Rates and characteristics of intensive care unit admissions and intubations among asthma-related hospitalizations

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Background: A life-threatening attack of asthma that leads to intensive care unit (ICU) admission, intubation, or both identifies patients at high risk of subsequent morbidity and mortality and represents a major cost burden.

Objective: To assess the rates, characteristics, and costs of ICU admissions and intubations among asthma-related hospitalizations.

Methods: This analysis was performed using a database of 215 hospitals representing more than 3 million annual inpatient visits. Asthma-related hospital admissions were identified by a primary diagnosis code for asthma during 2000. Logistic regression was used to estimate the odds ratios (ORs) for predictors of ICU admission, intubation, and in-hospital mortality. Ordinary least squares regression was used to estimate adjusted mean costs and length of stay.

Results: Of 29,430 admissions with a primary diagnosis of asthma, 10.1% were admitted to the ICU and 2.1% were intubated. The risk of in-hospital death was significantly greater in patients who were intubated but not admitted to the ICU (OR, 96.20; 95% confidence interval [CI], 50.24–184.20), those who were admitted to the ICU and intubated (OR, 62.69; 95% CI, 38.17–102.96), and patients with more severe comorbidities (OR, 1.53; 95% CI, 1.38–1.70). On average, intubated patients stayed in the hospital 4.5 days longer and incurred more than $11,000 in additional costs; patients admitted to the ICU stayed 1 day longer and accounted for $3,000 in additional costs vs standard admissions.

Conclusions: The inpatient mortality, morbidity, and cost burden of life-threatening asthma in the United States is considerable. This study characterizes patients with asthma at risk of ICU admissions and intubations. Appropriate recognition and treatment are needed to prevent these severe and potentially life-threatening events.

INTRODUCTION

Asthma is one of the most common chronic conditions in the United States, affecting more than 26 million Americans. The asthma mortality rate has increased more than 2-fold since the late 1970s despite numerous advances in its evaluation and treatment. The annual economic burden of asthma in the United States is estimated to be $12.7 billion, with approximately $7.4 billion being direct medical costs. Of these direct medical expenditures, approximately 29% are related to hospital care. In 1999, asthma was responsible for nearly 450,000 hospitalizations at a cost of approximately $3.2 billion. In general, intensive care unit (ICU) beds currently account for approximately 7% of all hospital beds in the United States and for 20% to 30% of hospital costs. Care in the ICU is estimated to account for nearly 1% of the entire gross domestic product of the United States. Intubations have a significant effect on the costs and outcomes of ICU and hospital admissions. An estimated 5% to 10% of ICU patients require prolonged mechanical ventilation, and this group consumes more than 50% of the resources in terms of cost and length of stay (LOS).

The objective of this study is to evaluate the frequency, characteristics, and costs of ICU admissions and intubations among patients hospitalized with asthma. Although the prevalence and cost of asthma in the emergency department and hospital have been reported, little is known about the prevalence and outcomes of ICU admissions and intubations among patients admitted for asthma. The combination of expensive asthma-related hospitalizations and increased asthma mortality rates has resulted in greater emphasis on assessing these events and outcomes.

METHODS

This study was designed primarily to identify the number and percentage of asthma-related admissions that were (1) standard hospital admissions, (2) ICU admissions, and (3) intubations. Total costs, LOS, and in-hospital mortality rates

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were secondarily evaluated. The study used discharge data from the NDCHealth Hospital Patient Level Database from 215 hospitals across the United States representing more than 3 million annual inpatient visits. The data are from hospitals’ operational billing systems, which are used to compile Uniform Bill-92 (UB-92) forms and are regularly audited for accuracy. The database includes information on patient age, sex, geographic region, diagnosis and procedure codes, revenue codes, charges, and hospital teaching status and bed size. Forty-six percent of the admissions in the database were in teaching hospitals, and most hospitals were located in the southern (37%) and northern (23%) regions of the country. Sixty-nine percent of admissions in the database were in hospitals with greater than 200 beds.

The study population included inpatient hospital admissions of greater than 1 day occurring between January 1, 2000, and December 31, 2000. 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 (code 493.xx). The top 5 secondary diagnoses for each admission were also identified using ICD-9-CM codes and included pneumonia (codes 481–486), hypertension (code 401), acute upper respiratory tract infection (code 465), congestive heart failure (code 428), and diabetes mellitus (code 250). Secondary diagnoses for chronic obstructive pulmonary disease (COPD) (codes 491, 492, and 496) were also identified. Treatment in the ICU was identified using ICU-specific UB-92 revenue codes (codes 200–204, 206, and 209). ICD-9-CM procedure codes for intubation (codes 96.01–96.05) and mechanical ventilation (code 96.7x) were used to identify patients who were intubated. Each hospital admission was treated as a unique episode of care for this study. Hospital readmissions during the study period were identified using a common medical record number for patients within a hospital.

Patient demographics, admission details, and hospital characteristics were summarized in frequency tables by admissions that involved ICU care, intubation, or both and those that did not. χ² Tests were conducted to detect differences between subgroups using categorical data. Continuous data were summarized as the mean (SD), and analysis of variance was used to evaluate whether the mean values of the groups were significantly different at α = .05. Logistic regression models were used to estimate the odds ratios (ORs) for predictors of ICU admission, intubation, and in-hospital mortality. Logistic regression analyses were used due to the dichotomous nature of the dependent variables. Covariates in the regression model included age, sex, comorbidities, hospital characteristics, and previous admission during the study period. For predicting in-hospital mortality, comorbid conditions were classified using the Charlson comorbidity index, which accounts for the seriousness of comorbid disease. Asthma-related hospital charges were converted to costs using hospital-specific cost-to-charge ratios. Ordinary least squares regression modeling was used to estimate adjusted mean costs and LOS. Cost and LOS variables were log-transformed before regression modeling because of the large positive skew of the variables. The estimated logged mean cost and mean LOS were retransformed using a parametric retransformation method to facilitate interpretation. All analyses were performed using statistical software (SAS version 8.1, SAS Institute Inc. Cary, NC).

RESULTS

Demographic Characteristics

A total of 29,430 hospital admissions were identified with a principal diagnosis of asthma. Of these admissions, 2,976 (10.1%) were admitted to the ICU and 632 (2.1%) were intubated (with or without ICU admission). Patients not admitted to the ICU or intubated (89.3%) are referred to as “standard” admissions throughout this article. Of the 632 patients who were intubated, 173 (27.4%) were not admitted to the ICU during the hospital visit at which the procedure was performed. Of the 2,976 patients admitted to the ICU, 459 (15.4%) were also intubated. Because the ICU cohort and the intubation cohort are not mutually exclusive, 3 mutually exclusive cohorts were created: ICU and intubation (n = 459), intubation only (n = 173), and ICU admission only (n = 2,517).

The demographic characteristics of these cohorts are given in Table 1. Most patients were female. There were significantly more females in the ICU plus intubation cohort (67%) and significantly fewer females in the intubation-only cohort (55%) compared with the ICU-only and standard admission cohorts (61%). Mean (SD) ages ranged from 33.7 (25.8) years in the standard cohort to 46.8 (20.7) years in the ICU + intubation cohort. The ICU plus intubation and intubation-only cohorts had significantly older patients and significantly fewer patients younger than 18 years compared with the ICU-only and standard admission cohorts (P < .001).

The 5 most common comorbid medical conditions in all patients were pneumonia, hypertension, diabetes mellitus, acute upper respiratory tract infection, and heart failure. Secondary diagnoses of COPD (codes 491, 492, and 496) were minimal and did not appear in the top 5 secondary diagnoses, occurring in only 136 admissions (0.46%). Patients in the standard admission cohort had significantly more secondary diagnoses of hypertension, diabetes mellitus, and acute upper respiratory tract infection (P < .001) and significantly fewer secondary diagnoses of heart failure (P < .001) compared with patients in the other cohorts. Patients in the ICU-only cohort had significantly more secondary diagnoses of pneumonia (P < .001).

Most patients (>68%) were treated in facilities with more than 200 beds. The intubation-only cohort had the fewest patients admitted to small hospitals (<200 beds: 7.5%; P < .001). Approximately 65% of all standard and ICU-only admissions occurred in teaching hospitals, and 76% of intubations with or without ICU admission occurred in teaching hospitals (P < .001). This is considerably higher than the distribution of all hospital admissions in the NDCHealth Hospital Patient Level
Database, where approximately 45% of patients were admitted to teaching hospitals. While most patients (72%) were admitted through the emergency department, admission source was significantly different by cohort ($P < .001$). Patients in the standard admission cohort were less likely to be admitted from the emergency department compared with other cohorts. Patients with standard admissions were more likely to have a routine admission or to have been referred or admitted through another outpatient source compared with those in the other cohorts.

The distributions of discharge status were significantly different across the 4 cohorts. Most patients were discharged to home after receiving acute asthma care; however, more patients in the standard admission and ICU-only cohorts were...
discharged to home (92% and 89%, respectively) compared with the ICU plus intubation and intubation-only cohorts (67% and 64%, respectively). Patients in both intubation cohorts were more likely to be discharged to an alternate treatment facility, such as an intermediate or long-term care facility, than those in the ICU-only and standard admission cohorts. Patients in the 2 intubation cohorts were more likely to have an in-hospital death compared with patients in the ICU-only and standard admission cohorts. The death rates were approximately 100 times greater in the intubation cohorts. The mean (SD) age of patients in the ICU-only and standard admission cohorts (9.4% in the ICU plus intubation cohort, 10.4% in the intubation-only cohort, and 0.1% in the standard admission cohort. The death rates were approximately 100 times greater in the intubation cohorts. The mean (SD) age of patients in the ICU-only and standard admission cohorts was 68 (16.5) years (range, 34–97 years), with zero in-hospital deaths recorded in the pediatric population (<18 years) and zero deaths recorded in patients with a secondary diagnosis of COPD.

Patients in the 2 ICU cohorts were significantly more likely to be readmitted to the hospital within the 1-year observation period and were also more likely to be readmitted to the ICU (P < .001 for both). The unadjusted LOS for patients in the ICU plus intubation cohort was, on average, 7 days greater than that for patients with standard admissions, whereas unadjusted LOS for patients in the intubation-only cohort was approximately 4.5 days greater (P < .001). Patients in the intubation plus ICU cohort had a mean (SD) LOS of 6.5 (8.8) days in the ICU, and patients in the ICU-only cohort stayed a mean (SD) of 2.4 (2.2) days in the ICU. The total unadjusted costs for patients in the ICU plus intubation cohort were approximately $21,000 higher than costs for standard admissions, and unadjusted costs for patients in the intubation-only and ICU-only cohorts were approximately $12,000 and $3,000 higher, respectively (P < .001) (Table 1).

### Multivariate Analyses

Three separate logistic regression analyses were performed to identify risk factors for in-hospital death (n = 107; Table 2) and admission to the ICU (n = 2,976) and intubation (n = 632; Table 3). Older patients, patients with higher Charlson comorbidity index scores (ie, more severe comorbidities: OR, 1.53; 95% confidence interval [CI], 1.38–1.70), and patients who were intubated (with ICU admission: OR, 62.69; 95% CI, 38.17–102.96; without ICU admission: OR, 96.20; 95% CI, 50.24–184.20) were significantly more likely to have an in-hospital death. The risk of death for patients admitted to teaching hospitals was significantly lower compared with nonteaching hospitals (OR, 0.83; 95% CI, 0.37–0.99). Patients in medium or large hospitals or patients who had previous admissions had similar risk of in-hospital mortality.

In the logistic regression analyses to identify the risk factors for ICU admission and intubation, older patients, patients with higher Charlson comorbidity index scores (more severe comorbid conditions), patients admitted to teaching hospitals, and patients with previous ICU admission(s), intubation(s), or both were more likely to be admitted to the ICU or to be intubated (Table 3). There seemed to be regional differences in admission patterns. Compared with patients in the northern region of the country, those in the western region were significantly more likely to be admitted to the ICU (OR, 1.62; 95% CI, 1.41–1.86) or intubated (OR, 1.36; 95% CI, 1.04–1.79), whereas patients in the southern region were signifi-

### Table 2. Multivariate Logistic Regression Analyses for In-Hospital Death

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age category, y</td>
<td></td>
</tr>
<tr>
<td>40–59</td>
<td>4.50 (1.92–10.56)</td>
</tr>
<tr>
<td>60–79</td>
<td>9.29 (3.99–21.67)</td>
</tr>
<tr>
<td>≥80</td>
<td>32.13 (13.27–77.79)</td>
</tr>
<tr>
<td>Female</td>
<td>0.95 (0.60–1.51)</td>
</tr>
<tr>
<td>Charlson comorbidity index</td>
<td>1.53 (1.38–1.70)</td>
</tr>
<tr>
<td>ICU/intubation</td>
<td></td>
</tr>
<tr>
<td>Intubation + ICU</td>
<td>62.69 (38.17–102.96)</td>
</tr>
<tr>
<td>Intubation, no ICU</td>
<td>96.20 (50.24–184.20)</td>
</tr>
<tr>
<td>ICU, no intubation</td>
<td>1.82 (0.83–2.98)</td>
</tr>
<tr>
<td>Hospital bed size</td>
<td></td>
</tr>
<tr>
<td>200–399 beds</td>
<td>0.94 (0.56–1.58)</td>
</tr>
<tr>
<td>≥400 beds</td>
<td>0.82 (0.43–1.55)</td>
</tr>
<tr>
<td>Region</td>
<td></td>
</tr>
<tr>
<td>Southern</td>
<td>1.95 (0.94–4.01)</td>
</tr>
<tr>
<td>Eastern</td>
<td>2.38 (1.19–4.76)</td>
</tr>
<tr>
<td>Western</td>
<td>1.55 (0.62–3.88)</td>
</tr>
<tr>
<td>Teaching hospital admission</td>
<td>0.83 (0.37–0.99)</td>
</tr>
<tr>
<td>Previous admission</td>
<td>1.08 (0.52–2.25)</td>
</tr>
<tr>
<td>Previous ICU admission, intubation, or both</td>
<td>1.77 (0.49–6.40)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; ICU, intensive care unit; OR, odds ratio.

### Table 3. Multivariate Logistic Regression Analyses for ICU Admissions and Intubations

<table>
<thead>
<tr>
<th>Variable</th>
<th>ICU admission (n = 2,976)</th>
<th>Intubation (n = 632)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.02 (1.01–1.02)</td>
<td>1.08 (1.06–1.09)</td>
</tr>
<tr>
<td>Female</td>
<td>0.93 (0.85–1.01)</td>
<td>0.74 (0.62–0.87)</td>
</tr>
<tr>
<td>Charlson comorbidity index</td>
<td>1.09 (1.04–1.13)</td>
<td>1.13 (1.05–1.21)</td>
</tr>
<tr>
<td>Hospital bed size of 200–399 beds</td>
<td>0.71 (0.65–0.78)</td>
<td>1.27 (1.01–1.59)</td>
</tr>
<tr>
<td>Hospital bed size of ≥400 beds</td>
<td>0.78 (0.70–0.87)</td>
<td>1.35 (1.06–1.73)</td>
</tr>
<tr>
<td>Southern region</td>
<td>0.85 (0.75–0.95)</td>
<td>0.73 (0.58–0.92)</td>
</tr>
<tr>
<td>Eastern region</td>
<td>0.98 (0.85–1.07)</td>
<td>0.67 (0.54–0.84)</td>
</tr>
<tr>
<td>Western region</td>
<td>1.62 (1.41–1.86)</td>
<td>1.36 (1.04–1.79)</td>
</tr>
<tr>
<td>Teaching hospital admission</td>
<td>1.24 (1.13–1.36)</td>
<td>1.78 (1.45–2.19)</td>
</tr>
<tr>
<td>Previous admission</td>
<td>0.80 (0.70–0.92)</td>
<td>0.81 (0.61–1.06)</td>
</tr>
<tr>
<td>Previous ICU admission, intubation, or both</td>
<td>5.22 (4.20–6.49)</td>
<td>3.11 (2.02–4.80)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; ICU, intensive care unit; OR, odds ratio.
Table 4. Adjusted Mean Length of Stay and Adjusted Mean Costs

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Patients, No.</th>
<th>Adjusted mean (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LOS, d</td>
</tr>
<tr>
<td>All asthma-related admissions</td>
<td>29,430</td>
<td>3.44 (3.40–3.48)</td>
</tr>
<tr>
<td>Standard admissions</td>
<td>26,281</td>
<td>3.09 (3.06–3.11)</td>
</tr>
<tr>
<td>ICU + intubation</td>
<td>3,149</td>
<td>4.85 (4.74–4.96)</td>
</tr>
<tr>
<td>ICU admissions</td>
<td>2,976</td>
<td>3.99 (3.98–4.09)</td>
</tr>
<tr>
<td>Intubation</td>
<td>632</td>
<td>7.47 (6.81–8.20)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; ICU, intensive care unit; LOS, length of stay.

In interpreting these findings, several potential methodological limitations should be considered. First, asthma-related hospital admissions, ICU events, intubations, and readmissions were identified in the 1-year period 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 the potential for miscoding, resulting in an inaccurate estimation of the prevalence of asthma-related hospitalizations. Medical record review may have been helpful in confirming cases and in determining the indications and length of intubations; however, record review also has limitations similar to those encountered using administrative data. Despite these limitations, our results are comparable to those reported by Eisner et al, who found that 13.2% of 2,344 adults hospitalized were admitted to the ICU during a 2-year period.

Second, data on ethnicity, insurance status, and socioeconomic factors were not available and would have been useful to explore in terms of their relationship with the rates of asthma-related ICU admissions and intubations. Third, in assessing in-hospital death, it is important to keep in mind that this is all-cause mortality, and it should not be assumed that asthma was the cause of all of these in-hospital deaths. Only a clinical review of death records would enable us to attribute the cause of death. Finally, it is likely that the criteria by which the decision is made to admit a patient to the ICU and the nature of the intensive hospital care may differ among hospitals. This was evident in the study and is likely to reflect differences in staffing, administrative policies, and pressures due to hospital occupancy and capacity. Previous studies have examined the variations among hospitals in the use of ICUs for patients with lower severity of illness. In our study, patients who were admitted to hospitals with greater than 200 beds were significantly less likely to be admitted to the ICU and were significantly more likely to be intubated compared with patients who were admitted to smaller hospitals. This may indicate that larger hospitals have the ability to provide adequate care in non-ICU settings and that only the sickest patients are admitted to the ICU in these larger hospitals, which include academic medical centers. Likewise, smaller hospitals may experience more ICU admissions due to staffing, occupancy, or administrative reasons different from those experienced by larger hospitals.
The average LOS reported in this study was 3.4 days, with an overall average cost of a hospitalization of $4,287 (in 2000 dollars). These findings are similar to those reported by Stanford et al., in which the average LOS for asthma-related hospital admission was 3.8 days, with an average cost of $3,103 (in 1997 dollars). Costs in our study were calculated using cost-to-charge ratios, which may explain some of the difference; however, it is highly likely that the average cost of an asthma-related hospital admission may have increased during the 3-year period between the 2 studies.

Patients who were admitted to the ICU stayed in the hospital approximately 1 day longer and incurred more than $3,000 in additional costs than patients who were neither admitted to the ICU nor intubated. Patients who were intubated had a LOS approximately 4.5 days longer and had additional costs of more than $11,000 per hospital stay. Other studies have reported similar increases for LOS in the ICU for all hospital admissions and for patients with asthma who are intubated.

Patients who required intubation, with or without ICU admission, had a 60- to 90-fold higher in-hospital mortality rate (approximately 10%) compared with patients with a standard asthma hospitalization. This is consistent with previous research that observed mean mortality of 13% in patients requiring mechanical ventilation. It could be considered that these patients experienced a near-fatal asthma attack. Patients with a near-fatal asthma attack who require mechanical ventilation have a higher risk of readmission and of asthma-related death in the future. Our study takes a slightly different approach in classifying patients by examining those who were intubated and admitted to the ICU and those who were not. It is possible that patients who were intubated outside the ICU, possibly in the emergency department, may have died before it was possible to transport the patient to the ICU. On the other hand, it is also likely that these patients only required brief intubation to stabilize their condition and that intensive care was not needed. Owing to the inherent limitations of claims data, we can only speculate about the reasons for intubation without ICU admission and about whether these decisions were based on medical judgment or hospital staffing, occupancy, or administrative policies. Although the death rate is significantly higher in patients who were intubated, it is important to keep in mind that most patients (90%) survived. Additional studies have also shown that patients admitted to medical ICUs have significantly higher mortality rates compared with patients not admitted to the ICU. We also observed an asthma-related ICU readmission rate of 5.1%, which is similar to the overall ICU readmission rate of 7% reported by Rosenberg and Watts.

The subsequent risk of mortality following an ICU admission for asthma is substantial, with initial mortality of 3% to 10% per year reported in studies from Canada, New Zealand, France, and Switzerland. Indeed, a previous ICU admission or intubation for asthma is recognized to be the strongest risk factor that can be identified for subsequent death from asthma. This finding contributes to the considerable evidence that patients admitted to the ICU for asthma are similar to those dying of asthma in terms of their socioeconomic, demographic, psychological, and clinical characteristics, such as recognized markers of asthma severity and utilization of medical resources, and that both groups come from the same high-risk population. This also suggests that in asthmatic patients who experience a life-threatening attack, intensive medical treatment and follow-up should be arranged.

Efforts to reduce the number of asthma-related hospitalizations should lead to similar reductions in ICU admission rates and intubations and a corresponding reduction in the overall mortality caused by asthma. The database used in our study did not include information on the prescribed medications taken by patients admitted to hospital. However, in a previous study based on the database of Kaiser Permanente, the largest nonprofit health maintenance organization in the United States, inhaled corticosteroids were prescribed to only 45% of patients in the 3 months before hospital admission for asthma. Increasing the use of appropriate pharmacotherapy as recommended by the National Heart, Lung, and Blood Institute guidelines represents a simple method whereby asthma-related hospitalizations could be reduced in the United States. In this respect, inhaled corticosteroids are the only medications that have been associated with decreases in asthma-related emergency department visits, hospitalizations, and mortality rates. Ideally, inhaled corticosteroids would be prescribed within the framework of a guided self-management plan system that represents the optimal regimen in which treatment can be delivered in asthma.

This study documents the considerable burden of life-threatening asthma in the United States in terms of incidence, inpatient mortality, morbidity, and economic cost. One of the priorities is for a greater emphasis on management strategies, which have been shown to reduce the risk of hospital admission, including life-threatening asthma that results in ICU admission, intubation, or both.

**REFERENCES**

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