Nationwide trends in hospitalization, medical costs, and mortality for asthma after introduction of biologics: A cross-sectional study in the United States

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Plain language summary

In 2015, new treatments for severe asthma were introduced in the United States. Then during 2016-2018, hospital admission rates and readmission rates for asthma decreased though hospital costs increased. Trends in the length of the stay for a first hospital admission decreased. Death rates remained stable.

Implications for managed care pharmacy

This analysis showed that during 2016-2018, following the introduction of novel controller therapies such as biologics, there was a decreasing trend in asthma-related hospital admissions and readmissions although hospital costs increased.

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ABSTRACT

BACKGROUND: Asthma is the most common inflammatory lung disease in the United States. Since 2015, biologic therapies have provided targeted treatment for patients with severe asthma.

OBJECTIVE: To evaluate the trends for in-hospital outcomes of asthma before (2012-2014) and after (2016-2018) the introduction of biologic therapies for asthma.

METHODS: We conducted a nationwide cross-sectional analysis of patients aged 2 years or older who were hospitalized for asthma between 2012 and 2018 using data from the Nationwide Readmissions Database. Outcomes included rates of asthma hospital admission and asthma-related 30-day readmission, hospital length of stay, hospital costs, and inpatient mortality. Generalized linear models assessed trends in rates of asthma admission and readmission, length of stay, costs, and mortality quarterly during 2012-2014 and 2016-2018.

RESULTS: Among 691,537 asthma-related admissions, quarterly asthma admission rates significantly decreased (–0.90%, 95% CI = –1.46% to – 0.34%; $P = 0.002$) during 2016-2018, mainly among adults, but not during 2012-2014. Quarterly assessed readmission rates decreased by 2.40% (–2.85% to –1.96%; $P < 0.0001$) during 2012-2014 and by 2.12% (–2.74% to – 1.50%; $P < 0.0001$) during 2016-2018. Mean length of stay for asthma admissions decreased quarterly by 0.44% (–0.49% to – 0.38%; $P < 0.0001$) during 2012-2014 and by 0.27% (–0.34% to – 0.20%; $P < 0.0001$) during 2016-2018. Quarterly hospital costs for admissions were unchanged during 2012-2014 but increased by 0.28%

(0.21% to 0.35%; $P<0.0001$) during 2016-2018. There were no significant trends in inpatient mortality during 2012-2014 and 2016-2018.

CONCLUSIONS: After the introduction of new biologics for severe asthma in 2015, asthma-related hospital admissions decreased significantly, whereas hospital costs increased. Asthma-related 30-day readmission rates and length of stay for asthma admissions continuously decreased, whereas inpatient mortality rates remained stable.

Asthma is a common, chronic respiratory disease that affects 25 million Americans, approximately 8% of the US population.[1-3] Despite asthma prevalence remaining stable in the last few years,[4,5] asthma still poses significant public health and economic burdens for the US health care system and for society.[3,6] According to the Centers for Disease Control and Prevention, there were more than 1.8 million asthma-related emergency department visits and 169,330 hospitalizations in 2019.[7,8] Although mortality due to asthma has slowly decreased since 2001, overall no further reduction has been observed recently and asthma still accounts for more than 3,500 deaths each year, which may be attributed to racial, ethnic, geographical, or socioeconomic disparities in asthma burden.[9] The total annual cost of asthma in the United States equaled $89.1 billion in 2013, including direct and indirect costs,[10] representing more than $30 billion compared with 2007[11]; hospitalizations accounted for approximately 16% of the medical costs.[10] In addition, projected economic burden associated with uncontrolled asthma among US adolescents and adults older than 20 years (2019-2038) is estimated to be $300.6 billion (direct costs) and $963.5 billion (indirect cost added).[12]

In recent years, the emergence of biologic therapies for the treatment of asthma has provided promising targeted therapy for patients with severe uncontrolled asthma. In addition to anti–immunoglobulin E therapy (omalizumab in 2003) that has improved outcomes in allergic asthma for almost 2 decades, 3 anti–interleukin 5 biologics (mepolizumab in 2015, reslizumab in 2016, and benralizumab in 2017), 1 anti–interleukin 4 and anti–interleukin 13 biologic (dupilumab in 2018), and 1 agent targeting thymic stromal lymphopoietin (tezepelumab in 2021) have recently emerged as promising treatments for type 2 inflammation in asthma, which encompass systemic T helper 2–type responses and are broadly relevant across the severe asthma population.[13,14] The targeted therapies approved since 2015 have been shown in clinical trials to reduce asthma exacerbations, improve lung function, and decrease oral corticosteroid use.[1,15,16] Moreover, randomized clinical trials and observational studies have shown a reduction in hospitalizations with the use of biologic treatments.[13,17]

Despite the advent of novel pharmacological therapies and the implementation of several other efforts to improve asthma control during the last decades, including annual updates in the Global Initiative for Asthma clinical guidelines and quality improvement interventions (eg, the Hospital Readmission Reduction Program under the Affordable Care Act),[6,15,18-23] the quality of care provided to patients continues to be variable.[6,19,20] Although several studies have assessed asthma-related hospital readmissions and related factors and economic burdens,[24-26] these studies have included only young children.

Thus, we aimed to examine the trends in asthma-related hospital admissions and 30-day readmissions in the United States before (2012-2014) and after (2016-2018) anti-interleukin biologics for asthma treatment were widely available. We also assessed and compared trends in hospital length of stay, hospital costs, and inpatient all-cause mortality rates for those same periods.

Methods

DATA SOURCE

We conducted a cross-sectional study using 2012-2018 data in the Healthcare Cost and Utilization Project (HCUP) Nationwide Readmissions Database (NRD) from the Agency for Healthcare Research and Quality.[27] The NRD is a discharge-level database constructed from the State Inpatient Databases with verified patient linkage numbers that track individuals across hospitals within a state and capture all-payer inpatient care, and thus it provides nationally representative information on hospital readmissions. The database contains multistate data—28 states as of 2018—from approximately 18 million discharges each year and is weighted to estimate roughly 35 million discharges nationally.[27] NRD data include deidentified information for demographic characteristics, payers, diagnosis and procedure codes, admission sources, disposition after hospitalization, hospital length of stay, and total charges for hospitalization.[28] The institutional review board (IRB) at the University of Florida approved this study and waived the requirement for the need to obtain informed consent because the NRD contains deidentified, publicly available data. This study was conducted in compliance with all relevant regulations and guidelines. The IRB at the University of Florida reviewed the use of NRD, a large US database with deidentified publicly available data, and approved this study. The IRB waived the requirement for the need to obtain informed consent because this research was deemed exempt from being considered human subjects research.

STUDY POPULATION

The study included all patients who were admitted to a hospital from 2012 to 2018 with a primary diagnosis of asthma on discharge (*International Classification of Diseases, Ninth Edition, Clinical Modification* [ICD-9-CM] codes of 493.xx and ICD-10-CM codes of J45.xx, J44.9, J46.xx, J82.83, Z79.51, or Z79.52). We included patients with asthma aged 6 years or older because the biologic therapies for the treatment of asthma have been generally approved in patients aged 6 years or older (omalizumab was approved for adults and adolescents in 2003 and for children in 2016; reslizumab was approved for adults in 2016; mepolizumab, benralizumab, and dupilumab was approved for adults and adolescents in 2015, 2017, and 2018, respectively). Patients were excluded if they had a missing patient identification number or a missing hospital length of stay.

OUTCOME MEASUREMENTS

We examined the rates of asthma-related hospital admissions, asthma-related 30-day readmissions, and all-cause 30-day readmissions as the primary outcomes. The asthma admission rate was defined as the number of hospitalizations with a primary diagnosis of asthma on discharge divided by the number of total admissions recorded in the NRD data (per 100 admissions). Among the asthma admissions, we defined the index admission as any hospitalization with a primary diagnosis of asthma on discharge that did not result in patient death. The asthma-related 30-day readmission rate was defined as the number of index admissions for asthma with at least 1 subsequent asthma-related admission within 30 days divided by the total number of index admissions for asthma (per 100 index admissions). Similarly, the all-cause 30-day readmission rate was defined as the number of index admissions for asthma with at least 1 subsequent admission within 30 days divided by the total number of index admissions of asthma. A patient was allowed to have multiple index admissions, and readmission could also serve as an index admission for subsequent readmission, as suggested by HCUP.[29,30] Patients discharged in December were excluded because the HCUP databases are calendar-year files and December discharges could not be followed up for 30 days. No more than 1 readmission per index admission was counted within the 30 days.

The secondary outcomes included mean hospital length of stay, mean total hospital costs for index admissions and 30-day readmissions, and all-cause in-hospital mortality rates. The total hospital costs were calculated by converting total hospital charges using the HCUP Cost-to-Charge Ratio file and were adjusted for inflation to 2018 US dollars.[31] In addition, the all-cause in-hospital mortality rate among patients with asthma was calculated by dividing the number of deaths in the hospital by the total number of patients who were admitted with a primary diagnosis of asthma.

All variables that were used to assess the outcomes were weighted for national estimates according to HCUP standards based on the characteristics of the treating hospital and on patient factors.[27] Because previous reports have suggested that changes in ICD coding on October 1, 2015, may have affected the hospital coding system in 2015, data for 2015 were excluded from our analyses. To minimize confounding bias due to changes in ICD codes for asthma, we did not directly compare outcomes between 2012-2014 and 2016-2018 but assessed the slopes in the trends for outcomes within each study period.

COVARIATES

The covariates were patient characteristics, including demographic information (eg, age, sex, community-level income, and rural or urban residence) and clinical factors (eg, comorbidities and intubation or mechanical ventilation during hospital stays), and health care system and hospitalization-related factors (eg, expected payer, hospital ownership, admission type, disposition after hospitalization, and admission season). Comorbidities defined by ICD-9-CM and ICD-10-CM diagnosis codes included obesity, gastroesophageal reflux disease, anxiety, depression, rhinitis, sinusitis, nasal polyps, obstructive sleep apnea, atopic dermatitis, chronic obstructive pulmonary disease (COPD), tobacco use, cystic fibrosis, and anomalies of the respiratory system (see Supplementary Table 1, available in online article).[6,32] We included intubation or mechanical ventilation during hospitalization using ICD-9-CM and ICD-10-CM procedure codes as a marker of life-threatening asthma (see Supplementary Table 2).[33] We accounted for seasonality by including admission season considering there are seasonal fluctuations for asthma exacerbations, with high rates recorded in autumn.[6]

STATISTICAL ANALYSIS

Descriptive statistics were used to summarize patient characteristics, clinical factors, health care systems, and hospitalization-related factors. For the trends in outcomes, we calculated the outcomes each quarter, which included 24 time points (ie, 12 quarters during 2012-2014 and 12 quarters during 2016-2018) using generalized linear models (GLMs) and estimated coefficients for the slope of the regression line in each period. To evaluate the overall asthma-related hospital admission rate, we used dehydration (ICD-9-CM codes 276.xx, and ICD-10-CM codes E86.xx and E87.xx), a common cause of hospital admission, as a control group.[34] To evaluate crude and adjusted outcomes, we used GLMs

with a Poisson distribution for the trends in asthma-related hospital admission and asthma-related 30-day readmission, GLMs with a gamma distribution for the trends in hospital length of stay and costs, and GLMs with a negative binomial distribution for the trends in mortality.

Because biologics for asthma treatment were mainly approved for adults and adolescents (aged ≥12 years) during the study period, we conducted a subgroup analysis for asthma admission rate according to age groups and type of payers.

Statistical analyses were conducted using SAS version 9.4 (SAS Institute Inc.), and Stata version 16.0 (StataCorp). A 2-sided *P* value of less than 0.05 was considered statistically significant.

The data that support the findings of this study are available from the Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are, however, available from the authors upon reasonable request and with permission of the Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project.

Results

BASELINE CHARACTERISTICS OF PATIENTS WITH ASTHMA-RELATED HOSPITAL ADMISSION

We identified discharge records from 122,921 patients in 2012, 126,040 patients in 2013, 128,746 patients in 2014, 81,037 patients in 2016, 80,566 patients in 2017, and 77,045 patients in 2018 who were hospitalized with a primary diagnosis of asthma on discharge (Supplementary Table 3). Across all years, the majority of patients were female (range = 64.4%-66.6%), lived in large metropolitan areas with at least 1 million residents (range = 60.3%-62.3%), and were admitted to nonprofit private hospitals (range = 68.5%-74.7%) through the emergency department (range = 82.5%-86.6%). Approximately one-third of patients were Medicaid beneficiaries (range = 27.0%-38.3%).

Among total asthma-related hospital admissions, compared with 2012-2014, the proportion of patients aged 6-39 years increased in 2016-2018, whereas the proportion of patients aged 40 years or older decreased in 2016-2018. In addition, the proportion of patients with obesity, rhinitis, nasal polyps, atopic dermatitis, or COPD was higher in 2016-2018, whereas the proportion of patients with gastroesophageal reflux disease, depression, sinusitis, or tobacco use was lower in 2016-2018. The proportion of patients with intubation or mechanical ventilation during hospital stays was significantly increased between the 2 periods.

TRENDS IN HOSPITAL ADMISSION RATES FOR ASTHMA VS DEHYDRATION

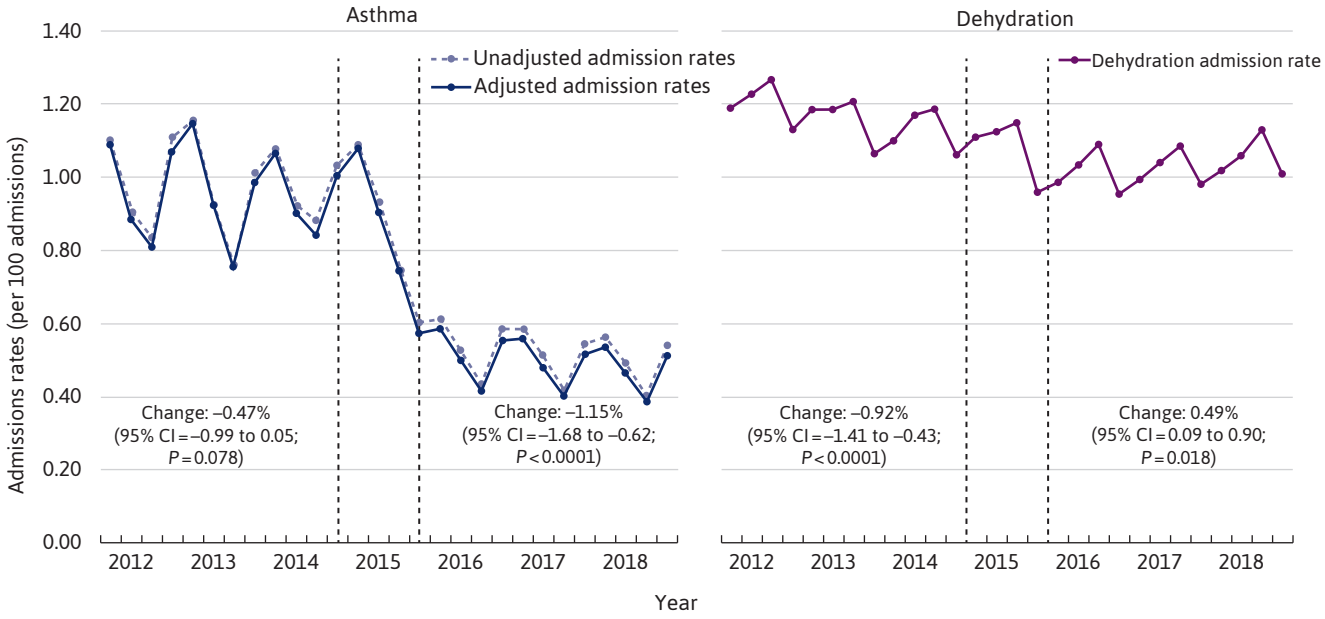
A statistically significant decrease in asthma-related admission rates was observed after adjustment for covariates (1.15% reduction in admission rates per quarter [95% CI = –1.68% to – 0.62%; $P < 0.0001$]) with seasonal fluctuations during 2016-2018 (Figure 1). During 2012-2014, there were no significant changes in hospital admission rates for asthma (0.47% reduction in admission rates per quarter [95% CI = –0.99% to 0.05%; $P = 0.078$]). The overall hospital admission rates for dehydration, which served as a control group, remained stable from 2012 to 2018, with a slightly decreasing trend during 2012-2014 (0.92% reduction per quarter [95% CI = –1.41% to – 0.43%; $P < 0.0001$]) and a slightly increasing trend during 2016-2018 (0.49% increase per quarter [95% CI = 0.09% to 0.90%; $P = 0.018$]) (Figure 1).

The age subgroup analysis for trends in hospital admission rates for asthma showed much higher admission rates across the entire period for patients aged 6-11 years and those with Medicaid coverage (Supplementary Figure 1 and Supplementary Figure 2). Notably, admission rates for the youngest group showed an increasing trend during 2012-2014 (2.03% increase per quarter [95% CI = 0.71% to 3.35%; $P = 0.003$]) but the trend became stable during 2016-2018. The trend in hospital admission rates for asthma in adolescents also remained unchanged during the 2 time periods (1.37% increase per quarter [95% CI = –0.37% to 3.01%; $P = 0.101$] during 2012-2014; 0.43% reduction per quarter [95% CI = –2.13% to 1.28%; $P = 0.621$] during 2016-2018). The admission rates for adults showed a significantly decreasing trend among patients aged 40-64 years (1.40% reduction per quarter [95% CI = –2.09% to 0.72%; $P < 0.0001$]) and 65 years or older (1.75% reduction per quarter [95% CI = –2.38% to –1.11%; $P < 0.0001$]) during 2016-2018.

TRENDS IN ASTHMA-RELATED 30-DAY HOSPITAL READMISSION RATES

Figure 2A provides the crude and adjusted asthma-related 30-day readmission rates. During 2012-2014, the quarterly estimated readmission rates ranged from 4.37 to 5.35 per 100 admissions and decreased quarterly by 2.42% (95% CI = –2.87% to –1.97%; $P < 0.0001$). During 2016-2018, the quarterly estimated readmission rates ranged from 3.39 to 4.33 per 100 admissions, and the decreasing trend was similar to that observed during 2012-2014 (2.14% reduction per quarter [95% CI = –2.78% to –1.50%]; $P < 0.0001$). The all-cause 30-day readmission rates were similar to the asthma-related 30-day readmission rates (Figure 2B).

FIGURE 1 Trends in Admission Rates for Asthma and Dehydration (Control) Per Quarter During 2012-2014 and 2016-2018



Adjusted mean admission rate was estimated using generalized linear models with a Poisson distribution after controlling for patient characteristics, health care systems, and hospitalization-related factors.

HOSPITAL LENGTH OF STAY DURING ASTHMA-RELATED INDEX ADMISSIONS AND 30-DAY READMISSIONS

The hospital length of stay for asthma-related readmissions was longer than that for asthma index admissions during the study period (Figure 3A). The length of stay for index admissions during 2012-2014 ranged from 3.40 to 3.63 days and decreased quarterly by 0.44% (95% CI = –0.50% to – 0.38%; P < 0.0001), and during 2016-2018, they ranged from 3.09 to 3.21 days and decreased quarterly by 0.26% (95% CI = –0.33% to – 0.18%; P < 0.0001). Hospital length of stay for readmissions during 2012-2014 decreased from 4.24 to 3.64 days and showed a decreasing trend (–0.63%; 95% CI = –0.95% to – 0.32%; P < 0.0001) and continued decreasing from 3.87 to 3.33 days during 2016-2018 (–0.46%; 95% CI = –0.89% to – 0.02%; P = 0.039).

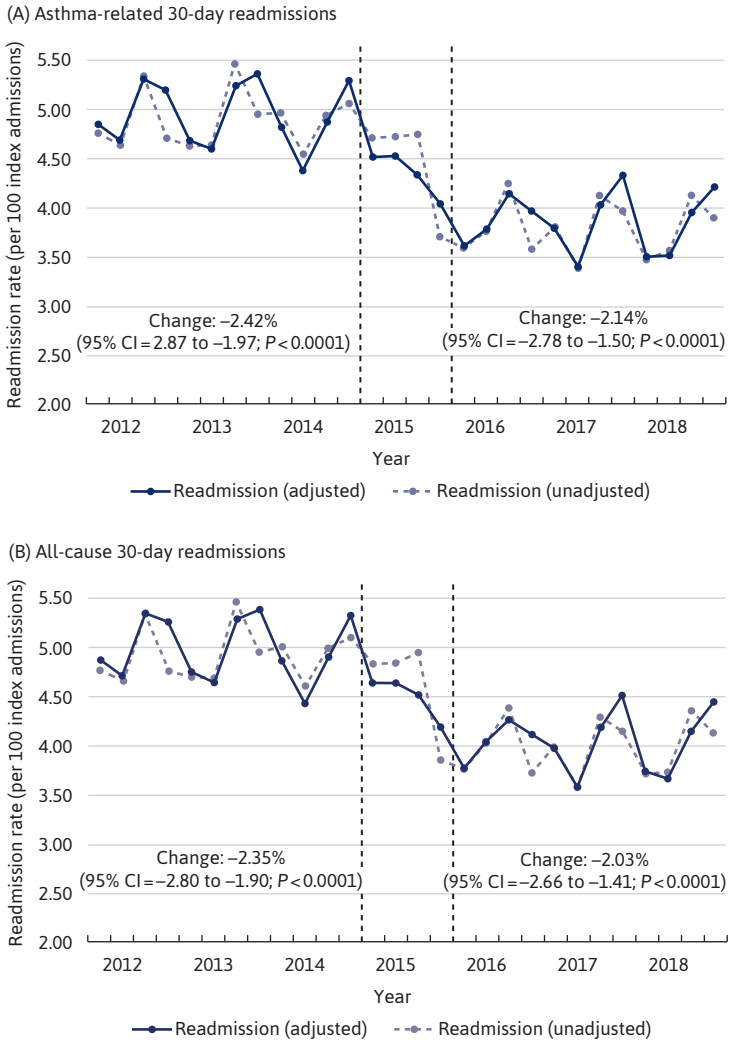
ECONOMIC BURDEN FOR ASTHMA-RELATED INDEX ADMISSIONS AND 30-DAY READMISSIONS

After adjusting for covariates and inflation, the mean total hospital cost for asthma-related 30-day readmissions was higher than that for asthma-related index admissions (Figure 3B). The hospital costs for index admissions showed a slightly decreasing trend during 2012-2014 (0.07% reduction per quarter [95% CI = – 0.13% to – 0.01%; P = 0.028]), but during 2016-2018, the cost ranged from $7,051 to $7,504, with an increasing trend in the quarterly change of 0.23% (95% CI = 0.15% to 0.30%; P < 0.0001). By contrast, the hospital cost for readmission during 2012-2014 ranged from $8,103 to $9,402 and showed a decreasing trend (– 0.56%, – 0.90% to – 0.23%; P = 0.001), but the trend was not statistically significant during 2016-2018 (range, $8,017 - $9,172; P = 0.582). When analyzed by type of payers, overall hospital cost was higher in patients with Medicare and private insurance compared with Medicaid (Supplementary Figure 3).

INPATIENT ALL-CAUSE MORTALITY RATES

The adjusted inpatient all-cause mortality rate remained stable during both 2012 - 2014 and 2016-2018, with ranges between 0.27% and 0.40% during 2012-2014 and between 0.31% and 0.51% during 2016-2018. There was no statistically significant trend in inpatient all-cause mortality rates during either period (2012-2014: 0.07%, 95% CI = –1.47% to 1.61% [P = 0.930]; 2016-2018: – 0.12%, 95% CI = –1.94 to 1.71 [P = 0.900]) (Supplementary Figure 4).

FIGURE 2 Trends in 30-Day Readmission Rates Per 100 Index Admissions Per Quarter During 2012-2014 and 2016-2018



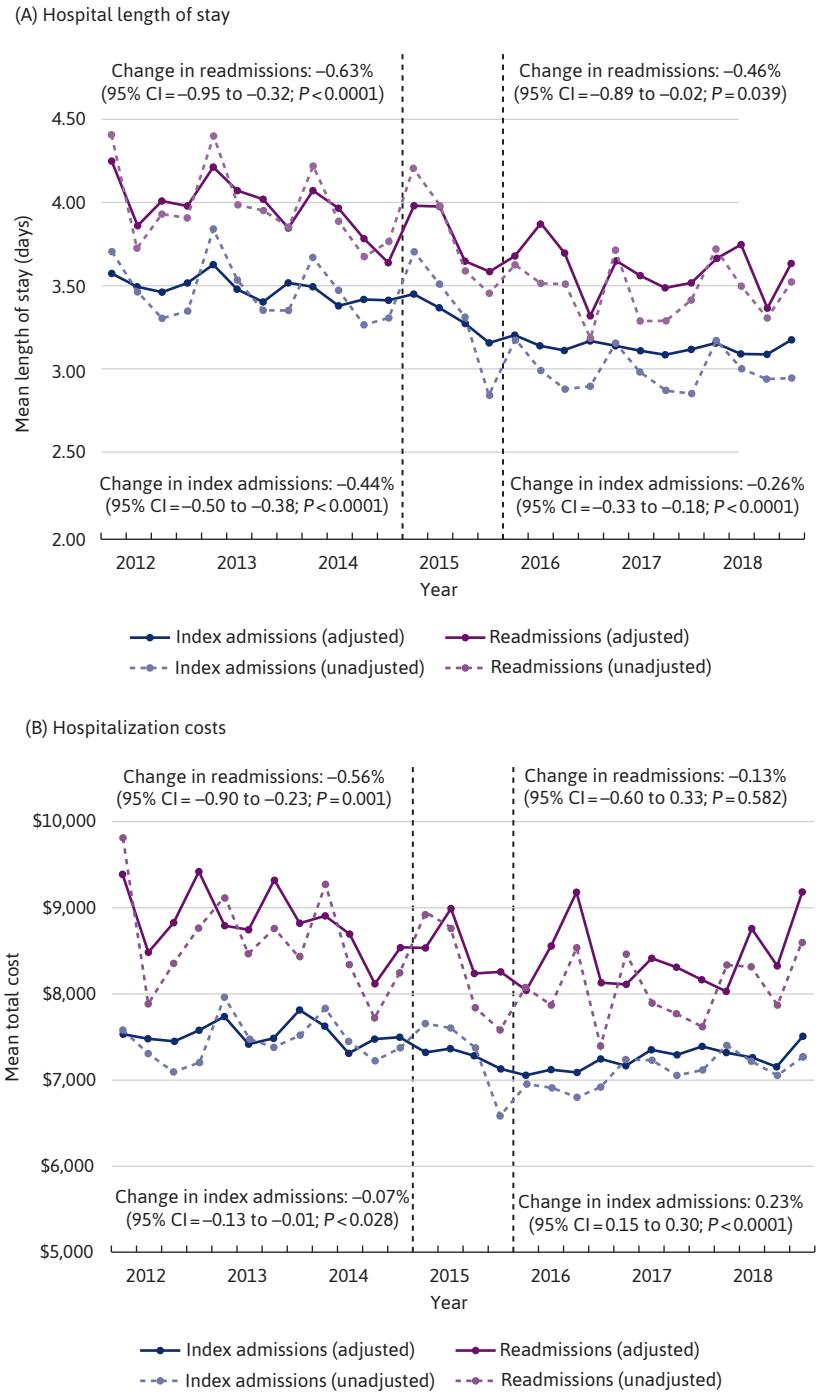
Adjusted mean readmission rate was estimated using generalized linear models with a Poisson distribution after controlling for patient characteristics, health care systems, and hospitalization-related factors. For asthma-related 30-day readmission, International Classification of Diseases, Ninth Edition, Clinical Modification [ICD-9-CM] codes of 493.xx and ICD-10-CM codes of J45.xx, J44.9, J46.xx, J82.83, Z79.51, or Z79.52) were used for 2012-2014 and 2016-2018, respectively.

Discussion

In this nationwide cross-sectional analysis of patients admitted to the hospital for asthma, we evaluated trends in asthma-related hospital admission and readmission rates before and after the approval of new biologics for treatment of asthma. Our key findings included a significant decreasing trend in admission rates after the introduction of new biologics, mainly in adults, and a continuously decreasing trend in asthma-related 30-day readmission rates during 2012-2014 and 2016-2018, seperately. In addition, the mean hospital length of stay for index admissions showed a decreasing trend, whereas the mean hospital cost for index admissions showed an increasing trend during 2016-2018. Inpatient all-cause mortality rates remained stable for both 2012-2014 and 2016-2018.

Randomized clinical trials have shown that new biologics reduce exacerbation rates and improve lung function among patients with severe uncontrolled asthma.[16] Clinical trials and recent Cochrane reviews of randomized clinical trials have reported that each biologic treatment has shown a reduction in the rate of asthma exacerbation leading to hospitalization.[35-37] However, owing to variations in inclusion criteria and natural variations in enrolled cohorts, baseline clinical traits and severity among study populations for asthma biologic trials differed significantly (eg, omalizumab for patients with moderate to severe allergic asthma and dupilumab for patients with moderate to severe asthma with an eosinophilic phenotype or with oral corticosteroid–dependent asthma). Thus, little is known about the real-world clinical impact of biologic therapy in the overall asthma population.[1] Although changes in the ICD codes in 2015 must be considered when comparing data from 2012-2014 with 2016-2018, there was no significant change in the control population with a diagnosis of dehydration during 2015. Further studies need to investigate this association, but the introduction of new biologics were possibly associated with decreasing trends in the asthma-related admissions rate during 2016-2018. In fact, asthma treatment visits in which a biologic therapy was reported increased from approximately 0.1% of asthma-related visits in 2013 to 1% in 2015 and doubled to 2% by 2019 in the United States, of which omalizumab accounted for 37%, mepolizumab 21%, benralizumab 27%, dupilumab 15%, and reslizumab less than 1% in 2019.[38]

FIGURE 3 Trends for Asthma Index Admissions and Readmissions Per Quarter During 2012-2014 and 2016-2018



Adjusted mean hospital length of stay and mean total costs were estimated using generalized linear models with a gamma distribution after controlling for patient characteristics, health care systems, and hospitalization-related factors. For asthma-related 30-day readmission, International Classification of Diseases, Ninth Edition, Clinical Modification [ICD-9-CM] codes of 493.xx and ICD-10-CM codes of J45.xx, J44.9, J46.xx, J82.83, Z79.51, or Z79.52) were used for 2012-2014 and 2016-2018, respectively.

Furthermore, real-world studies have similarly demonstrated a reduction in exacerbation and potential hospitalization with each biologic therapy.[39-41] We also observed a decreasing trend in asthma-related 30-day readmission rates for both 2012-2014 and 2016-2018. This finding suggests that the introduction of new biologics did not appear to reduce readmission rates as much as it did index admission rates among patients with asthma. This finding may be explained by the role of biologic therapy in improving asthma control and consequently lowering the necessity of hospitalization, whereas biologic therapy may not have changed the quality of care or best practices for treatment by health care professionals during inpatient settings that may be related to readmissions.

A previous study assessing patients with asthma and analyzing data for 2001-2010 reported a slight decrease in hospital length of stay after 2008.[42] Our study, providing more recent findings, indicated that the mean hospital length of stay improved from 2012 through 2018. The mean hospital length of stay decreased for asthma index admissions and readmissions although the latter was not statistically significant during 2016-2018. Despite decreased hospital length of stay for index admissions, the economic burden for patients hospitalized with asthma consistently increased over the study period. Considering that severe asthma affects 10% of patients with asthma but accounts for 50% of all health care costs,[43] it is important to understand the reasons costs continued to increase over time despite decreased readmission rates and hospital length of stay. One explanation may be that an increasing proportion of patients with asthma and comorbid respiratory diseases (eg, COPD was 5.4% in 2012 vs 13.4% in 2018) and an increasing proportion of patients with asthma admitted to hospitals through an emergency department (81.3% in 2012 vs 85.4% in 2018) may require more resources and may result in more aggressive respiratory care during hospital stays and increases in hospital costs despite decreased hospital length of stay. Another potential explanation for high hospital costs is the increasing use of noninvasive positive pressure ventilation for patients with acute asthma exacerbation.[44] Although the use of this type of ventilation has been associated with decreased length of stay among patients hospitalized with asthma,[45] its use may increase hospital costs because it mainly occurs in the intensive care unit or respiratory intermediate intensive care unit setting.[46,47]

Our study found that inpatient all-cause mortality rates remained relatively stable among patients hospitalized for asthma, with nonsignificant changes in trends during 2012-2014 and 2016-2018. According to the asthma surveillance data from the US National Health Interview Survey, the asthma mortality rate decreased significantly, with −2.1% annual change ($P = 0.049$) during 2014-2018.[48] However, the surveillance data analyzed mortality rates in a study population with asthma as an underlying cause of death (ie, asthma-related mortality), whereas we analyzed all-cause mortality among patients hospitalized with a primary diagnosis of asthma. Thus, the difference in mortality rates obtained by the 2 studies may be explained by the type of mortality assessed. Further studies are needed with long-term follow-up data to examine the effects of biologic treatment on mortality rates among patients with asthma.

LIMITATIONS

This study has several limitations. First, we could not rule out confounding by the change in ICD coding. Although data for 2015 were excluded from the analysis, the change in the ICD coding system may have impacted diagnoses that were recorded during 2016-2018. Second, owing to a lack of prescription data, we were unable to distinguish patients who received biologic treatment from those who did not. Thus, even though we observed a decreasing trend in the rate of asthma-related hospital admissions, we cannot compare clinical outcomes based on exposure to biologic treatment. Third, because this was a cross-sectional study and was subjected to the inherent limitations of NRD data, we could not follow-up with individual patients across years and it may be possible that admissions recorded in January were readmissions from the prior year. Fourth, we were unable to ascertain several clinical and sociodemographic variables that may be associated with the risk of asthma-related admissions or readmission, such as race and ethnicity, prescribed medication, adherence to asthma medication, or severity of asthma at the initial hospitalization. Fifth, although HCUP data are considered to be accurate and are widely used to estimate diagnoses and hospital admission frequency, it is possible that incomplete, missing, or miscoded claims may impact study findings, especially, during the ICD code transition period.[5,49] Finally, because this was an observational study, we were unable to determine causal effects of the emergence of new biologics on readmission, hospital length of stay, costs, and mortality-rate outcomes.

Our study has several strengths, the greatest of which may be the use of a large representative database, enabling a population-level analysis. This study assessed not only asthma-related admission and readmission rates but also hospital length of stay, hospital costs, and inpatient mortality rate, which advanced our understanding regarding the quality of care for patients with asthma. Moreover, our study findings

may be generalizable to patients with asthma of all ages in the United States because we included both pediatric and adult patients in the study population. In addition, since episode-based bundled payments were introduced by Medicare in 2013 by the Bundled Payment for Care Improvement, some readmissions may not be captured in claims databases if the claims were from participating hospitals, whereas the NRD database could capture readmissions as it included discharge records.

Conclusions

This nationally representative cross-sectional analysis provides an assessment of the trends in asthma-related hospital admission rates and relevant outcomes, including readmission and mortality, after the introduction of biologic therapies for asthma treatment. The findings suggest that the introduction of novel controller therapies, such as biologics, may be associated with a decreasing trend in asthma-related hospital admissions during 2016-2018.

Future studies must continue to investigate the effects of recent biologics on asthma-related health and economic outcomes.

DISCLOSURES

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The data that support the findings of this study are available from the Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of the Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project.

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