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Utilization of Mechanical Ventilation for Asthma Exacerbations – Analysis of a National Database

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Abstract

Background: The current frequency of non-invasive (NIV) and invasive mechanical ventilation use in acute asthma exacerbations (AAE) and their relationship to outcomes is unknown.

Methods: We used the Nationwide Inpatient Sample to identify patients discharged with a principal diagnosis of AAE. For each discharge we determined whether NIV or invasive mechanical ventilation was initiated during the first two hospital days. Using multivariable logistic regression to adjust for potential confounders, we determined whether use of mechanical ventilation and in-hospital mortality changed between 2000 and 2008.

Results: The number of AAE increased by 15.8% from 2000 to 2008. The proportion of admissions where invasive mechanical ventilation was used during the first 2 days decreased from 1.4% in 2000 to 0.73% in 2008 while NIV increased from 0.34% to 1.9%. The adjusted mortality in AAE requiring NIV or invasive mechanical ventilation was unchanged through 2000 to 2008. LOS was also unchanged.

Conclusion: There was a substantial increase in the use of mechanical ventilation, accompanied by a shift from invasive mechanical ventilation to NIV. Although we cannot determine the clinical reasons for this increase, LOS and mortality were unchanged. A randomized trial is needed to determine whether NIV can improve outcomes in AAE, before widespread adoption makes it impossible to conduct such a trial.

KEY WORDS: asthma; mechanical ventilation; intensive care unit

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Abbreviation:

AAE: Acute Asthma Exacerbation

MV: Mechanical Ventilation

NIV: Non Invasive Mechanical Ventilation

LOS: Length of Hospital Stay

OR: Odds Ratio

95%CI: 95% Confidence Interval

NIS: Nationwide Inpatient Sample

ICD9CM: International Classification of Diseases – 9th Clinical Modification

CCI - Charlson's co-morbidity index

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Introduction

Asthma is a common illness with a spectrum of presentation ranging from mild disease to a severe resistant phenotype resulting in respiratory failure requiring mechanical ventilation. Acute asthma exacerbations (AAE) account for approximately 2 million emergency room visits annually in United States, 25% of which lead to hospitalization [1]. Although asthma related hospitalizations rarely end in death[2], about 10% do include an intensive care unit (ICU) stay[3]; a significant fraction of patients hospitalized for AAE (2-4%) require mechanical ventilation (MV); their mortality has been reported to be as high as 22%[3-8]. However, most studies of the outcomes of persons hospitalized for asthma reflect the experience at a single center, limiting inference about national outcomes.

The use of non-invasive mechanical ventilation (NIV) for acute respiratory failure has gained wide acceptance and indications for its use have expanded over the past decade [9, 10]. Improved outcomes from the avoidance of complications of endotracheal intubation and invasive mechanical ventilation have been demonstrated for diseases such as acute exacerbations of chronic obstructive pulmonary disease [11, 12], acute cardiogenic pulmonary edema[13] and respiratory failure in immunocompromised patients[14]. Although sporadic single center reports have described NIV use for AAE, its benefits in this setting are not well established [15-19]; hence its use remains controversial. We, however, suspect that increasing familiarity with the use of NIV combined with the fact it can be used outside of the ICU has led to its broader use in AAE.

We therefore carried out the present study to describe changes in the patterns of invasive mechanical ventilation and NIV use in AAE over time. We hypothesized that the use of NIV rose while invasive mechanical ventilation use fell since NIV use has become more widely used for other indications. To test our hypothesis, enhance generalizability of our results and detect small but important differences, we utilized a large nationally representative administrative database from the years 2000 to 2008. To better understand the impact of changes in use of these modalities, we also describe associated changes in mortality and other outcomes.

Methods

Data source

We used the Healthcare Cost and Utilization Project - Nationwide Inpatient Sample (NIS) which is an administrative dataset created by the Agency for Healthcare Research and Quality that contains data from approximately 20-percent sample of U.S. community hospitals. Each hospitalization is treated as an individual entry in the database; the principal diagnosis, up to 14 secondary diagnoses, and 15 procedural diagnoses associated with that stay are coded using the International Classification of Disease, 9th revision, Clinical Modification (ICD-9-CM). The details of the NIS can be found online[20]. We used data from 2000 to 2008 for the purposes of our study.

Since we used a publically available database without patient identifiers, our study was examined and found exempt from formal review by the IRB of the Medical College of Wisconsin.

Study population

We identified adult patients (aged 18 years or more) discharged with the principal diagnosis of AAE (ICD-9-CM code 493.xx). We excluded patients with a secondary diagnosis of pneumonia (480-486), severe sepsis[21] or chronic obstructive pulmonary disease (ICD-9-CM code 490-492,496), since MV in these patients may result from these secondary diagnoses rather than AAE itself (Figure 1). We included persons with ICD-9-CM codes indicating the presence of sleep apnea syndromes in our analysis because of the overlap between sleep disordered breathing and asthma especially difficult to control asthma[22]. For our analysis of MV use and outcomes, we excluded admissions with missing data regarding mortality, age and gender.

Outcomes

Our primary outcome of interest was use of any type of MV. We used ICD-9-CM procedure codes to identify persons receiving NIV (ICD-9-CM code 93.90) or invasive mechanical ventilation (ICD-9-CM codes 96.7x). The NIS includes the hospital day MV is initiated; we were thus able to determine time to MV in days from admission. Because MV use for AAE is typically initiated around the time of admission, our primary analysis examined only MV use initiated on the first or second hospital day. We also examined use of invasive

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mechanical ventilation and NIV separately. For these analyses, we classified those who received both NIV and invasive mechanical ventilation during the first two hospital days with those receiving only invasive mechanical ventilation. To account for the increasing prevalence of sleep disordered breathing and the utilization of NIV for these diagnoses, we also examined the use of NIV by excluding persons who had obstructive sleep apnea (OSA) coded as a secondary diagnosis.

We used the discharge destination variable to determine in-hospital mortality and whether or not surviving patients were discharged to a nursing home or home with home care. As secondary outcomes, we examined length of hospital stay (LOS), prolonged invasive mechanical ventilation (defined by invasive mechanical ventilation on 4 or more hospital days), and whether the patient developed a pneumothorax (ICD-9-CM code 512, 998.2) and received a tracheostomy (ICD-9-CM code 31.1-31.2).

Definition of variables

We used NIS variables to identify patient age, gender and race. Information of race was missing in about 20% of records through the different years. We classified those with missing race information together in 'unknown' group. We used hospital teaching status, size and ownership categories provided by NIS.

We used ICD-9-CM codes to identify co-morbid conditions based on prior work or our clinical experience that would influence either the decision to use MV or the outcome of the AAE. These included diabetes mellitus (250), congestive heart failure (428), cancer (140-208), morbid obesity (278.01, V85.4), alcoholism (291, 303.0, 303.9, 305.0) and smoking (305.1, V15.82). We assessed the overall burden of co-morbid conditions using Deyo's modification of Charlson's co-morbidity index (CCI)[23]. The CCI is the sum of weights assigned to each of 17 co-morbid diseases, with higher scores corresponding to a greater co-morbidity burden. In our population, the CCI ranged from 1 to 16.

Statistical Analysis

We performed all statistical analysis in Stata IC 11.0 (Stata-Corp, College Station, TX). We first used strata weights and survey estimation commands to generate national estimates of the number of hospitalizations for AAE in each study year, and the proportion of those hospitalizations where patients received MV.

To more closely examine changes in MV use over this period, we compared persons admitted with AAE in 2000 to those admitted in 2008 using Pearson's Chi-square test for categorical variables; we used Students t-test or Wilcoxon's rank sum test to compare continuous variables, as appropriate for their distribution. We created dummy variables for each age group, race and insurance categories to compare them individually. To describe changes in the characteristics of persons receiving each form of MV, we made similar bivariable comparisons between persons receiving invasive mechanical ventilation for AAE during the years 2000 and 2008 and also between those receiving NIV in the same years. We made these comparisons both overall, and in the subgroups that received no MV, NIV only or invasive mechanical ventilation.

We then used multivariable logistic regression to examine the relative odds of receiving either form of MV in 2008 versus 2000, adjusting for potential confounders. First we tested the bivariable association of putative risk factors with receipt of MV, and then included those found significant at $p < 0.10$ in our final multivariable model. We also included factors clinically known to influence receipt of either form of MV regardless of their significance. To account for interactions between variables, we examined all two way interaction terms and retained those found significant in our model. For the variables we included in our final model, both the tolerance and the variation inflation factor were close to unity, indicating minimal collinearity. We then forced year into this final model to determine whether it added significantly to the model, and to estimate the magnitude of any change from 2000 to 2008. In sensitivity analyses we examined all MV, regardless of whether it was initiated during the first two hospital days, with results that were qualitatively similar, so we do not present these analyses. We then repeated this analysis using receipt of invasive mechanical ventilation as the outcome variable, excluding those persons who received NIV. Finally, we performed the analysis using receipt of NIV as the outcome variable, excluding those who received invasive mechanical ventilation.

We then constructed a multivariable model using similar techniques as described above to determine whether in-hospital mortality changed from 2000 to 2008. We also compared risk of mortality in our three a priori defined subgroups: 1) No MV; 2) invasive mechanical ventilation; and 3) NIV only. We repeated our mortality analysis considering only those deaths that occurred within three days of admission; the results were similar and are not presented. We used a similar approach to determine whether LOS had changed from 2000 to 2008, and whether this pattern differed among those receiving invasive mechanical ventilation, NIV or neither. In this analysis, we used log (LOS) as our outcome variable, since LOS has a highly skewed distribution, and used linear rather than logistic regression.

Results

We identified a total of 2,476,955 hospitalizations with the principal diagnosis of AAE in adults over 18 years of age from the years 2000 to 2008 in the United States. After excluding those with COPD, pneumonia and severe sepsis as secondary diagnoses, we were left with 2,291,729 discharges. The number of hospitalizations for AAE increased by 15.8% over the 9 year study period (from 226,385 discharges in 2000 to 262,190 in 2008), as shown in Figure 2. The age of persons hospitalized with AAE increased from 2000 to 2008 (50.6 vs. 55.2 years, $p < 0.001$); the proportion of hospitalizations involving persons aged 50 years old or older increased from 47.9% to 60.7% (Appendix 1&2). The degree of co-morbidity as measured by the CCI also increased. For clarity, the demographic and clinical characteristics of persons hospitalized with AAE for the years 2000 and 2008 are presented in Tables 1 and 2. Appendices 6, 7 and 8, show characteristics of patients in each individual year from 2000 to 2008.

Use of Mechanical Ventilation

In unadjusted analyses, the proportion of persons hospitalized for AAE receiving MV (invasive mechanical ventilation or NIV) increased by 45% from 2000 to 2008. This was primarily due to an increase in proportion of hospitalizations involving NIV by greater than 400% - from 0.35% of all AAE in 2000 to 1.9% in 2008, an annualized increase of 49%. Conversely the proportion of AAE hospitalizations involving invasive mechanical ventilation fell by 50%, from 1.4% to 0.73% (Table 1 and figure 2), an annualized decrease of 5.3%. After adjustment for potential confounding factors, the odds of persons hospitalized with AAE in 2008 receiving any form of MV were over twice that in 2000 (OR 2.43 95% CI 1.19 – 4.94)(Appendix 3). This was accompanied by a decrease in the odds of receiving invasive mechanical ventilation by 50% (OR 0.52, 95% CI 0.46 – 0.59) and a

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tripling of the odds of receiving NIV (OR 3.47, 95% CI 2.94 – 4.10) (Appendix 4&5). Even after exclusion of persons with OSA, the proportion receiving NIV rose by over 500% (0.21% in 2000 to 1.1% in 2008; Table 1).

Outcomes

Between 2000 and 2008, the case fatality rate among persons hospitalized with AAE decreased (0.33% vs. 0.28%). The case fatality rates among persons receiving no MV, NIV and invasive mechanical ventilation were unchanged between 2000 and 2008, though the 3 day mortality for persons who did not require MV was lower in 2008 when compared to 2000. However, after adjusting for demographic, clinical and hospital characteristics, the odds of inpatient mortality were significantly lower in 2008 than in 2000. (OR 0.64; 95% CI 0.51 – 0.81; Table 4).

When we examined subgroups defined by MV use, we found that the odds of in-hospital death decreased amongst person not receiving mechanical ventilation (OR 0.57, 95% CI 0.45 – 0.73), and those receiving NIV (OR 0.41, 95% CI 0.07-2.14), though the decrease in the latter was not significant. In addition, the decrease in the number of persons receiving invasive mechanical ventilation, who have the greatest risk, also contributed to the overall improved mortality. Among persons receiving any form of mechanical ventilation, both the unadjusted and adjusted mortality was not different between 2000 and 2008 (Tables 3&4). Age and receipt of mechanical ventilation were the most influential predictors of mortality in persons with asthma. The odds ratio for mortality compared with patients who did not receive mechanical ventilation increased from 4.78 among those who received NIV only (95% CI 3.58-6.39), to 35.1 among those received invasive mechanical ventilation as their initial form of mechanical ventilation (95% CI 30.3 – 40.7) (Table 5).

The median length of stay in patients requiring invasive mechanical ventilation or NIV was similar in 2000 and 2008 (Table 3). Persons initially requiring NIV, who later required invasive mechanical ventilation had a similar LOS in 2000 (4.5days, IQR 2.5-11) and 2008(6.5 days, IQR 4-10); their LOS was not significantly different from those requiring invasive mechanical ventilation from the outset.

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The proportion of patients who had prolonged invasive mechanical ventilation (≥96 hours) remained similar between 2000 and 2008 (23.1% versus 18.2%). Rates of pneumothoraces and tracheostomies were not significantly different between 2000 and 2008 (Table 3). In unadjusted analyses, persons discharged alive were more likely to be discharged to a healthcare facility (generally a skilled nursing facility), or home with home healthcare in 2008. Detailed outcomes of patients for each individual year, classified by utilization of mechanical ventilation are shown in appendix 9.

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Discussion

We report that from 2000 to 2008, a five-fold increase in the use of NIV led to a significant increase in the overall use of MV among adults hospitalized with AAE, despite a significant decline in invasive mechanical ventilation. The increment in utilization of NIV was the same even after excluding people with OSA. This increase also persisted after adjusting for the fact that adults hospitalized for AAE in 2008 were older and had more comorbidities. The adjusted odds of receiving MV more than doubled and NIV use was more than 3 times higher in 2008 while invasive mechanical ventilation use declined nearly two fold. During this same period, the odds of mortality, adjusted for differences in patient characteristics, decreased by one third.

Our finding of a remarkable increase in use of NIV is consistent with several single center reports of increased use of NIV for asthma [16-19, 24]. Like us, they note that more NIV use was associated with less invasive mechanical ventilation use and shorter LOS. Although our administrative data do not allow us to confirm the improvement in physiological parameters (e.g. FEV1 and arterial pH) that has been reported[15], it is possible that such changes contributed to our observed decrease in risk adjusted mortality.

We observed that the overall case fatality rate in acute asthma exacerbations remained unchanged from 2000 to 2008. This is consistent with other reports on asthma trends [25, 26]. But after adjusting for changes in demographical and clinical characteristics, we found the risk of mortality associated with hospitalization for acute asthma in 2008 was just 0.64 times that in 2000. To our knowledge, our study is the first to describe this remarkable decline. Though we cannot ascertain the reasons for this improvement from our administrative data sources, the national representation of our results make them even more noteworthy.

It is unclear whether this declining mortality is related to changes in the patterns of mechanical ventilation, since there have been substantial improvements in the management of both AAE[27] and respiratory failure more generally[28], including increased use of protocols[29, 30] and quality improvement projects[31, 32] centered on the care of persons admitted with AAE. Certainly, our findings of exponential increases in

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the adjusted risk of mortality as persons move from requiring NIV (OR 4.78) to invasive mechanical ventilation (OR 35.1) likely reflects increasing severity of illness leading to increasing mortality. However, the phenomenon of a shift to the use predominantly NIV and stable case fatality rates as well as LOS in both the invasive mechanical ventilation and NIV cohorts, suggests that initial NIV use may spare some patients the risks associated with IMV. This raises the possibility that use of NIV in place of invasive mechanical ventilation in appropriate persons may lower the risk of mortality associated with AAE hospitalizations.

We must acknowledge several important limitations of our study. First, although ICD-9-CM codes for acute asthma exacerbations have been previously validated and used, we cannot exclude the possibility of variations in accuracy of coding between hospitals [33]. Second, important clinical detail such as the severity of asthma exacerbation, appropriate use of therapies such as steroids and bronchodilators, environment of provision of NIV (ICU vs. non ICU) and baseline pulmonary function cannot be ascertained in NIS. Particularly, provision of NIV may frequently occur outside of the ICU setting and would obscure important severity aspects in analysis of administrative data .Such detail, if available, would allow for more robust analysis of the predictors of mortality and need for mechanical ventilation. Similarly, although we adjust our analysis for co-morbid conditions, ICD-9-CM codes do not allow detection of important clinical severity differences within each co morbid condition. Such differences may be significant confounders, for example the association of obesity and asthma[34]. Third, though procedure codes for invasive mechanical ventilation are reliable[35], the provision of such procedures may be unrelated to the asthma exacerbation itself. We try to circumvent this problem by examining only MV used during the first 2 days of a hospitalization for AAE, and by excluding persons with secondary diagnoses of COPD, pneumonia and severe sepsis – common reasons for initiation of respiratory support. Nevertheless, other diagnoses such as OSA may be the reason for the presence of these codes. If persons with underlying sleep apnea syndromes hospitalized with asthma exacerbations continued their prescribed home NIV in the hospital, it is likely that our results would be confounded by the inclusion of persons with a lesser severity of illness in the NIV cohort and our results would be biased towards lower risk adjusted mortality in people receiving NIV. However exclusion of such persons did not change the proportional increase in the utilization of NIV. Finally, since NIS does not contain patient identifiers, we could not identify readmissions of the same patient. This

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meant we could not examine readmissions, an important outcome. It also means that we slightly underestimate the precision of our estimates, since our statistical methods assume independent observations.

Despite its limitations, we believe our study provides important information about trends in MV use for AAE, and associated outcomes. The rapid increase in the proportion of persons receiving NIV has been associated with a significant decrease in adjusted mortality. While this suggests a causal relationship; that NIV use may be associated with improved mortality, either by avoiding the risks of invasive mechanical ventilation or by allowing use of MV in a broader spectrum of persons with AAE. Because observational studies of new technologies are subject to a number of biases, we believe more rigorous studies, such as randomized trials should be a high priority. This need is supported by the risk of complications of NIV, which may be increased as it is used in less intensively monitored settings, and by the concern that NIV use may delay the use of needed invasive mechanical ventilation [36].

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Table 1: Demographic and clinical characteristics of patients discharged with acute asthma exacerbation - comparison of 2000 and 2008.

Patient characteristics	**2000**	**2008**	**p-value**
Total	226,385	262,190	
Age in years, mean ± SD	50.6±18.1	55.2±17.8	<0.001
Age category, (%)			
18-34*	20.4	13.1	<0.001
35-49*	31.7	26.2	<0.001
50-64*	23.3	29.5	<0.001
65-79*	17	20.2	<0.001
80 or more*	7.6	11	<0.001
Gender (%)			
Female*	73.8	72.4	0.004
Race (%)			
White	43.8	46.9	0.20
African American	18.4	19.9	0.41
Hispanic	9.5	10	0.75
Asian or Pacific Islander	1.6	1.5	0.70
Other	2.7	3.0	0.81
Unknown*	23.9	18.6	0.04
Payer (%)			
Medicare*	30.5	40	<0.001
Medicaid	20.2	19.2	0.51
Private*	36.9	28.3	<0.001
Self	8.3	8.4	0.89
Other	4.2	4.2	0.9
Chalrson-Deyo's co-morbidity index* (%)			
1-2*	94.9	86.2	<0.001
3-4*	3.8	10.6	<0.001
5-6*	0.1	1.7	<0.001
7 or more	1.2	1.5	0.07
Co-morbidities (%)			
Diabetes mellitus*	16.5	26.7	<0.001
Congestive heart failure*	6.7	11.9	<0.001
Morbid obesity*	3.2	9.4	<0.001
Cancer*	4.0	6.2	<0.001
Alcoholism*	1.6	2.1	<0.001
Smoking*	15	33.2	<0.001
Obstructive sleep apnea*	2.7	10.3	<0.001
Hospital Characteristics (%)			
Teaching status			
Teaching	41.6	42.2	0.88
Hospital size			
Small	12.5	14.2	<0.001
Medium	31.9	26.1	<0.001
Large	55.6	59.7	<0.001
Hospital ownership			
Government-Non federal	14.7	13.5	<0.001
Private - non profit	73.3	72.3	0.74
Private - investor owned	12.0	14.2	<0.001
Mechanical Ventilation, N (%)			
Total NIV*	796 (0.35)	4908 (1.9)	<0.001
NIV in patients without OSA*	486 (0.21)	2987 (1.1)	<0.001
Total invasive mechanical ventilation *	3095 (1.4)	1931 (0.73)	<0.001
Any mechanical ventilation (invasive mechanical ventilation +NIV)	3891 (1.8)	6839 (2.6)	<0.001

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Table 2: Patient characteristics with non-invasive mechanical ventilation and invasive mechanical ventilation use among adults admitted with acute asthma exacerbation during 2000 and 2008.

Patient characteristics	**Non-invasive mechanical ventilation in first 2 days**		**Invasive mechanical ventilation in first 2 days**	
	2000	2008	2000	2008
Total	796	4908	3095	1931
Age in years, mean ± SD	50.2±14.7	54.6±15.8*	47.5±17.3	48.1±17.2
Age category, (%)				
18-34	14.5	10.5	26.5	24.9
35-49	37.1	29.6	31.9	30.1
50-64	30.2	32.9	22.9	26.2
65-79	15.1	19.7	13.7	13.3
80 or more	3.1	7.3	5.1	5.5
Sex (%)				
Male	27.0	34.1	35.6	32.5
Race (%)				
White	42.3	45.7	38.5	44.9
African American	36.7	30.3	26.6	29.3
Hispanic	8.0	11.1	14.5	9.0
Asian	-	1.6	5.7	2.5*
Others	7.9	2.9	4.4	5.9
Unknown	5.0	8.5	10.3	8.4
Payer (%)				
Medicare	33.3	43.8*	21.7	27.3
Medicaid	28.8	21.6	26.6	23
Private	30.4	24.2	36.3	28.3*
Self	6.4	6.3	10.8	14.2
Other	1.2	4.2	4.6	7.2
Charlson-Deyo's co-morbidity index (%)				
1-2	94.9	82.5*	95.4	85.9*
3-4	3.2	14.5*	3.8	10.7*
5-6	-	2.3	0.1	2.5*
7 or more	1.8	0.8	0.7	0.8
Co-morbidities (%)				
Diabetes mellitus	27.4	34.9	12.3	23.8*
Congestive heart failure	19.7	22.4	7.9	13.5*
Morbid obesity	17.5	24.9	2.5	8.9*
Cancer	2.5	5.2	2.3	4.1
Alcoholism	-	2.5	2.5	5.7*
Smoking	20.4	36.8*	12.4	34.7*
Hospital Characteristics (%)				
Teaching status				
Teaching hospital	56.8	56.6	56.7	55.3
Hospital size				
Small	10.1	14.3	12.9	7.6*
Medium	26.0	23.0	34.5	30.5
Large	63.9	62.7	52.5	61.9*
Hospital ownership				
Government-Non federal	12.6	14.6	19.1	18.1
Private - non profit	78.9	75.5	69.8	69.3
Private - investor owned	8.4	9.8	11.1	12.6

* Significant difference between 2000 and 2008 at $p<0.05$

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Table 3: Outcomes of patients with acute asthma exacerbation: Comparison between 2000 and 2008.

	2000			2008		
	No MV	NIV	invasive mechanical ventilation	No MV	NIV	invasive mechanical ventilation
All cause in-hospital mortality, (%)	0.24	1.22	6.37	0.21	0.84	6.92
3 day mortality, (%)	0.08	-	2.3	0.05*	0.6	4.5
Prolonged mechanical ventilation (>96hrs)	-	-	23.1	-	-	18.2
Tracheostomy (%)	-	-	0.8	-	-	1.5
Pneumothorax (%)	-	-	0.9	-	-	1.2
Disposition in survivors, (%)						
Home	89.3	76.9	75.6	84.5*	76.2	70.9
Home with home care	4.3	15.5	7.0	7.7*	13.2	11.8*
Inter hospital transfer	0.7	0.6	5.6	0.7	1.0	4.6
Skilled nursing facility^	3.5	5.1	7.0	4.7*	6.3	9.0
AMA/unknown	2.3	1.9	5.1	2.4	3.4	3.6
Median lengths of hospital stay in days, Inter quartile range.	3(2-5)	4(2-7)	5(3-8)	3(2-5)	4(2-6)	5(3-8)

* Significant difference between 2000 and 2008 at $p<0.05$

^ Also includes intermediate care

Table 4: Risk of death in patients admitted with acute asthma exacerbation: 2000 vs. 2008

Models	Risk of death 2000 vs. 2008 Odds ratio (95% confidence interval)
Unadjusted	0.83 (0.66-1.04)
Adjusted for demographics (age, gender, race)*	0.67 (0.53-0.84)
Adjusted for demographics & co-morbid index*	0.58 (0.45-0.73)
Adjusted for above and mechanical ventilation*	0.64 (0.51-0.81)
Subgroup analysis adjusting for demographics & co-morbid index.	
Among those not receiving MV*	0.57 (0.45-0.73)
Among those receiving early NIV	0.41 (0.07-2.14)
Among those receiving early invasive mechanical ventilation	1.08 (0.63-1.84)

* Significant difference between 2000 and 2008 at $p<0.05$

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Table 5: Predictors of mortality in acute asthma exacerbation (multivariable analysis).

Predictors	Odds ratio (95% Confidence Interval)
Mechanical Ventilation	
No mechanical ventilation	Reference
NIV*	4.78(3.58-6.39)
invasive mechanical ventilation *	35.1(30.3-40.7)
Age category	
18-34	Reference
35-49*	1.80(1.26-2.57)
50-64*	4.59(3.29-6.41)
65-79*	12.3(8.71-17.3)
80 or more*	25.6(18.0-36.4)
Gender (%)	
Male	Reference
Female*	0.79(0.70-0.88)
Race (%)	
White	Reference
African American*	0.74(0.62-0.87)
Hispanic*	0.48(0.38-0.61)
Asian	0.94(0.70-1.26)
Others	0.63(0.42-0.93)
Unknown	0.89(0.78-1.02)
Primary Payer (%)	
Medicare	Reference
Medicaid	1.14(0.92-1.40)
Private	0.92(0.77-1.10)
Self	1.00(0.73-1.38)
Other	1.31(0.93-1.85)
Chalrson-Deyo's co-morbidity index (%)	
1-2	Reference
3-4*	2.12(1.84-2.44)
5-6*	2.87(1.95-4.21)
7 or more*	5.25(4.01-6.88)
Hospital Characteristics (%)	
Non teaching hospital	Reference
Teaching hospital	1.00(0.90-1.12)
Pneumothorax*	20.7(14.1-30.1)
Year	
2000	Reference
2001	1.16(0.93-1.45)
2002	0.97(0.78-1.21)
2003	1.03(0.83-1.27)
2004	0.89(0.71-1.11)
2005*	0.74(0.59-0.93)
2006*	0.72(0.57-0.91)
2007*	0.67(0.53-0.85)
2008*	0.64(0.51-0.81)

* Significant at $p<0.05$

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Figure 1: Selection of asthma cases for this study.

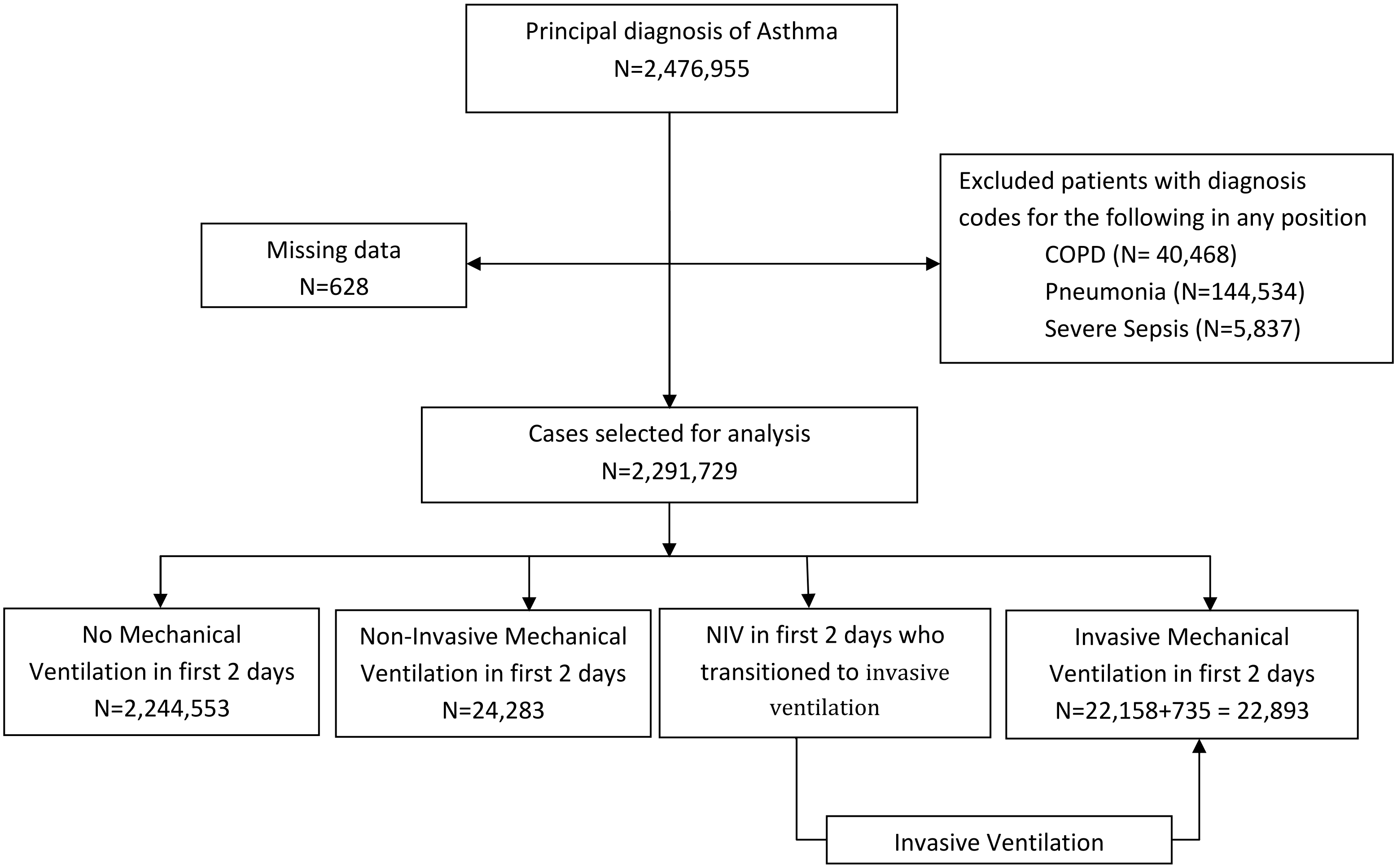

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Figure 2. Utilization of invasive and non-invasive mechanical ventilation in asthma (Bars represent standard error)