organization, all study subjects had equal access to health care. In addition, there were system-wide efforts within the organization to improve asthma care by disseminating asthma clinical practice guidelines to all primary care providers. Therefore, we were able to study the effects of asthma specialist care in a health care environment with a high quality of primary care for asthma.

METHODS

Overview

Using computerized utilization data, we identified all adult members of a closed panel managed care organization who were hospitalized for asthma during a 3-year period. We identified two groups of subjects: adults admitted to the intensive care unit (ICU) for asthma and those hospitalized without ICU admission. For each subject, we retrospectively ascertained pharmacy and health care utilization during the 12 months prior to hospitalization. After hospital discharge, we recruited a subgroup of adults with asthma to undergo structured telephone interviews that assessed sociodemographic characteristics, asthma history, and health status. In this analysis, we evaluate the longitudinal impact of asthma specialist care on the risk of ED visits and hospitalization for asthma. The study was approved by the University of California, San Francisco Committee on Human Research and the Kaiser Foundation Research Institute's institutional review board.

Subject Recruitment

We studied adult members of Kaiser Permanente Northern California (KPNC), the nation's largest nonprofit managed care organization. In Northern California, KPNCs share of the regional population ranges from 25 to 30 percent (Karter et al. 2002). The demographic characteristics of KPNC membership are similar to the overall Northern California population, except for the extremes of income distribution (Krieger 1992). Of the 2.0 million adult KP members ($\geq$ 18 years), an estimated 160,307 (8.1 percent) persons have asthma, which is similar to the general U.S. population (Mannino et al. 1998, 2002).

We employed previously described methods to identify adults hospitalized for asthma (Lieu et al. 1999). On a rolling monthly basis, we identified all adult Kaiser Permanente Medical Care Program (KPMCP) members ($\geq$ 18 years) hospitalized at any KPNC hospital between March 2000 and April 2003 with a principal Ninth International Classification of Diseases (ICD-9) discharge diagnosis code for asthma (codes 493.00–493.99). We also included KPMCP members hospitalized with a secondary ICD-9 discharge diagnosis code for asthma and a principle ICD-9 code for acute asthma-related respiratory conditions. Persons with a primary or secondary discharge diagnosis code for chronic bronchitis (491.xx), emphysema (492.xx), or chronic airway obstruction (496.xx) were excluded.

Using computerized discharge diagnoses, we identified 4,742 adults hospitalized for asthma. These subjects comprise the overall cohort for the

Table 1: Sociodemographic and Personal Characteristics of 4,742 Adults Hospitalized for Asthma

Characteristic	*Entire Cohort N (%) or Mean (SD)*	*Interviewed Subcohort N (%) or Mean (SD)*	*Non-Interviewed Subcohort N (%) or Mean (SD)*	*p-Value*
Sample size (*n*)	4,742 (100%)	596 (13%)	4,146 (87%)	
Age (mean, SD)	59.2 ± 18.1	59.7 ± 15.8	59.1 ± 18.4	.46
Gender (female)	3,290 (69%)	408 (68%)	2,882 (70%)	.60
Race (white)	3,359 (71%)	422 (71%)	2,937 (71%)	.98
Household income				
Lowest income (<$20k)	NA	88 (15%)	NA	
Medium income ($20–$60k)	NA	437 (73%)	NA	
Highest income ($60k+)	NA	71 (12%)	NA	
Educational attainment				
High school or less	NA	160 (25%)	NA	
Some college	NA	310 (52%)	NA	
College graduate or higher	NA	137 (23%)	NA	
Cigarette smoking history				
Ex-smoker	NA	334 (56%)	NA	
Current smoker	NA	61 (10%)	NA	
Never smoked	NA	201 (34%)	NA	
Severity-of-asthma score	NA	13.3 ± 4.4	NA	
ICU admission (index hospitalization)	485 (10%)	97 (16%)	388 (9%)	<.0001
Pharmacy benefits	3,893 (82%)	498 (84%)	3,395 (82%)	.32

NA, not available among subjects who were not sampled and recruited for telephone interviews (interview-based variables); ICU, intensive care unit.

present analysis. For some subsidiary analyses, we used more detailed information available for a subcohort who was recruited for structured telephone interviews ("interviewed subcohort"). Beginning in April 2000, we attempted to recruit all eligible adults who were admitted to the ICU for asthma, persons with the most severe disease. To broaden the spectrum of severe asthma, we also began recruiting a random sample of all eligible adults who were hospitalized for asthma without ICU admission (non-ICU group) in September 2000. The interview completion rate was 52 percent of eligible subjects. All interviewed subjects indicated self-reported physician diagnosed asthma. Subjects who completed interviews were similar in age, gender, and race/ethnicity to those who did not complete interviews (Table 1).

Validation of Asthma Diagnosis

To validate the diagnosis of asthma, we selected a stratified random sample of 100 patient medical records among subjects admitted to the ICU for asthma

and those hospitalized without ICU admission for asthma. The records were abstracted by a single trained medical record reviewer. Records were abstracted for a period ranging from 12 months before the index hospitalization until 6 months following the index date. The reviewer evaluated the records for a recorded diagnosis of asthma and related conditions, including exercise-induced asthma and reactive airway disease. Of the 100 medical records, 99 records had a physician's diagnosis of asthma recorded in the record. The other one subject had a diagnosis of reactive airway disease recorded in the medical record.

Asthma Specialty Care

We used the KPNC computerized ambulatory databases to ascertain visits to allergists and pulmonologists following the baseline hospitalization. Subjects who had one or more visits to an allergist or pulmonologist were considered to have received allergy or pulmonary specialist care. Some subjects received both allergy and pulmonary care. The referent group included subjects who had no allergy or pulmonary specialist visits, receiving only primary care. Persons with no visits during the study period were included in the referent group. Specialist visits were defined as time-dependent covariates in the extended Cox model (Hosmer and Lemeshow 1999).

As an alternate secondary method, we defined exposure to asthma specialty care based on asthma specialist care provided during the 12-month period preceding baseline hospitalization, rather than on specialty care provided after the hospitalization. Because the follow-up time after baseline hospitalization varied among subjects, the "opportunity" to received specialist care was also nonuniform. For example, a subject who was rehospitalized for asthma 1 month after their baseline hospitalization had a shorter time window to receive specialty care than did a subject who was rehospitalized 2 years later or not rehospitalized at all. The extended Cox model for time-dependent covariates does not eliminate this potential for nonuniform exposure opportunity (Hosmer and Lemeshow 1999). By ascertaining specialty care during the year prior to hospitalization, subjects had a uniform opportunity to have seen an asthma specialist. Moreover, the presumed benefits of specialist care, including asthma education, self-management training, and proper use of medications, should persist beyond the baseline hospitalization. This analysis is, however, more conservative, as it does not include subjects whose baseline hospitalization may have been prevented by an earlier specialist visit.

Medication Dispensing

The computerized KPNC pharmacy database was used to determine asthma medication use during the 12-month period preceding each subject's baseline hospital admission date. These included dispensing of specific medication groups classified in the NAEPP guidelines as long-term "controller medications" (NAEPP 1991, 1997): long-acting β-agonists (IBA, e.g., salmeterol), inhaled corticosteroids (ICS), leukotriene modifiers, methylxanthines, and oral corticosteroids. In addition, we assessed dispensing of short-acting inhaled β-agonists, inhaled anti-cholinergic medications, combined inhaled β-agonist/anti-cholinergic medication, and nebulizer use for any medication. The combined fluticasone propionate/salmetrol combination was counted in both the ICS and long-acting inhaled β-agonist category. For medications delivered by metered-dose inhaler (MDI), we defined each dispensed MDI as one unit. For other medications, including oral medications and solutions intended for a home nebulizer device, each prescription dispensed was defined as one unit (an approximate 1 month supply).

Based on previous work in asthma, we recognize that the relation between IBA and ICS dispensing and rehospitalization may be nonlinear or U-shaped (Donahue et al. 1997; Eisner et al. 2001). Consequently, we defined categories of inhaled medication use for the 12 month time period preceding the baseline hospitalization. For medications that are delivered by metered dose inhaler, we defined three categories based on their distribution: no dispensing, low-level dispensing, and high-level dispensing. The low-level and high-level categories were defined using the median among those with any use during the time period. Categories of oral steroid use were defined using the number of prescriptions in an analogous fashion. Because dispensing of medications for nebulizer use and oral leukotriene modifiers were less common, two dichotomous categories were defined: any dispensing versus none.

Study Outcomes: Emergency Utilization for Asthma

The primary study outcomes were ED visits and hospitalization for asthma following baseline hospitalization. These outcomes were chosen because they reflect a severe exacerbation that requires emergency medical care and are generally believed to be preventable (Bindman et al. 1995; Oster and Bindman 2003). Asthma-related hospitalization was defined as one or more hospitalization with a principal discharge diagnosis code for asthma (ICD-9 code 493.xx). Asthma-related ED use was identified as one or more visit with an

ICD-9 code for asthma (493.xx). In contrast to hospital discharge diagnoses, ED visits do not distinguish primary or secondary diagnoses in the Kaiser system.

Sociodemographic Factors and Smoking

For the entire cohort, age, sex, and race were ascertained from computerized KPNC databases. In the interviewed subcohort, a structured telephone interview also assessed additional personal characteristics. Cigarette smoking was measured using questions developed for the National Health Interview Survey (1999). Household income was evaluated as a series of $20,000 increments, with more detailed query for income less than $20,000. Based on the distribution of responses, we defined low-income (<$20,000), intermediate income ($20,000–$60,000), and higher income categories (>$60,000). As in previous studies, we defined educational attainment as high school or less, some college, or college/graduate degree (Eisner et al. 2002).

Asthma Severity

We measured asthma severity using two approaches. In the entire cohort, we ascertained detailed asthma medication dispensing data that can be used to indicate disease severity (Blais, Ernst, and Suissa 1996; Donahue et al. 1997; Eisner et al. 2001). Although asthma medication use can also reflect physician prescribing behavior, previous work indicates that asthma severity is a powerful determinant of asthma medication use (Snyder et al. 2004). Among the interviewed subcohort, we also measured severity-of-asthma with a previously developed and validated 13-item disease-specific severity-of-asthma score based on frequency of current asthma symptoms (daytime or nocturnal), use of systemic corticosteroids, use of other asthma medications (besides systemic corticosteroids), and history of hospitalizations and intubations (Blanc et al. 1993, 1996; Eisner et al. 1998). Possible total scores range from 0 to 28, with higher scores reflecting more severe asthma.

In the interviewed subcohort, we verified that medication dispensing provided adequate control for asthma severity, when compared with the more refined severity-of-asthma score. As shown later in Tables 4 and 5, the hazard ratios (HRs) controlling for asthma medication dispensing and other covariates were not substantially affected by addition of severity-of-asthma score to the model. Consequently, the control for asthma severity in the entire cohort, in which the severity score was not always available, appeared adequate.

Statistical Analysis

Statistical analysis was conducted using *SAS* 8.2 (Cary, NC, USA). Baseline characteristics were analyzed using the *t*-test or analysis of variance (ANOVA) for continuous, normally distributed variables and the χ^2-test for categorical variables. For these baseline comparisons, asthma specialty care was defined using visits during the year preceding baseline hospitalization to provide a comparable assessment for all subjects.

We used the extended Cox model to examine the impact of asthma specialist visits after the baseline hospitalization on the prospective risk of ED visits or hospitalization for asthma (Hosmer and Lemeshow 1999). Asthma specialist visits were defined as time-dependent covariates; visits were only counted if they occurred prior to the subsequent ED visit or hospitalization for asthma. Subjects were censored for death or termination of KPMCP membership. Multivariate Cox regression analysis was used to control for age, sex, race, and asthma medication use in the entire cohort. In the interviewed subcohort, we also controlled for smoking history, household income, educational attainment, and severity-of-asthma score.

We controlled for asthma severity in several ways. First, all subjects were hospitalized for asthma at baseline, ensuring more severe disease. Second, we controlled for age, sex, and race, which are determinants of health status and health care utilization in asthma (Osborne et al. 1998; Sunyer et al. 1998). Third, we controlled for medications that are used for the treatment of asthma, a severity strategy that we previously developed (Eisner et al. 1998, 2001). Fourth, we also controlled for the severity-of-asthma score in the interviewed subcohort.

We used Cox proportional hazards regression analysis to evaluate the prospective impact of specialist visits during the year prior to baseline hospitalization on the subsequent risk of ED visits or hospitalization for asthma. As in the previous analysis, multivariate analysis was used to control for the additional covariates.

To further evaluate the results, we conducted a series of sensitivity analyses. We repeated the multivariate analysis among the most severe adults with asthma, those who were hospitalized with admission to the ICU at baseline. An additional analysis was limited to persons who had KPNC pharmacy coverage, to ensure that there was no effect of incomplete medication ascertainment. To evaluate a "treated" subcohort of asthmatics, we repeated key analyses in the subgroup who had at least one asthma medication dispensed during the previous 12 months. Because asthma severity and medication could

be endogenous variables, we repeated the multivariate analysis in the interviewed subcohort controlling for severity-of-asthma score, but leaving out the medication dispensing variables.

RESULTS

Baseline Subject Characteristics

The overall cohort included 4,742 adult KPMCP members with asthma. The median duration of follow-up was 460 days (25th–75th interquartile range 184–776 days).

Of these subjects, the mean age was 59.2 years and the majority were women (68 percent) (Table 1). Although the majority of subjects were white, there was a substantial representation of other race/ethnic groups (29 percent). Among the interviewed subcohort, the minority indicated current cigarette smoking (10 percent); there was a substantial range of socioeconomic status, as indicated by educational attainment and household income. Based on demographic characteristics, members of the interviewed subcohort were similar to those who were not interviewed.

Treatment by Asthma Specialists during the Year before Baseline Hospitalization

In the overall cohort, 728 adults with asthma were treated by an asthma specialist during the year preceding baseline hospitalization (15.4 percent; 95 percent confidence interval [CI] 14.3–16.4 percent). Allergists were the most common asthma specialists consulted (9.5 percent; 95 percent CI 8.7–10.4 percent), followed by pulmonologists (5.0 percent; 95 percent CI 4.4–5.6 percent) and both allergists and pulmonologists (0.86 percent; 95 percent CI 0.62–1.18 percent), which reflects the pattern of referrals within KPNC.

In the interviewed subcohort, more detailed information was available for subject characteristics and asthma severity. Comparing the subjects treated by asthma specialists to those treated by generalists, there were no significant differences in sociodemographic characteristics, smoking history, or receipt of pharmacy benefits (Table 2). Asthma severity was greatest among subjects who had both allergy and pulmonary visits (mean score 15.7 points), followed by those who had pulmonary visits alone (mean score 14.7 points) and allergist visits alone (mean score 13.9 points) ($p = .04$). Severity-of-asthma scores were lowest among adults with asthma who did not see an asthma specialist (mean score 13.1 points).

Table 2: Physician Specialty and Subject Characteristics (Interviewed Subcohort)

Measure	*Allergist*	*Pulmonologist*	*Both*	*Neither*	*p-Value*
Sample size	72	34	7	483	
Age (mean, SD)	59.5 ± 14.4	59.6 ± 12.5	56.3 ± 15.1	59.8 ± 16.2	
Gender (female)	48 (67%)	19 (56%)	3 (43%)	338 (70%)	.16
Race (white)	52 (72%)	29 (85%)	4 (57%)	337 (70%)	.22
Household income					.99
Lowest income (<$20,000)	9 (12.5%)	4 (12%)	1 (14%)	74 (15%)	
Medium income ($20,000–60,000)	54 (75%)	26 (76%)	5 (72%)	352 (73%)	
Highest income ($60,000+)	9 (12.5%)	4 (12%)	1 (14%)	57 (12%)	
Educational attainment					.94
High school or less	15 (21%)	9 (26%)	2 (29%)	123 (25%)	
Some college	38 (53%)	19 (56%)	4 (57%)	249 (52%)	
College graduate or higher	19 (26%)	6 (18%)	1 (14%)	111 (23%)	
Cigarette smoking history					.38
Ex-smoker	38 (53%)	25 (74%)	4 (57%)	267 (55%)	
Current smoker	6 (8%)	2 (6%)	0 (0%)	53 (11%)	
Severity-of-asthma score	13.9 ± 4.3	14.7 ± 5.2	15.7 ± 3.4	13.1 ± 4.3	
Pharmacy benefits	60 (83%)	28 (82%)	6 (86%)	404 (84%)	.99

Data are presented as *N* (%) or mean (SD)

Among the entire cohort, asthma specialist visits were associated with a greater likelihood of the dispensing of all asthma medication classes (Table 3, $p<.001$). Reflecting the individual medication dispensing patterns, the proportion of adults with asthma who received at least one asthma medication from a Kaiser pharmacy was higher among those receiving care from an allergist (95 percent), pulmonologist (97 percent), or both (98 percent), compared with no specialist care (83 percent) ($p<.0001$).

Asthma Specialist Visits and the Risk of ED Use

A substantial proportion of the overall cohort and the interviewed subcohort had an ED visit for asthma during prospective followup (1,111/4,752 or 23 percent and 200/596 or 34 percent, respectively). In the overall cohort, there was little evidence that specialist visits after baseline hospitalization reduced the subsequent risk of ED visits for asthma during longitudinal follow-up. Compared with subjects who received no specialist visits, treatment by allergists (HR 1.04; 95 percent CI 0.87–1.26) or pulmonologists (HR 0.92; 95 percent CI 0.71–1.19) was not associated with a reduction in the risk of future

Table 3: Physician Specialty and Medication Dispensing during the Year Prior to Hospitalization (Entire Cohort)

	Allergist	*Pulmonologist*	*Both*	*Neither*	*p-Value*
Sample size	452	235	41	4,014	
Inhaled corticosteroids					<.0001
None	52 (12%)	45 (19%)	5 (12%)	1,496 (37%)	
Lower level	127 (28%)	70 (30%)	14 (34%)	1,405 (35%)	
Higher level	273 (60%)	120 (51%)	22 (54%)	1,113 (28%)	
Inhaled β-agonists					<.0001
None	92 (20%)	62 (26%)	5 (12%)	1,387 (35%)	
Lower level	159 (35%)	71 (30%)	12 (29%)	1,405 (35%)	
Higher level	201 (45%)	102 (44%)	24 (59%)	1,222 (30%)	
Long-acting inhaled β-agonists					<.0001
None	219 (48%)	160 (68%)	12 (29%)	3,382 (84%)	
Lower level	116 (26%)	41 (17%)	16 (39%)	359 (9%)	
Higher level	117 (26%)	34 (15%)	13 (32%)	273 (7%)	
Oral corticosteroids					<.0001
None	127 (28%)	78 (33%)	7 (17%)	2,123 (53%)	
Lower level	142 (31%)	58 (25%)	10 (24%)	1,168 (29%)	
Higher level	183 (41%)	99 (42%)	24 (59%)	723 (18%)	
Inhaled anticholinergics					<.0001
None	329 (73%)	159 (68%)	28 (68%)	3,309 (83%)	
Lower level	70 (15%)	32 (13%)	9 (22%)	407 (10%)	
Higher level	53 (12%)	44 (19%)	4 (10%)	298 (7%)	
Combined anticholinergic/ β-agonist					<.0001
None	400 (88%)	190 (81%)	33 (81%)	3,566 (89%)	
Lower level	30 (7%)	20 (8%)	1 (2%)	246 (6%)	
Higher level	22 (5%)	25 (11%)	7 (17%)	202 (5%)	
Oral methylxanthines	70 (15%)	31 (13%)	7 (17%)	328 (8%)	<.0001
Any medication by nebulizer	218 (48%)	113 (48%)	29 (71%)	938 (23%)	<.0001
Leukotriene modifiers	102 (23%)	35 (15%)	19 (46%)	229 (6%)	<.0001
Any asthma medication	431 (95%)	227 (97%)	40 (98%)	3,313 (83%)	<.0001
Pharmacy benefits	377 (83%)	195 (83%)	34 (83%)	3,287 (82%)	.85

ED visits for asthma, controlling for age, sex, race, asthma medication dispensing during the year preceding baseline hospitalization, and pharmacy benefits status (Table 4). Treatment by both allergists and pulmonologists was associated with a reduced risk of subsequent ED visits for asthma (HR 0.37; 95 percent CI 0.19–0.69). In the subcohort who completed telephone interviews, there was no indication that visits to an allergist (HR 1.37; 95 percent CI 0.88–2.13), pulmonologist (HR 0.81; 95 percent CI 0.45–1.48), or both (HR 0.75; 95 percent CI 0.27–2.09) reduced the risk of ED visits, controlling for the same

covariates plus additional sociodemographic measures, smoking history, and the severity-of-asthma score. When asthma specialist visits were defined during the year preceding baseline hospitalization, there was also no reduction in the longitudinal risk of ED visits (Table 4).

Asthma Specialist Visits and the Risk of Hospitalization for Asthma

A notable proportion of the overall cohort (958/4,742 or 20 percent) and the interviewed subcohort (159/596 or 27 percent) experienced hospitalization during longitudinal follow-up. We examined the impact of asthma specialist visits following the baseline hospitalization, defined as time-dependent covariates, on the prospective risk of hospitalization for asthma. In the overall cohort, there was no association between allergist visits and the risk of future hospitalization, controlling for covariates (HR 0.93; 95 percent CI 0.75–1.14) (Table 5). In contrast, visits to pulmonologists (HR 0.74; 95 percent CI 0.55–0.99) or to both an allergist and pulmonologist (HR 0.52; 95 percent CI 0.29–0.93) were related to a reduced risk of rehospitalization. When the interviewed subcohort was examined, treatment by allergists (HR 1.11; 95 percent CI 0.67–1.84), pulmonologists (HR 0.76; 95 percent CI 0.41–1.41), or both (HR 0.48; 95 percent CI 0.15–1.57) was not associated with the risk of subsequent hospitalization for asthma, controlling for asthma severity and the other covariates.

When asthma specialist visits were defined during the year preceding baseline hospitalization, there was no clear evidence that asthma specialist visits reduced the risk of future hospitalizations during prospective follow-up. Compared with subjects who received care from generalists only, visits to allergists (HR 1.14; 95 percent CI 0.94–1.39), pulmonologists (HR 0.85; 95 percent CI 0.63–1.14), or both (HR 1.34; 95 percent CI 0.84–2.13) were not associated with the risk of rehospitalization for asthma, controlling for covariates (Table 5). In the interviewed subcohort, treatment by pulmonologists was associated with a reduced risk of rehospitalization (HR 0.47; 95 percent CI 0.21–1.06), controlling for the additional sociodemographic measures, smoking history, and severity of asthma score; the risk estimate did not, however, exclude no effect. There was also no relation between treatment by allergists (HR 1.03; 95 percent CI 0.63–1.66) or both allergy and pulmonary specialists (HR 0.48; 95 percent CI 0.11–2.20) and the risk of subsequent asthma hospitalization. When we examined the joint outcome of ED visits or hospitalization for asthma, the pattern of results was similar (Table 6).

Table 4: Asthma Specialist Visits and the Longitudinal Risk of Emergency Department Visits for Asthma

	Entire Cohort			*Interviewed Subcohort*			
Specialty	*Unadjusted*	*Model 1*	*Model 2*	*Unadjusted*	*Model 1*	*Model 2*	*Model 3*
After baseline hospitalization*							
None (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)
Allergist	1.38 (1.15–1.66)	1.25 (1.04–1.50)	1.04 (0.87–1.26)	1.52 (1.01–2.28)	1.37 (0.90–2.08)	1.16 (0.76–1.78)	1.37 (0.88–2.13)
	0.0006	0.019	0.65	0.05	0.14	0.49	0.16
Pulmonologist	1.09 (0.84–1.41)	1.13 (0.87–1.46)	0.92 (0.71–1.19)	0.97 (0.54–1.71)	1.01 (0.57–1.79)	0.82 (0.45–1.48)	0.81 (0.45–1.48)
	0.51	0.35	0.52	0.90	0.98	0.51	0.50
Both	0.55 (0.30–1.04)	0.52 (0.28–0.98)	0.37 (0.19–0.69)	1.04 (0.38–2.81)	1.00 (0.37–2.71)	0.74 (0.27–2.05)	0.75 (0.27–2.09)
	0.07	0.042	0.0018	0.94	1.0	0.56	0.59
During the year prior to baseline hospitalization*							
None (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)
Allergist	1.81 (1.53–2.13)	1.74 (1.47–2.05)	1.26 (1.06–1.51)	1.45 (0.98–2.13)	1.44 (0.98–2.12)	1.13 (0.74–1.72)	1.16 (0.76–1.77)
	<0.0001	<.0001	0.01	0.06	0.07	0.58	0.48
Pulmonologist	1.25 (0.96–1.62)	1.34 (1.03–1.73)	1.06 (0.81–1.38)	0.91 (0.50–1.69)	0.99 (0.53–1.83)	0.79 (0.42–1.49)	0.78 (0.41–1.50)
	0.09	0.03	0.68	0.77	0.97	0.47	0.46
Both	1.90 (1.17–3.07)	1.78 (1.10–2.87)	1.08 (0.66–1.78)	2.56 (0.96–6.92)	3.09 (1.12–8.53)	2.77 (0.84–9.15)	3.30 (1.02–10.7)
	0.009	0.02	0.75	0.06	0.03	0.09	0.05

Hazard ratio (95% CI) and *p*-value.

Model 1 controls for age, sex, race, pharmacy benefits status.

Model 2 controls for age, sex, race, pharmacy benefits status, asthma medication dispensing.

Model 3 controls for age, sex, race, pharmacy benefits status, asthma medication dispensing, smoking history, educational attainment, income, severity-of-asthma score.

*First analysis defines asthma specialist visits after baseline hospitalization as a time-dependent covariate; second analysis defines specialist visits during the year preceding baseline hospitalization.

Table 5: Asthma Specialist Visits and the Longitudinal Risk of Rehospitalization for Asthma

	Entire Cohort			*Interviewed Subcohort*			
Specialty	*Unadjusted*	*Model 1*	*Model 2*	*Unadjusted*	*Model 1*	*Model 2*	*Model 3*
After baseline hospitalization*							
None (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)
Allergist	1.20 (0.98–1.48)	1.13 (0.92–1.39)	0.93 (0.75–1.14)	1.29 (0.81–2.06)	1.25 (0.79–2.00)	0.95 (0.58–1.56)	1.11 (0.67–1.84)
	0.08	0.24	0.47	0.28	0.34	0.84	0.69
Pulmonologist	0.89 (0.67–1.19)	0.90 (0.67–1.19)	0.74 (0.55–0.99)	0.96 (0.53–1.72)	0.96 (0.54–1.73)	0.78 (0.43–1.44)	0.76 (0.41–1.41)
	0.44	0.45	0.041	0.88	0.90	0.43	0.38
Both	0.78 (0.44–1.38)	0.74 (0.42–1.32)	0.52 (0.29–0.93)	0.75 (0.24–2.38)	0.78 (0.24–2.46)	0.44 (0.14–1.43)	0.48 (0.15–1.57)
	0.39	0.31	0.028	0.63	0.67	0.17	0.24
During the year prior to baseline hospitalization*							
None (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)
Allergist	1.62 (1.35–1.94)	1.57 (1.31–1.88)	1.14 (0.94–1.39)	1.36 (0.88–2.09)	1.36 (0.88–2.10)	0.88 (0.54–1.42)	1.03 (0.63–1.66)
	<0.0001	<.0001	0.19	0.16	0.16	0.60	0.92
Pulmonologist	1.08 (0.81–1.44)	1.10 (0.82–1.47)	0.85 (0.63–1.14)	0.60 (0.28–1.30)	0.63 (0.29–1.35)	0.47 (0.21–1.05)	0.47 (0.21–1.06)
	0.62	0.53	0.29	0.20	0.23	0.06	0.07
Both	2.65 (1.70–4.13)	2.45 (1.57–3.82)	1.34 (0.84–2.13)	1.29 (0.32–5.23)	1.26 (0.31–5.17)	0.49 (0.11–2.28)	0.48 (0.11–2.20)
	<0.0001	0.0001	0.22	0.72	0.75	0.37	0.35

Hazard ratio (95% CI) and p value.

Model 1 controls for age, sex, race, pharmacy benefits status.

Model 2 controls for age, sex, race, pharmacy benefits status, asthma medication dispensing.

Model 3 controls for age, sex, race, pharmacy benefits status, asthma medication dispensing, smoking history, educational attainment, income, severity-of-asthma score.

*First analysis defines asthma specialist visits after baseline hospitalization as a time-dependent covariate; second analysis defines specialist visits during the year preceding baseline hospitalization.

Table 6: Asthma Specialist Visits and the Longitudinal Risk of Either ED Visit or Rehospitalization for Asthma

	Entire Cohort			*Interviewed Subcohort*			
Specialty	*Unadjusted*	*Model 1*	*Model 2*	*Unadjusted*	*Model 1*	*Model 2*	*Model 3*
After baseline hospitalization*							
None (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)
Allergist	1.25 (1.05–1.48)	1.14 (0.96–1.35)	0.94 (0.79–1.12)	1.32 (0.89–1.95)	1.26 (0.85–1.88)	1.02 (0.67–1.53)	1.19 (0.78–1.82)
	0.011	0.13	0.50	0.16	0.24	0.94	0.41
Pulmonologist	1.00 (0.80–1.26)	1.02 (0.81–1.28)	0.83 (0.65–1.04)	0.78 (0.45–1.36)	0.81 (0.47–1.41)	0.70 (0.40–1.22)	0.65 (0.37–1.16)
	0.9894	0.8883	0.1095	0.3883	0.4592	0.2087	0.1457
Both	0.44 (0.23–0.84)	0.41 (0.21–0.80)	0.28 (0.15–0.55)	0.84 (0.31–2.26)	0.81 (0.30–2.19)	0.48 (0.17–1.33)	0.53 (0.19–1.49)
	0.014	0.008	0.0002	0.73	0.67	0.16	0.23
During the year prior to baseline hospitalization*							
None (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)	1.0 (referent)
Allergist	1.63 (1.40–1.89)	1.57 (1.35–1.82)	1.12 (0.95–1.31)	1.34 (0.94–1.91)	1.33 (0.93–1.89)	0.95 (0.64–1.40)	1.02 (0.69–1.50)
	<0.0001	<0.0001	0.1765	0.1091	0.1219	0.7809	0.9375
Pulmonologist	1.13 (0.90–1.43)	1.18 (0.93–1.49)	0.92 (0.72–1.16)	0.74 (0.41–1.33)	0.78 (0.43–1.40)	0.64 (0.35–1.18)	0.61 (0.33–1.13)
	0.29	0.17	0.48	0.32	0.40	0.15	0.12
Both	1.99 (1.32–3.01)	1.83 (1.21–2.77)	0.98 (0.64–1.51)	1.89 (0.70–5.08)	2.14 (0.78–5.87)	1.20 (0.37–3.86)	1.48 (0.47–4.66)
	0.0011	0.004	0.94	0.21	0.14	0.76	0.51

Hazard ratio (95% CI) and *p* value.

Model 1 controls for age, sex, race, pharmacy benefits status.

Model 2 controls for age, sex, race, pharmacy benefits status, asthma medication dispensing.

Model 3 controls for age, sex, race, pharmacy benefits status, asthma medication dispensing, smoking history, educational attainment, income, severity-of-asthma score.

*First analysis defines asthma specialist visits after baseline hospitalization as a time-dependent covariate; second analysis defines specialist visits during the year preceding baseline hospitalization.

Sensitivity Analysis

To further evaluate the results, we conducted a series of sensitivity analyses among the entire cohort. We repeated the multivariate analysis among the most severe asthmatics, those who were hospitalized with admission to the ICU at baseline ($n = 485$). There was no association between visits to allergists (HR 1.23; 95 percent CI 0.64–2.35) or pulmonologists (HR 0.75; 95 percent CI 0.33–1.67) and the risk of rehospitalization for asthma. An additional analysis was limited to persons who had KPNC pharmacy coverage, to ensure that there was no effect of incomplete medication ascertainment ($n = 3{,}893$). There was also no impact of allergy specialty care and the risk of future hospitalization (HR 0.92; 95 percent CI 0.74–1.15); pulmonary care was associated with decreased risk, as in the primary analysis (HR 0.73; 95 percent CI 0.54–0.99). To evaluate a "treated" subcohort of asthmatics, we repeated key analyses in the subgroup who had at least one asthma medication dispensed during the previous 12 months ($n = 4{,}011$). Allergy and pulmonary physician care were not related to the risk of subsequent hospitalization for asthma (HR 0.95; 95 percent CI 0.76–1.17 and HR 0.72; 95 percent CI 0.54–0.98, respectively).

Because asthma severity and medication dispensing could be endogenous variables, we repeated the multivariate analysis in the interviewed subcohort after controlling for severity-of-asthma score, but excluding the medication variables. As in the primary analyses, there was no association between allergy specialty care and the risk of subsequent hospitalization (HR 1.42; 95 percent CI 0.88–2.28). Pulmonary specialty visits during the year prior to baseline appeared to be associated with decreased hospitalization risk (HR 0.49; 95 percent CI 0.22–1.06), which was highly similar to the primary analysis.

DISCUSSION

Because asthma specialists appear to follow the national asthma guidelines more closely, we hypothesized that allergy or pulmonary specialty care would reduce the risk of a severe asthma exacerbation requiring emergency health care utilization. In a large cohort of managed care organization members, we found some evidence that treatment by a pulmonologist reduced the risk of rehospitalization for asthma. In the entire cohort, pulmonary specialist visits after baseline hospitalization appeared to reduce the risk of rehospitalization. The estimate of benefit was similar in the interviewed subcohort after

additional control for severity-of-asthma score, but the CI was wider because of the smaller sample size. In the secondary analysis, pulmonary visits before baseline hospitalization appeared to reduce hospitalization in the interviewed subcohort only. This latter analysis, which ensures an equal "opportunity" for all subjects to have had a specialist visit, is more conservative and could underestimate the benefit. Finally, there was no evidence that pulmonary specialist visits reduced the risk of ED visits for asthma. Taken together, pulmonary specialist visits probably reduce the risk of emergency asthma utilization.

There was no evidence that allergist visits reduced the risk of ED visits or hospitalization for asthma. Visits to both allergy and pulmonary specialists reduced the risk of ED visits in some, but not all, analyses. Taken together, allergy specialist care did not appear to substantially reduce the risk of severe asthma exacerbation among members of a large managed care organization that provides comprehensive prepaid medical care. Although the reasons for the possible differential benefit of pulmonary and allergy care were not determined by this study, it could reflect unmeasured differences in practice style, such as use of objective assessment by spirometry or peak expiratory flow monitoring.

Asthma specialist care may have had less benefit than in previous studies because the NAEPP guidelines have now had 12 years to be widely disseminated. In addition, KPNC has made its own intensive efforts to develop and disseminate asthma clinical practice guidelines to primary care physicians in order to improve asthma care quality. KPNC has also implemented an asthma population management system that screens asthma patients and stratifies them by severity, level of disease control, and risk for future health care utilization. Asthma care managers, who are respiratory therapists, registered nurses, nurse practitioners, or clinical pharmacists, track high risk patients, provide direct care, and refer to asthma specialists within a chronic disease management model. Consequently, the modest association between asthma specialist visits and subsequent asthma outcomes may reflect the regional efforts to improve asthma treatment provided in primary care.

Our study is one of the largest of its kind and included a diverse population with respect to race/ethnicity and socioeconomic status. Using the KPNC centralized computer databases enabled a comprehensive account of medication dispensing and asthma-related health outcomes that included ED visits and hospitalizations. In contrast, previous studies that have compared specialist and generalist asthma care have generally used survey responses to determine medication use and health outcomes (Vollmer et al. 1997; Wu et al. 2001). In addition, we performed a more detailed assessment of asthma

severity and socioeconomic status among the interviewed subcohort, allowing more rigorous statistical control for these potentially confounding variables.

Our study has several limitations. At the study's inception, we understood that there would be confounding by severity of disease. Patients who are referred to asthma specialists are likely to have more severe asthma (Eisner et al. 1998). We attempted to control for severity of asthma both in the study design, by limiting study enrollment to those subjects who were hospitalized, and in analysis, by controlling for medication use, sociodemographic factors, and severity-of-asthma score in the multivariate analysis. Because the risk estimates tended to decrease when we controlled for these variables, there appeared to be reduction in confounding. However, residual confounding is still likely. This may explain the results of the analysis that found an apparent increased risk of ED visits among subjects who were treated by allergists. The net effect of such residual confounding would generally be to underestimate the benefits of specialty care.

Another limitation of our study is that our results may not generalize to other health care settings or practices. The managed care organization we selected for our study provides comprehensive prepaid health care and has made specific regional efforts to improve the quality of asthma care. In another health care setting, the quality of asthma care provided by primary care physicians may be lower, thus making asthma specialist care more valuable. The results may also not generalize to other health care settings in which specialist referral increases access to asthma care in general, rather than providing care that is supplementary to adequate primary care (Mayo et al. 1990; Zeiger et al. 1991). Consequently, our results may represent the lower bound on the potential benefit of specialty care. Supporting this contention, previous studies have shown even greater effects of specialty care on quality of life (Vollmer et al. 1997; Wu et al. 2001). Although KPNC provides care to patients of diverse race/ethnicity, we lacked the statistical power to evaluate the differential impact of specialty care on these subgroups. Other limitations include the lack of longitudinal information on health-related quality of life and other patient-centered outcomes. Our study was designed to evaluate the impact of specialty care on future health care utilization outcomes, but our results could have missed a more subtle benefit. In addition, it was not possible to control for some more subtle factors that could affect a patient's ability to attend specialist visits, such as flexibility of work schedule and distance to the provider.

We cannot exclude some misclassification of asthma and chronic obstructive pulmonary disease (COPD). A minority of subjects did carry concomitant diagnostic codes consistent with COPD (33 percent). This diagnostic

overlap is well known, and reflects the difficulties inherent in distinguishing asthma and COPD, particularly in older adults (Dodge, Cline, and Burrows 1986; Enarson et al. 1987; McWhorter, Polis, and Kaslow 1989). It has not been possible to completely separate the two conditions, both in clinical practice and research studies. Excluding older adults, however, would severely limit the results, as older asthmatics have the highest disease severity and risk of death from asthma (Burrows et al. 1991; Enright et al. 1999). National data indicate that more than 50 percent of asthma deaths occurred among adults aged 65 years or older (Mannino et al. 1998). To mitigate against misclassification with COPD, we used a systematic approach that was consistent with previous studies using ICD-9 discharge diagnoses to define persons hospitalized for asthma (Krieger 1992; Spitzer et al. 1992; Lieu et al. 1999; Eisner et al. 2001). In addition, all subjects in the interviewed subcohort study reported a physician's diagnosis of asthma, which is a standard epidemiologic tool for identifying asthma cases (Toraen, Brisman, and Jearvholm 1993). Our validation study, which included randomly selected members of the overall and interviewed cohorts, strongly supported the diagnosis of asthma: 99 percent of subjects had a physician's diagnosis of asthma recorded in the medical record; the remaining one subject had "reactive airways disease," which is consistent with asthma. Taken together, we believe that our results are applicable to adults with asthma treated in a managed care organization.

Although we found only modest evidence that asthma specialist visits may improve outcomes, we believe that specialists may still play a critical role in managing asthma. In particular, asthma specialists play a central role in developing clinical practice guidelines and educating primary care physicians about the appropriate management of asthma. Moreover, specialists may provide benefit in selected cases in which clinical response to therapy is inadequate or there are other comorbid health conditions. In clinical settings that do not have a systematic screening and intervention program for asthma, asthma specialists may provide additional direct clinical benefit over primary care. Further studies are needed to define the optimal role of asthma specialists in different clinical and health care delivery environments.

ACKNOWLEDGMENTS

Dr. Eisner was supported by K23 HL04201, National Heart, Lung, and Blood Institute, National Institutes of Health, with cofunding by the Social Security Administration.

REFERENCES

Bindman, A. B., K. Grumbach, D. Osmond, M. Komaromy, K. Vranizan, N. Lurie, J. Billings, and A. Stewart. 1995. "Preventable Hospitalizations and Access to Health Care." *Journal of the American Medical Association* 274 (4): 305–11.

Blais, L., P. Ernst, and S. Suissa. 1996. "Confounding by Indication and Channeling Over Time: The Risks of Beta 2-Agonists." *American Journal of Epidemiology* 144 (12): 1161–9.

Blanc, P. D., M. Cisternas, S. Smith, and E. Yelin. 1996. "Occupational Asthma in a Community-Based Survey of Adult Asthma." *Chest* 109 (3, suppl): 56S–7S.

Blanc, P. D., M. Jones, C. Besson, P. Katz, and E. Yelin. 1993. "Work Disability among Adults with Asthma." *Chest* 104 (5): 1371–7.

Brunner, E. J., H. Wunsch, and M. G. Marmot. 2001. "What Is an Optimal Diet?" *International Journal of Obesity Related Metabolic Disorders* 25 (1): 45–53.

Burrows, B., R. A. Barbee, M. G. Cline, R. J. Knudson, and M. D. Lebowitz. 1991. "Characteristics of Asthma among Elderly Adults in a Sample of the General Population." *Chest* 100 (4): 935–42.

Carr, W., L. Zeitel, and K. Weiss. 1992. "Variations in Asthma Hospitalizations and Deaths in New York City." *American Journal of Public Health* 82 (1): 59–65.

Diette, G. B., E. A. Skinner, T. T. Nguyen, L. Markson, B. D. Clark, and A. W. Wu. 2001. "Comparison of Quality of Care by Specialist and Generalist Physicians as Usual Source of Asthma Care for Children." *Pediatrics* 108 (2): 432–7.

Dodge, R., M. G. Cline, and B. Burrows. 1986. "Comparisons of Asthma, Emphysema, and Chronic Bronchitis Diagnoses in a General Population Sample." *American Review of Respiratory Disease* 133 (6): 981–6.

Donahue, J. G., S. T. Weiss, J. M. Livingston, M. A. Goetsch, D. K. Greineder, and R. Platt. 1997. "Inhaled Steroids and the Risk of Hospitalization for Asthma." *Journal of the American Medical Association* 277 (11): 887–91.

Eisner, M. D., P. P. Katz, E. H. Yelin, J. Henke, S. Smith, and P. D. Blanc. 1998. "Assessment of Asthma Severity in Adults with Asthma Treated by Family Practitioners, Allergists, and Pulmonologists." *Medical Care* 36 (11): 1567–77.

Eisner, M. D., T. A. Lieu, F. Chi, A. Capra, G. Mendoza, and P. D. Blanc. 2001. "Beta Agonists, Inhaled Steroids, and the Risk of Intensive Care Unit Admission for Asthma." *European Respiratory Journal* 17: 233–40.

Eisner, M. D., E. H. Yelin, L. Trupin, and P. D. Blanc. 2002. "The Influence of Chronic Respiratory Conditions on Health Status and Work Disability." *American Journal of Public Health* 92 (9): 1506–13.

Enarson, D. A., S. Vedal, M. Schulzer, A. Dybuncio, and M. Chan-Yeung. 1987. "Asthma, Asthmalike Symptoms, Chronic Bronchitis, and the Degree of Bronchial Hyperresponsiveness in Epidemiologic Surveys." *American Review of Respiratory Disease* 136 (3): 613–7.

Engel, W., D. A. Freund, J. S. Stein, and R. H. Fletcher. 1989. "The Treatment of Patients with Asthma by Specialists and Generalists." *Medical Care* 27 (3): 306–14.

Enright, P. L., R. L. McClelland, A. B. Newman, D. J. Gottlieb, and M. D. Lebowitz. 1999. "Underdiagnosis and Undertreatment of Asthma in the Elderly." *Chest* 116 (3): 603–13.

Frieri, M., J. Therattil, D. Dellavecchia, S. Rockitter, J. Pettit, and M. Zitt. 2002. "A Preliminary Retrospective Treatment and Pharmacoeconomic Analysis of Asthma Care Provided by Allergists, Immunologists, and Primary Care Physicians in a Teaching Hospital." *Journal of Asthma* 39 (5): 405–12.

Hosmer, D. W., and S. Lemeshow. 1999. *Applied Survival Analysis.* New York: John Wiley & Sons.

Karter, A. J., A. Ferrara, J. Y. Liu, H. H. Moffet, L. M. Ackerson, and J. V. Selby. 2002. "Ethnic Disparities in Diabetic Complications in an Insured Population." *Journal of the American Medical Association* 287 (19): 2519–27.

Krieger, N. 1992. "Overcoming the Absence of Socioeconomic Data in Medical Records: Validation and Application of a Census-Based Methodology." *American Journal of Public Health* 82 (5): 703–10.

Legorreta, A. P., J. Christian-Herman, R. D. O'Connor, M. M. Hasan, R. Evans, and K. M. Leung. 1998. "Compliance with National Asthma Management Guidelines and Specialty Care: A Health Maintenance Organization Experience." *Archives of Internal Medicine* 158 (5): 457–64.

Lieu, T. A., A. M. Capra, C. P. Quesenberry, G. R. Mendoza, and M. Mazar. 1999. "Computer-Based Models to Identify High-Risk Adults with Asthma: Is the Glass Half Empty of Half Full?" *Journal of Asthma* 36 (4): 359–70.

Mahr, T. A., and R. Evans. 1993. "Allergist Influence on Asthma Care." *Annals of Allergy* 71 (2): 115–20.

Mannino, D. M., D. M. Homa, L. J. Akinbami, J. E. Moorman, C. Gwynn, and S. C. Redd. 2002. "Surveillance for Asthma—United States." *Morbidity and Mortality Weekly Report. CDC Surveillance Summaries* 51 (SS-1): 1–13.

Mannino, D. M., D. M. Homa, C. A. Pertowski, A. Ashizawa, L. L. Nixon, C. A. Johnson, L. B. Ball, E. Jack, and D. S. Kang. 1998. "Surveillance for Asthma—United States." *Morbidity and Mortality Weekly Report. CDC Surveillance Summaries* 47 (1): 1–27.

Mayo, P. H., J. Richman, and H. W. Harris. 1990. "Results of a Program to Reduce Admissions for Adult Asthma." *Annals of Internal Medicine* 112 (11): 864–71.

McWhorter, W. P., M. A. Polis, and R. A. Kaslow. 1989. "Occurrence, Predictors, and Consequences of Adult Asthma in NHANESI and Follow-up Survey." *American Review of Respiratory Disease* 139 (3): 721–4.

Meng, Y. Y., K. M. Leung, D. Berkbigler, R. J. Halbert, and A. P. Legorreta. 1999. "Compliance with US Asthma Management Guidelines and Specialty Care: A Regional Variation or National Concern?" *Journal of Evaluation and Clinical Practice* 5 (2): 213–21.

National Asthma Education and Prevention Program (NAEPP). 1991. "Guidelines for the Diagnosis and Management of Asthma. National Heart, Lung, and Blood Institute. National Asthma Education Program. Expert Panel Report." *Journal of Allergy and Clinical Immunology* 88 (3, Part 2): 425–534.

———. 1997. *Expert Panel 2:Guidelines for the Diagnosis and Management of Asthma.* Bethesda, MD: U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health, National Heart, Lung and Blood Institute.

———. 1999. "Cigarette Smoking among Adults—United States, 1997." *Morbidity and Mortality Weekly Report* 48 (43): 993–6.

———. 2002. "National Asthma Education and Prevention Program. Expert Panel Report: Guidelines for the Diagnosis and Management of Asthma Update on Selected Topics—2002." *Journal of Allergy and Clinical Immunology* 110 (5, suppl): S141–219.

Osborne, M. L., W. M. Vollmer, K. L. Linton, and A. S. Buist. 1998. "Characteristics of Patients with Asthma within a Large HMO: A Comparison by Age and Gender." *American Journal of Respiratory and Critical Care Medicine* 157 (1): 123–8.

Oster, A., and A. B. Bindman. 2003. "Emergency Department Visits for Ambulatory Care Sensitive Conditions: Insights into Preventable Hospitalizations." *Medical Care* 41 (2): 198–207.

Snyder, L., P. D. Blanc, P. P. Katz, E. H. Yelin, and M. D. Eisner. 2004. "Leukotriene Modifier Use and Asthma Severity: How Is a New Medication Being Used by Adults with Asthma?" *Archives of Internal Medicine* 164 (6): 617–22.

Sperber, K., H. Ibrahim, B. Hoffman, B. Eisenmesser, H. Hsu, and B. Corn. 1995. "Effectiveness of a Specialized Asthma Clinic in Reducing Asthma Morbidity in an Inner-City Minority Population." *Journal of Asthma* 32 (5): 335–43.

Spitzer, W. O., S. Suissa, P. Ernst, R. I. Horwitz, B. Habbick, D. Cockcroft, J. F. Boivin, M. McNutt, A. S. Buist, and A. S. Rebuck. 1992. "The Use of Beta-Agonists and the Risk of Death and Near Death from Asthma." *New England Journal of Medicine* 326 (8): 501–6.

Storms, B., L. Olden, R. Nathan, and S. Bodman. 1995. "Effect of Allergy Specialist Care on the Quality of Life in Patients with Asthma." *Annals of Allergy and Asthma Immunology* 75 (6, Part 1): 491–4.

Sunyer, J., J. M. Anto, D. McFarlane, A. Domingo, A. Tobias, M. A. Barcelo, and A. Munoz. 1998. "Sex Differences in Mortality of People Who Visited Emergency Rooms for Asthma and Chronic Obstructive Pulmonary Disease." *American Journal of Respiratory and Critical Care Medicine* 158 (3): 851–6.

Toraen, K., J. Brisman, and B. Jearvholm. 1993. "Asthma and Asthma-like Symptoms in Adults Assessed by Questionnaires. A Literature Review." *Chest* 104 (2): 600–8.

Vollmer, W. M., M. O'Hollaren, K. M. Ettinger, T. Stibolt, J. Wilkins, A. S. Buist, K. L. Linton, and M. L. Osborne. 1997. "Specialty Differences in the Management of Asthma. A Cross-Sectional Assessment of Allergists' Patients and Generalists' Patients in a Large HMO." *Archives of Internal Medicine* 157 (11): 1201–8.

Wu, A. W., Y. Young, E. A. Skinner, G. B. Diette, M. Huber, A. Peres, and D. Steinwachs. 2001. "Quality of Care and Outcomes of Adults with Asthma Treated by Specialists and Generalists in Managed Care." *Archives of Internal Medicine* 161 (21): 2554–60.

Zeiger, R. S., S. Heller, M. H. Mellon, J. Wald, R. Falkoff, and M. Schatz. 1991. "Facilitated Referral to Asthma Specialist Reduces Relapses in Asthma Emergency Room Visits." *Journal of Allergy and Clinical Immunology* 87 (6): 1160–8.