

ORIGINAL ARTICLE

Seasonal Variation in Asthma-Related Hospital and Intensive Care Unit Admissions

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Seasonal trends in asthma-related hospitalizations are widely recognized; however, little is known about trends in asthma-related intensive care unit (ICU) admissions or intubations. The objective of this study is to examine monthly rates of asthma-related ICU admissions and/or intubations as a percent of total asthma-related admissions and to identify seasonality. This analysis was performed in a database of 285 hospitals representing > 3 million annual inpatient visits. Asthma-related hospital admissions for patients aged 5 and older were identified with a primary diagnosis of asthma (493.xx) during calendar years 2001–2002. The percents of the total admissions per month were compared. Monthly means were calculated and data were presented as moving averages. A total of 76,916 hospital admissions were identified with a primary diagnosis of asthma. Just over 10% (n = 7,803) were admitted to the ICU and/or intubated, with the majority among patients > 35 years of age (>70%). A peak in asthma-related hospitalizations occurred in the winter months (10.3%) and a nadir in the summer months (5.9%; $p < 0.004$) with similar trends for ICU admissions. Despite this finding, ICU admissions and intubations remained relatively constant as a percent of total asthma-related hospitalizations, ranging from 9.2 to 10.9% and did not dip during the summer months when the overall asthma-related hospitalization rates were lowest. Significant differences in seasonal variation were also noted by age group and by region, but not by gender. These findings suggest a need for year-round vigilance and improved compliance with asthma therapy, especially during the summer when asthma attacks are perceived to be infrequent.

Keywords asthma, seasonal trends, seasonality, hospitalization, intensive care units, intubation

INTRODUCTION

Asthma is one of the most common chronic conditions in the United States, affecting > 26 million Americans (1, 2). Despite numerous advances in diagnosis and treatment (3), asthma is responsible for 10 million missed school days, > 1.5 million emergency room visits, approximately 500,000 hospitalizations, and 5,000 deaths each year (1, 2). In addition, because of its high prevalence and significant morbidity, asthma represents a tremendous burden to society with annual costs estimated to be \$12.7 billion, with approximately \$7.4 billion being direct medical costs. Of these direct medical expenditures, around 29% are related to hospital care (4).

Asthma, like other conditions, such as influenza, myocardial infarction, and cerebrovascular accidents, shows a seasonal pattern (5). Some of the potential factors that may be contributing to the seasonal pattern in asthma morbidity include changes in temperature; seasonal patterns of viral infections; variation in tree, grass and weed pollen counts; and fluctuations in the amount of fungal spores and house dust mites (5, 6). Seasonality is reflected in the incidence of

asthma attacks, in admissions to hospitals and emergency rooms, and in asthma mortality rates (7). Several studies have recognized the seasonal patterns in asthma-related hospitalizations and mortality, and results indicate an increase in hospital admissions during the winter months and higher mortality rates during the summer months (5–12).

Seasonal trends in asthma-related hospitalizations are widely recognized; however, little is known about trends in asthma-related intensive care unit (ICU) admissions or intubations. To our knowledge, there is no published evidence regarding the seasonal variation in ICU admissions or intubations associated with asthma. The clear recognition and better understanding of seasonality of asthma hospitalizations and ICU events will help in improving surveillance and education in asthma and may allow the development of effective treatment strategies.

The present study was undertaken to retrospectively examine the seasonal trends in asthma-related ICU admissions and/or intubations. The specific objectives were to 1) examine monthly rates of asthma-related hospital admissions and asthma-related ICU admissions and intubations combined, 2) determine monthly asthma-related ICU admissions and intubations as a proportion of total asthma-related hospital admissions, and 3) identify seasonal trends in asthma-related ICU admissions and intubations by age, gender, and region.

METHODS

The study involved the use of discharge data from the NDC Health Hospital Patient Level Database from 285

These data were presented in part at the 2003 American Academy of Asthma, Allergy and Immunology Annual Meeting in Denver, Colorado, March 10, 2003.

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TABLE 1.—Demographic characteristics of the study population.

	ICU/intubation	Standard admission
Admissions %	7,803 (10.1%)	69,113 (89.9%)
Age, y (SD)	43.0 (22.4)	42.4 (22.9)
5–34	28.3%	27.5%
35–64	39.4%	36.7%
65 and over	15.8%	14.6%
Female ^a	63.1%	65.9%
Hospital size (beds) ^a		
< 200	22.9%	21.6%
200–499	48.0%	53.2%
≥ 500	29.1%	25.2%
Teaching ^a	65.0%	60.1%
Urban ^a	98.4%	94.3%
In-hospital death	2.8%	0.1%
Region ^a		
Northeast	45.3%	53.1%
South	19.9%	23.6%
Midwest	22.2%	17.3%
West	15.5%	6.0%

^a*p* < 0.0002.

hospitals across the United States representing > 3 million annual inpatient visits. The data are from hospitals' operational billing systems, which are used to compile Uniform Bill-92 forms (UB-92) and are regularly audited for accuracy. The database includes information on patient age, gender, geographic region, diagnosis and procedure codes, revenue codes, and charges.

The study population included inpatient hospital admissions of >1 day, occurring between January 1, 2001, and December 31, 2002. Asthma-related hospitalizations were identified as having a principal International Classification of Diseases, Ninth Revision-Clinical Modification (ICD-9-CM) discharge diagnosis code for asthma (493.xx). Patients aged ≥ 5 years at the time of admission were included in the analysis. Treatment within the ICU was identified by using ICU-specific UB-92 revenue codes (200–204, 206, 209). ICD-9-CM procedure codes for intubation (96.01–96.05) and mechanical ventilation (96.7x) were used to identify patients who were intubated. Each hospital admission was treated as a unique episode of care for this study.

Statistical Analyses

Patient demographics and admission details were summarized into frequency tables by admissions involving ICU care and/or intubation and those that did not. Chi-squared tests were conducted to detect differences between subgroups with categorical data. Continuous data were summarized as the mean (SD), and Student's t-test was used to assess whether the means of the groups were significantly different at an alpha of 0.05. Data from 2001 and 2002 were combined, and the percents of the total asthma-related admissions per month were compared. Moving averages (average of actual month's data and preceding and following months) were calculated for all months except January and December. The monthly means were compared with the overall average monthly rate, and significance was tested by independent sample t-test. As multiple comparisons were conducted, Bonferroni's tech-

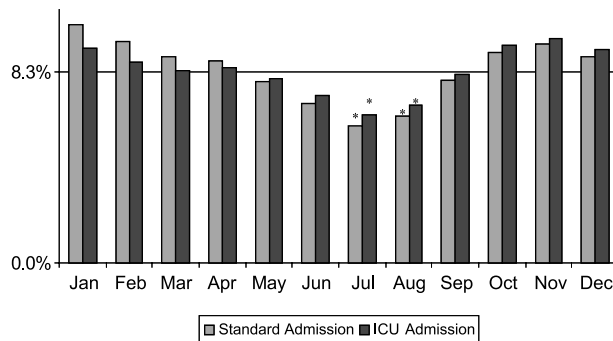


FIGURE 1.—Distribution of monthly asthma-related hospital and ICU admissions. *Statistically significant [$\alpha = 0.05/\#$ of contrasts (12) = 0.004] compared to overall mean of 8.3% (1 of 12).

nique for adjusting the level of significance was used. The monthly rates of admissions were presented as a percent above or below the overall average monthly value for the 24-month study period. This graphic presentation of seasonal trend was based on the method adopted by Weiss (9). Chi-squared tests were used to compare seasonal trends by age group, gender, and region. All statistical analyses were performed by using SAS software, version 8.2 (13). Throughout the manuscript, winter is defined as December through February, spring is defined as March through May, summer is defined as June through August, and fall is defined as September through November.

RESULTS

Demographic Characteristics

A total of 76,916 patients aged ≥ 5 years with a principal diagnosis of asthma were identified. Of these admissions, 7,803 (10.1%) were admitted to the ICU and/or intubated. Patients not admitted to the ICU and/or intubated (89.9%) will be referred to as the "standard admissions" cohort throughout the rest of this article. Those admitted to the ICU and/or intubated will be referred to as the "ICU" cohort throughout the rest of the article, because the

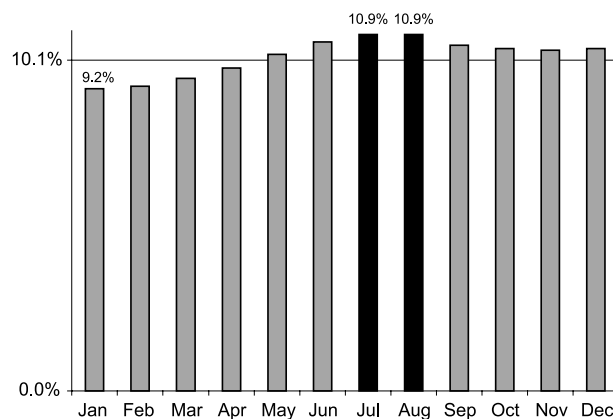


FIGURE 2.—Monthly ICU/intubation admissions as a percent of asthma hospitalizations. Note: Darker bars denote highest monthly percent. 10.1% is the overall percent of ICU/intubation admissions (see Table 1).

majority of patients who were intubated were also admitted to the ICU during the hospital visit in which the procedure was performed.

The demographic characteristics of these admissions are given in Table 1. There were no differences in mean age by cohort. The majority of patients in both cohorts were female with a slightly greater proportion of females in the standard admissions cohort (65.9% vs. 63.1%, $p < 0.0002$). The majority of patients (77%) were treated

in facilities with > 200 beds. A greater proportion of patients in the ICU admissions cohort were admitted to teaching hospitals (65%) than in the standard admissions cohort (60.1%; $p < 0.0002$). More than 90% of all admissions occurred in hospitals located in urban areas, with the majority of admissions to hospitals located in the Northeast region. The distribution of admissions by region were significantly different between the cohorts ($p < 0.0002$), with a greater proportion of ICU admissions occurring in

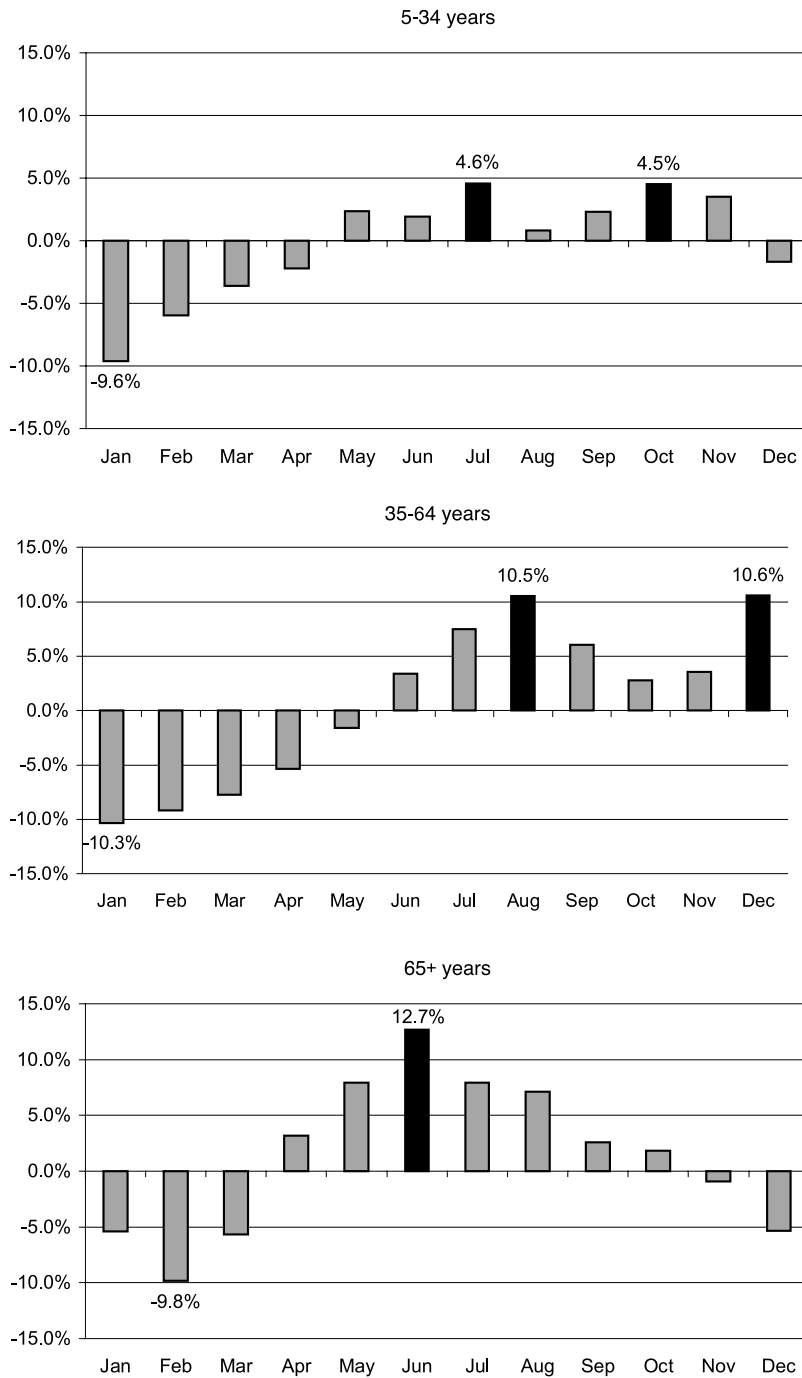


FIGURE 3.—Monthly ICU/intubation admissions as a percent of asthma hospitalizations by age: percent monthly variation about the mean; $p < 0.0001$ seasonal distribution of ICU/intubation by age category. Darker bars denote greatest percent increase.

the Western region (15.5% for ICU cohort vs. 6.0% for standard cohort).

Seasonality in Asthma-Related Hospital and ICU Admissions

Figure 1 shows the frequency of asthma-related hospital admissions and asthma-related ICU admissions by month. The average number of hospitalizations per month is expected to be 8.3% (1 of 12). The greatest proportion of total asthma-related hospital admissions occurred October through February (9.1–10.3%), with declining rates beginning in March, and the lowest in the summer (June through August; 5.9–6.9%). A similar trend was seen in the total number of asthma-related ICU admissions with the greatest proportion of admissions seen in October through February (8.7–9.8%) and lowest in the summer (June through August; 6.4–7.3%).

Figure 2 shows the monthly asthma-related ICU admissions as a percent of total asthma-related hospital admissions by month. Overall, asthma-related ICU admissions remained relatively constant as a percent of total asthma-related hospitalizations, ranging from 9.2 to 10.9%. The proportion of asthma-related ICU admissions were the lowest in January through March (9.2–9.5%) and highest during July and August (10.9%). The peaks in July and August did not quite reach statistical significance com-

pared with the overall mean of 10.1% ($p = 0.0602$ and $p = 0.0588$, respectively).

Seasonality in Asthma-Related Hospital and ICU Admissions by Age

The overall proportions of asthma-related ICU admissions as a percent of total asthma-related hospital admissions were 9.9% for the 5–34 age group and 10.3% for the 35–64 and the 65 and older age groups. Figure 3 shows the seasonal trends in the proportion of asthma-related ICU admissions presented as the percentage above or below the overall average proportion of ICU admissions for each age group. The seasonal distribution of ICU admissions as a proportion of total asthma admissions differed by age group ($p < 0.0001$). All age groups showed peaks in ICU admissions as percent of total asthma admissions in the summer months (July for the 5–34 age group; August for the 35–64 age group; and June for the 65+ age group) and troughs in the months of January through March. The 5–34 age group also showed additional peaks during September through November, whereas the 35–64 age group experienced an additional peak in December. The percentage increase in the proportion of ICU admissions for the 5–34 age group (4.6%) was not as large as the percentage increases for the 35–64 (10.6%) and the 65 and older (12.7%) age groups.

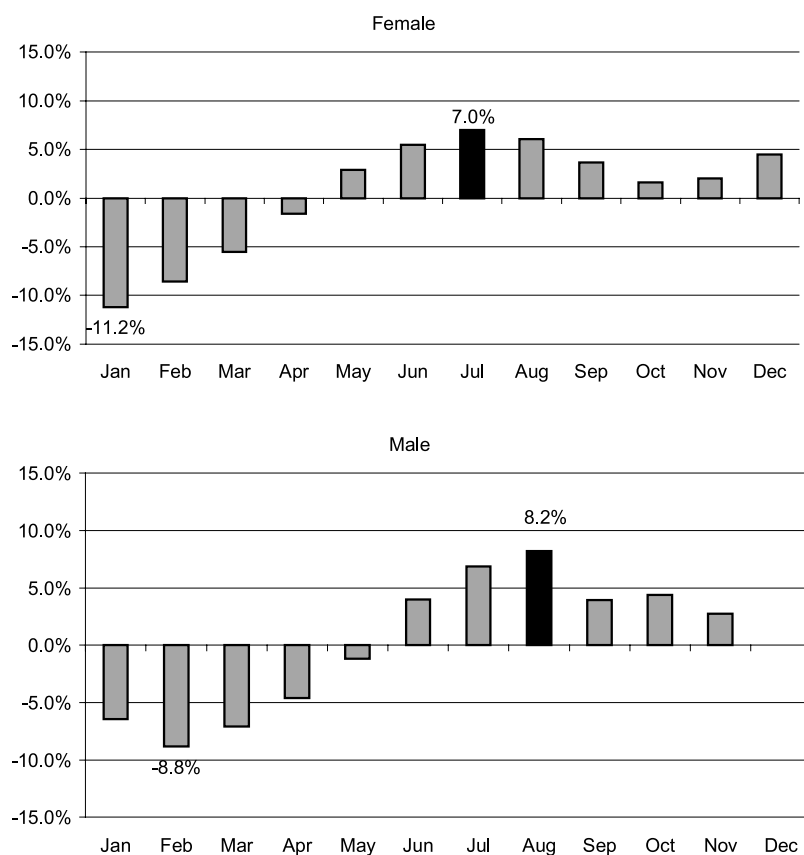


FIGURE 4.—Monthly ICU/intubation admissions as a percent of asthma hospitalizations by gender: percent monthly variation about the mean; $p = 0.1268$ seasonal variation in ICU/intubation by gender. Darker bars denote greatest percent increase.

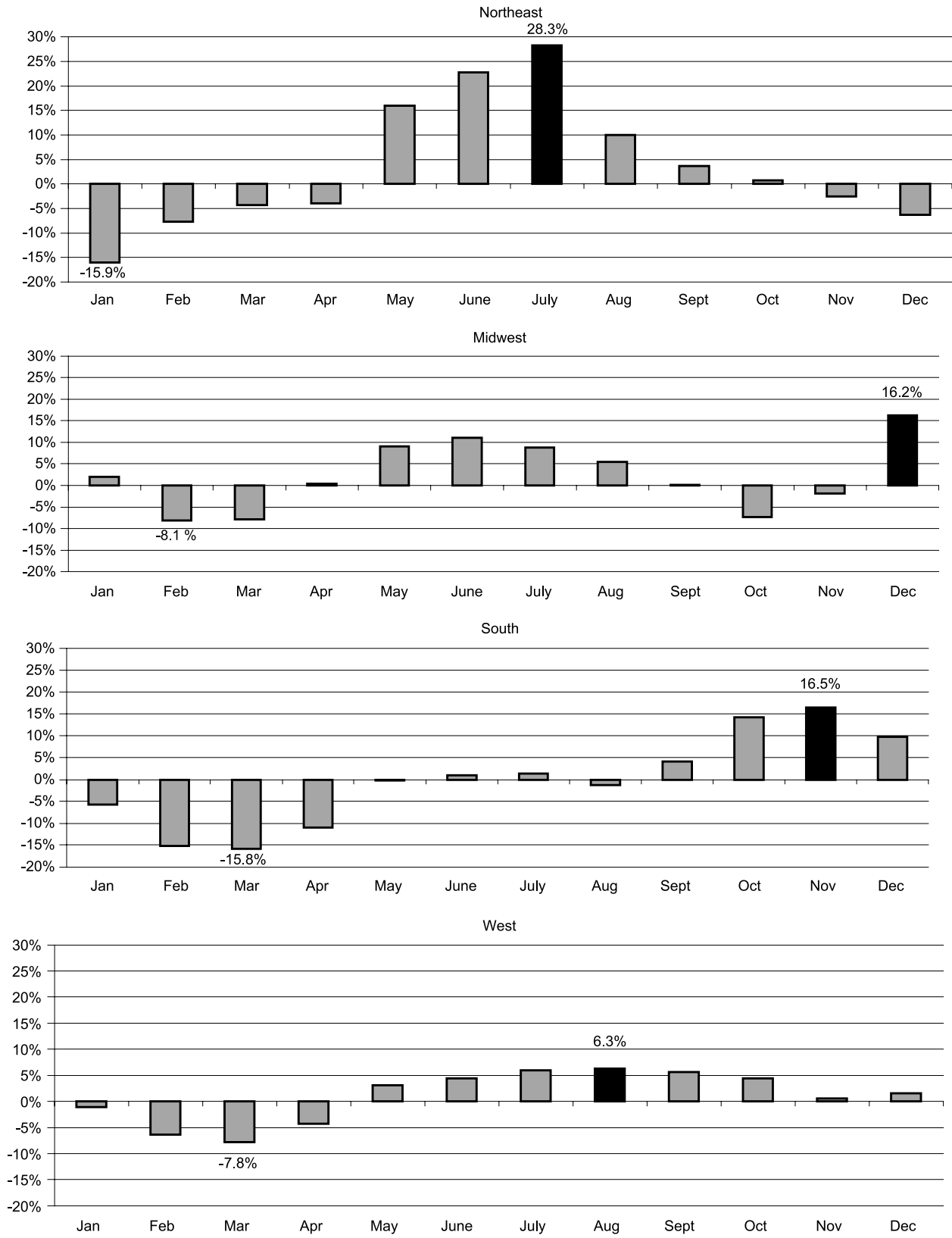


FIGURE 5.—Monthly ICU/intubation admissions as a percent of asthma hospitalizations by region; percent monthly variation about the mean; $p = 0.0149$ seasonal variation in ICU/intubation by region. Darker bars denote greatest percent increase.

Seasonality in Asthma-Related Hospital and ICU Admissions by Gender

The overall proportions of asthma-related ICU admissions as a percent of total asthma-related hospital admissions were 11.2% for females and 12.1% for males. Figure 4 shows the seasonal trends in the proportion of asthma-related ICU admissions presented as the percentage above or below the overall average proportion of ICU admissions by gender. The seasonal distribution of ICU admissions as a proportion of total asthma admissions did not differ by gender ($p < 0.1268$) nor by gender and age category. The percentage change in monthly rates ranged from -11.2% to 7.0% for females and -8.8% to 8.2% for males. Peak admissions were observed in the summer months of July and August for both females and males. Troughs were observed from January through April.

Seasonality in Asthma-Related Hospital and ICU Admissions by Region

The Western region of the country had the highest overall proportion of asthma-related ICU admissions as a percent of total asthma-related hospital admissions at 18.9%, followed by the Midwest at 12.7%, the Northeast at 9.0%, and the South at 8.7% ($p < 0.0002$). The seasonal distribution of ICU admissions as a proportion of total admissions differed significantly by region ($p < 0.0149$). Figure 5 shows the seasonal trends in the proportion of asthma-related ICU admissions presented as the percentage above or below the overall average proportion of ICU admissions by region. In the Northeast, the proportion of ICU admissions was greatest May through August, with the peak occurring in July (28.3% increase). The highest rates in the Midwest were observed in May through August and December with the peak in December (16.2% increase). In the South, the greatest percent increases occurred September through December, with the peak occurring in November (16.5% increase). The seasonal variation in the West did not appear to be as dramatic (range -7.8% to 6.3%), although small peaks were observed May through October, with the peak in August.

DISCUSSION

This study has revealed several findings regarding seasonal patterns for asthma-related hospital and ICU admissions. First, the number of asthma-related hospitalizations and ICU admissions were greatest during the fall and winter months (October through January) and lowest during the summer months (June through August). Second, a higher proportion of asthma-related hospital admissions were admitted to the ICU from June through September, with peak ICU admissions occurring in July and August. Third, despite the fact that the proportion of ICU admissions peaked in the summer months for all age groups, the seasonal distribution varied significantly by age group, but when the seasonal patterns were analyzed by gender, no significant differences were noted. Finally, significant regional differences were observed in the distribution of the proportion of ICU admissions.

In interpreting these findings, several potential limitations should be considered. The study looked at seasonal trends in ICU admissions and/or intubations over a 2-year period. It would be interesting to see if similar seasonal patterns were observed in studies conducted over a longer duration of time. In addition, asthma-related hospital admissions, ICU events, and intubations were identified through the use of ICD-9-CM codes and UB-92 revenue codes. Misclassification or underclassification of the actual rate of these events is possible because administrative claims data lack clinical detail and have potential for miscoding (14–16), resulting in an inaccurate estimation of the prevalence of asthma-related hospitalizations. Data on ethnicity and socioeconomic factors were not available and would have been useful to explore in terms of their relationship with the seasonal rates of asthma-related ICU admissions. And finally, a more detailed assessment of the regional differences in the seasonal trends of asthma-related hospital and ICU admissions would have been valuable. An effective method would be to couple claims data with monthly data on outdoor allergens for smaller geographic areas and study the seasonal trends, similar to the method used by Crystal-Peters et al., who studied the changes in health care costs of allergic rhinitis-related conditions due to allergy season (17). In the present study, it is interesting to note that the seasonal peaks in hospital admissions occurred in months without peak pollen counts and tended to correlate more with viral respiratory seasons (18).

Previous research has identified areas of the country with higher hospitalization rates for asthma despite comparable prevalence rates with other areas (19). In our study, the highest proportion of asthma-related ICU admissions as a percent of total admissions was observed in the Western region of the country. It is unclear whether this higher rate reflects more severe asthma or other factors that have little to do with the presentation of asthma, such as hospital occupancy, staffing or physician practices. This study did note regional differences in the seasonality of ICU admissions. The monthly proportion of ICU cases did not vary dramatically in the West, indicating very little seasonality, whereas the Northeast experienced peaks in the summer months along with the Midwest, which also experienced an additional peak in December. Seasonal trends in the South occurred with peaks during the fall and winter months (September through December). It is difficult to determine the possible causes for these fluctuations, and future research linking these hospital data with other data sources would enable further investigation of other factors related to health care access, insurance status, use, physician practice patterns, and environmental conditions that may influence ICU admission.

A number of studies have described the seasonal variations in asthma exacerbations and its impact on hospitalization rates in children and adults (6–10, 20). Findings of this present study are similar to those patterns observed in the United Kingdom, the United States, and New Zealand (9–11), which show an increase in the asthma-related hospital admission rates during the fall and winter months. In our study, however, a greater proportion of asthma-related ICU admissions occurred in the summer

months (June through August) and September. Thus, during the summer months, when the actual number of asthma-related hospital admissions is lowest, the percentage of severe cases is greatest.

Perhaps the peak in the proportion of ICU cases during these months may be due to the fact that patients are feeling well and subsequently stop taking their medication. This hypothesis is supported by declining trends in the number of prescriptions filled for asthma controller medications during the summer months (21). Although the exact explanation for the peak in the proportion of ICU admissions is not clear, it is clear that the substantial risk of mortality following an ICU admission is substantially higher. A few possible explanations for these trends include exposure of this group to outdoor aeroallergens or pollutants, patients not adhering with their prophylactic treatments, changes in access to care due to vacationing, loss of supervision or changes in routine (5, 8–10, 21). It is interesting to note that Flemming et al. (7) reported a peak in asthma-related deaths in midsummer, and Weiss (9) and Cadet et al. (12) noted a similar trend in out-of-hospital asthma deaths in 5- to 34-year olds. Previous research has shown that fatal and near fatal asthma attacks (those involving ICU admissions) may have common causes (22–24). Therefore, further exploration of trends in asthma-related ICU admissions may help in the development of strategies to prevent future fatal asthma attacks.

ABBREVIATIONS

ICD-9-CM	International Classification of Diseases, 9th Revision—Clinical Modification
ICU	Intensive care unit
SD	Standard deviation
UB-92	Uniform Bill 92

ACKNOWLEDGMENTS

The authors thank Khalid Kamal for his assistance and review of this manuscript.

This study was funded by GlaxoSmithKline, Inc.

Richard Beasley has received research funding and consultancies from GlaxoSmithKline, AstraZeneca, Novartis, and Aventis in recent years.

David Stempel is a consultant to GlaxoSmithKline and is on the speaker's bureau for GlaxoSmithKline.

REFERENCES

- Mannino DM, Homa DM, Akinbami LJ, Moorman JE, Gwynn C, Redd SC. Surveillance for asthma—United States, 1980–1999. *MMWR* 2002; 51(SS-1):1–14.
- Centers for Disease Control and Prevention. Asthma prevalence and control characteristics by race/ethnicity—United States, 2002. *MMWR* 2004; 53:145–148.
- Mannino DM, Homa DM, Pertowski CA, Ashizawa A, Nixon LL, Johnson CA, Ball LB, Jack E, Kang DS. Surveillance for asthma—United States, 1960–1995. *MMWR* 1998; 47(SS-1):1–28.
- Weiss KB, Sullivan SD. The health economics of asthma and rhinitis. I. Assessing the economic impact. *J Allergy Clin Immunol* 2001; 107:3–8.
- Crighton EJ, Mamdani MM, Upshur RE. A population based time series analysis of asthma hospitalizations in Ontario, Canada: 1988 to 2000. *BMC Health Serv Res* 2001; 1:7.
- Harju T, Keistinen T, Tuuponen S, Kivela L. Seasonal variations in childhood asthma hospitalizations in Finland, 1972–1992. *Eur J Pediatr* 1997; 156:436–439.
- Fleming DM, Cross KW, Sunderland R, Ross AM. Comparison of the seasonal patterns of asthma identified in general practitioner episodes, hospital admissions, and deaths. *Thorax* 2000; 55:662–665.
- Grech V, Balzan M, Ascik RP, Buhagiar A. Seasonal variations in hospital admissions for asthma in Malta. *J Asthma* 2002; 39(3):263–268.
- Weiss KB. Seasonal Trends in US asthma hospitalizations and mortality. *JAMA* 1990; 263(17):2323–2328.
- Dunn KM, Pearce N, Beasley R. Seasonal variation in asthma hospitalizations and death rates in New Zealand. *Respirology* 2000; 5:241–246.
- Khot A, Burn R. Seasonal variation and time trends of death from asthma in England and Wales 1960–1982. *BMJ* 1984; 289:233–234.
- Cadet B, Robine JM, Leibovici D. Dynamics of asthma mortality in France: seasonal fluctuations and peaking of mortality in 1985–87. *Rev Epidemiol Sante Publ* 1994; 42:103–118.
- SAS Institute. SAS Procedures Guide, Version X. Cary, NC: SAS Institute, 2001.
- Warren JL, Feuer E, Potosky AL, Riley GF, Lynch CF. Use of medicare hospital and physician data to assess breast cancer incidence. *Med Care* 1999; 37:445–456.
- Newton KM, Wagner EH, Ramsey SD, McCulloch D, Evans R, Sandhu N, Davis C. The use of automated data to identify complications and comorbidities of diabetes: a validation study. *J Clin Epidemiol* 1999; 52:199–207.
- Fisher ES, Whaley FS, Drushat WM, Malenka DJ, Fleming C, Baron JA, Hsia DC. The accuracy of medicare's hospital claims data: progress has been made, but problems remain. *Am J Public Health* 1992; 82:243–248.
- Crystal-Peters J, Neslusan CA, Smith MW, Toggias A. Health care costs of allergic rhinitis-associated conditions vary with allergy season. *Ann Allergy Asthma Immunol* 2002; 89:457–462.
- Johnston SL, Pattermore PK, Sanderson G, Smith S, Campbell MJ, Josephs LK, Cunningham A, Robinson BS, Myint SH, Ward ME, Tyrrell DA, Holgate ST. The relationship between upper respiratory infections and hospital admissions for asthma: a time-trend analysis. *Am J Respi Crit Care Med* 1996; 154:654–660.
- Homa DM, Mannino DM, Redd SC. Regional differences in hospitalizations for asthma in the United States, 1988–1996. *J Asthma* 2002; 39(5):449–455.
- Harju T, Tuuponen S, Keistinen T, Kivela L. Seasonal variations in hospital treatment periods and deaths among adult asthmatics. *Eur Respir J* 1998; 12:1362–1365.
- “PHAST Prescription Monthly” NDC Pharmaceutical Audit Suite. NDCHealth Pharmaceutical Services. 6/30/2003 (Data on File).
- Beasley R, Pearce N, Crane J. Use of near-fatal asthma for investigating asthma deaths. *Thorax* 1993; 48:1093–1094.
- Campbell DA, McLennan G, Contes JR, Frish PA, Gluyas PA, Latimer KM, Frith PA, Gluyas PA, Latimer KM, Martin AJ, Roder DM, Ruffin RE, Scarce D. Near fatal asthma attacks: the reliability of descriptive information collected from close acquaintances. *Thorax* 1993; 48:1099–1104.
- Richards G, Kolbe J, Fenwick J, Rea H. Demographic characteristics of patients with severe life threatening asthma: comparison with asthma deaths. *Thorax* 1993; 48:1105–1109.

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