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Improving Quality of Acute Asthma Care in US Hospitals

Changes Between 1999-2000 and 2012-2013

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BACKGROUND: Little is known about the longitudinal change in the quality of acute asthma care for hospitalized children and adults in the United States. We investigated whether the concordance of inpatient asthma care with the national guidelines improved over time, identified hospital characteristics predictive of guideline concordance, and determined whether guideline-concordant care is associated with a shorter hospital length of stay (LOS).

METHODS: This study was an analysis of data from two multicenter chart review studies of hospitalized patients aged 2 to 54 years with acute asthma during two time periods: 1999-2000 and 2012-2013. Outcomes were guideline concordance at the patient and hospital levels, and association of patient composite concordance with hospital LOS.

RESULTS: The analytic cohort for the comparison of guideline concordance comprised 1,634 patients: 834 patients from 1999-2000 vs 800 patients from 2012-2013. Over these 15 years, inpatient asthma care became more concordant at the hospital-level, with the mean composite score increasing from 74 to 82 ($P < .001$). However, during 2012-2013, wide variability in guideline concordance of acute asthma care remained across hospitals, with the greatest variation in provision of individualized written action plan at discharge (SD, 36). Guideline concordance was significantly lower in Midwestern and Southern hospitals compared with Northeastern hospitals. After adjusting for severity, patients who received care perfectly concordant with the guidelines had significantly shorter hospital LOS (–14% [95% CI, –23 to –4]; $P = .009$).

CONCLUSIONS: Between 1999 and 2013, the guideline concordance of acute asthma care for hospitalized patients improved. However, interhospital variability remains substantial. Greater concordance with evidence-based guidelines was associated with a shorter hospital LOS.

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KEY WORDS: asthma; guideline; hospitalization; quality of care

ABBREVIATIONS: LOS = length of stay; MARC-37 = 37th Multicenter Airway Research Collaboration; NAEPP = National Asthma Education and Prevention Program; UHC = University HealthSystem Consortium

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Asthma is an important public health problem in the United States. In 2011, 26 million Americans had asthma, with an estimated direct cost of $50 billion annually.[1] Acute asthma (or asthma exacerbation) accounts for a substantial proportion of this burden (eg, 347,000 hospitalizations in 2013).[2] To reduce the societal burden, in *Healthy People 2020*,[3] the US government promoted asthma care that is more concordant with the National Asthma Education and Prevention Program (NAEPP) guidelines[4] as a nationwide objective.

Assessment of concordance with evidence-based guideline recommendations is commonly used to examine quality of care and identify care gaps for quality improvement efforts.[5] However, compared with other disease conditions (eg, heart failure),[6,7] the quality of acute asthma care among hospitalized patients, a population with high morbidity and high health-care utilization, has received less attention. Indeed, most studies have focused on the quality of chronic care in patients with asthma[8-10] or those in an ambulatory care setting.[11-15] In addition, the inferences of previous studies on quality of inpatient care were potentially limited because of highly selected populations (eg, single-center study, patients in freestanding children's hospitals),[16-22] use of administrative data sets,[17,18] and limited number of quality measures (eg, three Children's Asthma Care measures).[17-21] Despite the apparent importance of this issue, little is known about whether the guideline concordance of inpatient asthma care for children and adults improved (or deteriorated) over time.

To address this knowledge gap, we analyzed the data from two multicenter observational studies of children and adults hospitalized for acute asthma; the earlier study examined care during 1999-2000, and the recent study focused on 2012-2013. The three study objectives were as follows: (1) to investigate the change in concordance of inpatient acute asthma management with NAEPP guidelines over these 15 years; (2) to identify hospital characteristics predictive of guideline concordance; and (3) to determine whether guideline-concordant care is associated with hospital length of stay (LOS).

Methods and Materials

Study Design and Setting

The current analysis combined the data from two multicenter observational studies of children and adults hospitalized for acute asthma that examined care in 1999-2000 and 2012-2013, respectively. In the earlier study, the University HealthSystem Consortium (UHC) conducted a multicenter observational study of hospitalized patients (aged 2-54 years) with acute asthma (the UHC Asthma Clinical Benchmarking Project).[23] The UHC study consisted of chart reviews to assess patient characteristics, presentation of asthma exacerbation, inpatient asthma management, and disposition. The design, setting, and methods of data collection used in the study have been reported previously,[24,25] with key elements as described later in the present article.

We recently completed another multicenter chart review study to characterize children and adults hospitalized for acute asthma and to determine the quality of their inpatient asthma care during 2012-2013.[26-29] This study, the 37th Multicenter Airway Research Collaboration (MARC-37), was coordinated by the Emergency Medicine Network, a collaboration with 235 participating hospitals.[30] To better evaluate secular changes in inpatient asthma care, hospitals were recruited for MARC-37 by primarily inviting the sites that had participated in the earlier UHC study. A total of 25 hospitals across 18 states completed the MARC-37 study (e-Fig 1, e-Table 1). In both studies, patients were managed at the discretion of the treating physician. The institutional review board of participating hospitals approved the study (2014P001083).

Participants

In MARC-37, each hospital used the *International Classification of Diseases, Ninth Revision, Clinical Modification,* code 493.xx[31] to identify all hospitalizations with a principal discharge diagnosis of asthma during any 12-month period from January 1, 2012, to December 31, 2013 (ie, each hospital used a 24-month window from which to select the 12-month study period). Similar to the 1999-2000 study, the inclusion criteria were hospitalizations made by patients aged 2 to 54 years with a history of physician-diagnosed asthma before the index hospitalization. The following were excluded: (1) hospitalizations made by patients with a history of physician-diagnosed COPD or cystic fibrosis; (2) transfer hospitalizations; (3) hospitalizations not prompted largely by asthma exacerbation, in the judgment of the site Principal Investigator (a board-certified allergist/immunologist, pulmonologist, pediatrician, and/or emergency physician); and (4) repeat hospitalizations during the 12-month study period by the same individual. In the case of repeat hospitalizations, we only included a single randomly sampled hospitalization. This method was used to avoid systematic retention of the earlier (or later) hospitalization during the 12-month period that would result in overrepresentation of hospitalizations that occurred earlier (or later) in the 12-month period.

Methods of Measurement

In the MARC-37 study, onsite chart abstractors reviewed medical records of 40 hospitalized patients who were randomly selected by the Emergency Medicine Network Coordinating Center at Massachusetts General Hospital. All abstractors were trained with a 1-h online lecture, followed by the review of two practice medical records, which were evaluated against a criterion standard. If a reviewer's accuracy was <80% per medical record, the reviewer was retrained.

By using a standardized form, both in the UHC and MARC-37 studies, data were abstracted from medical records during hospitalizations, ED visits, and office visits with primary care physicians or asthma specialists. The measured variables included patients' demographic characteristics, primary care physician status, primary insurance type, asthma history, current asthma medications, details of the

current asthma exacerbation, inpatient asthma management, hospital disposition, hospital LOS (in days), discharge medications, and posthospitalization asthma care. Hospital LOS was defined as a total duration of inpatient stay, including observation status/unit, regular ward, stepdown unit, and/or ICU. We also collected a site survey from each participating hospital. Hospital-level characteristics included annual volume of hospitalizations, annual volume of asthma-related hospitalizations, and US region.

Quality Measures

On the basis of common recommendations included in the 1997 and 2007 NAEPP guidelines,[4,32] we derived a priori 10 explicit process measures to be applied to patients eligible to receive the specified management. These process measures included five Level A and five Level B evidence-based measures (Table 1). First, these evidence-based process measures were summarized by using a single patient composite concordance score. The patient composite concordance score was computed by summing the guideline-concordant care measures for each patient, dividing this sum by the patient's total number of eligible opportunities, and then multiplying by 100.[33] These scores were then averaged across patients at the hospital level to obtain hospital composite scores.[34] Scores ranged from 0 to 100, with a score of 100 indicating perfect guideline concordance. To determine whether the concordance varied according to level of evidence, we also computed the scores for Level A and Level B guideline-recommended measures separately.

Data Analysis

At the patient level, the change in the item-by-item concordance scores and the composite concordance scores between the time periods were

TABLE 1] Description of Quality Measures for Inpatient Acute Asthma Care

Process Measures	Numerator	Denominator	Level of Evidence According to EPR-3
Treatment with inhaled β-agonists in the inpatient setting	Inhaled β-agonist given in the inpatient setting	Patients being hospitalized with an asthma exacerbation	A
Treatment with inhaled anticholinergic agents in the inpatient setting	Not given inhaled anticholinergic agents in the inpatient setting	Patients being hospitalized with an asthma exacerbation	A
Treatment with systemic corticosteroids in the inpatient setting	Systemic corticosteroids given in the inpatient setting	Patients being hospitalized with an asthma exacerbation	A
Treatment with methylxanthines in the inpatient setting	Not given methylxanthines in the inpatient setting	Patients being hospitalized with an asthma exacerbation	A
Treatment with oral corticosteroids at hospital discharge	Oral corticosteroids given at hospital discharge	Patients being hospitalized with an asthma exacerbation and discharged	A
Treatment with inhaled corticosteroids at hospital discharge	Initiation of inhaled corticosteroid at hospital discharge Continuation of inhaled corticosteroids initiated at hospital discharge	Patients not taking inhaled corticosteroids prior to the hospitalization, and being discharged Patients taking inhaled corticosteroids prior to the hospitalization, and being discharged	B
Treatment with antibiotics in the inpatient setting	Not given antibiotics in the inpatient setting	Patients being hospitalized with an asthma exacerbation. Exclusion: infections that are generally of bacterial origin (eg, pneumonia, otitis media, pharyngitis, sinusitis)	B
Treatment with oral antibiotics at hospital discharge	Not given oral antibiotics at hospital discharge	Patients being hospitalized with an asthma exacerbation and discharged. Exclusion: infections that are generally of bacterial origin (eg, pneumonia, otitis media, pharyngitis, sinusitis)	B
Written asthma action plan at hospital discharge	Individualized written asthma action plan given at hospital discharge	Patients being hospitalized with an asthma exacerbation and discharged	B
Follow-up asthma care appointment at hospital discharge	Instruction for a follow-up asthma care appointment within 1-4 wk at hospital discharge	Patients being hospitalized with an asthma exacerbation and discharged	B

EPR-3 = Third Expert Panel Report.

examined by using χ^2 or unpaired *t* tests. At the hospital level, these changes were examined by using paired *t* tests to account for correlations within hospitals. The 1999-2000 vs 2012-2013 comparison was based on the 20 hospitals that participated in both studies (n = 834 and n = 800, respectively).

To identify hospital characteristics associated with patient-level guideline concordance in the 2012-2013 period, we fitted a hierarchical model (mixed-effects linear regression model) adjusting for 11 patient-level covariates (age, sex, race/ethnicity, insurance, primary care physician status, current use of systemic corticosteroids and inhaled corticosteroids, comorbidities, and respiratory rate, oxygen saturation, and initial peak flow at hospitalization). For regressions, the data from all MARC-37 participating hospitals (1,000 patients from 25 hospitals) were used; the inclusion of additional hospitals enhanced the generalizability and statistical power. To account for missingness of the covariates, a multiple imputation approach was used.[35] The details of the imputation method are described in e-Appendix 1.

To investigate the association of patient composite concordance score with hospital LOS for acute asthma in the 2012-2013 period, we next constructed a multivariable negative binomial model with estimating SEs.[36] We adjusted for the 11 patient-level covariates and dummy variables for the 25 participating sites (ie, site fixed effects). The patient composite score was treated as a dichotomous independent variable (perfect vs imperfect concordance) because of highly skewed distribution. In addition, dichotomizing concordance enabled us to determine how results differed by using an all-or-none quality metric.[37] For the models, four Level A evidence-based inpatient care variables were used for calculating the composite score (ie, use of inhaled β-agonists and systemic corticosteroids, nonuse of inhaled anticholinergic agents or methylxanthines during the inpatient course) to give more weight to the treatments that might be associated with hospital LOS.[4]

Results

The analytic cohort for the comparison of inpatient acute asthma care comprised 1,634 patients (729 children and 905 adults): 834 patients from 1999-2000 vs 800 patients from 2012-2013. Hospitalized patients with acute asthma in the 2012-2013 period were older and less likely to be non-Hispanic white race and have a public health insurance (all, $P < .05$) (Table 2). The proportion of patients who were hospitalized for acute asthma in the preceding year was 65% in the 1999-2000 period and 58% in the 2012-2013 period ($P = .01$). Likewise, use of long-term control medications before the index hospitalization increased over the time periods. For instance, the proportion of patients who had been treated with inhaled corticosteroids increased from 35% to 55% ($P < .001$). At the ED or clinic presentation, patients in the 2012-2013 period were more likely to receive systemic corticosteroids and inhaled anticholinergic agents (both, $P < .001$). After ED or clinic management, 16% of patients were hospitalized in the ICU in 1999-2000 vs 19% in 2012-2013 ($P = .004$). The median hospital LOS was 2 days (interquartile range, 1-3 days) in both periods.

Change in Guideline Concordance

At the patient level, inpatient asthma care became more concordant, with a composite concordance score of 74 (SD, 14) in 1999-2000 rising to 82 (SD, 14) in 2012-2013 ($P < .001$) (Fig 1). This significant improvement persisted with stratification according to level of recommendation (ie, the recommendations based on Level A and Level B evidence; both, $P < .001$) and according to age group (ie, children and adults; both, $P < .001$) (e-Table 3). Although item-by-item measures revealed that most of the process measures improved, the proportion of patients who received an instruction for a follow-up asthma care appointment declined from 87% to 80% ($P < .001$) (Table 3).

The level of concordance varied considerably according to quality measure in the 2012-2013 period. Using 70% as the criterion standard,[14] inpatient asthma care remained disconcordant in two areas: nonuse of inhaled anticholinergic agents (50% did not receive these drugs, which is consistent with the recommendation not to use after the initial emergency treatment) and provision of individual written action plan at discharge (61%).

At the hospital level, inpatient asthma care also became more concordant over the two time periods, with a mean composite score of 74 (SD, 6) rising to 82 (SD, 7; $P < .001$) (Fig 2, Table 3). However, in the 2012-2013 period, the variability in guideline concordance remained wide across hospitals. The best-performing hospital scored 92, whereas the worse-performing hospital scored 66. Specifically, guideline concordance with the recommendations based on Level B evidence was variable (e-Fig 2), with the greatest variation in provision of individualized written action plans at discharge (SD, 36).

Association of Hospital Characteristics with Guideline Concordance in 2012-2013

After adjusting for 11 patient-level characteristics and clustering of patients within hospitals, Midwestern (−7.86 [95% CI, −11.4 to −4.34]; $P < .001$) and Southern (−4.10 [95% CI, −7.89 to −0.31]; $P = .03$) hospitals had lower composite scores compared with Northeastern hospitals (Table 4). The sensitivity analysis that excluded all patients who died during hospitalization or who left the hospital against medical advice did not materially change any of these results.

TABLE 2] Patient and Hospital Characteristics According to the Time Period

Characteristic	1999-2000 (n = 834)	2012-2013 (n = 800)	*P* Value
Patient characteristics			
Demographics			
Age, y			< .001
2-4	150 (18)	111 (14)	
5-11	215 (26)	149 (19)	
12-17	62 (7)	42 (5)	
18-29	97 (12)	109 (14)	
30-39	138 (17)	152 (19)	
40-54	172 (21)	237 (30)	
Female	451 (54)	421 (53)	.56
Race/ethnicity[a]			< .001
Non-Hispanic white	293 (35)	217 (27)	
Non-Hispanic black	386 (46)	413 (52)	
Hispanic ethnicity	135 (16)	99 (12)	
Others	16 (2)	31 (4)	
Having primary care physician	621 (74)	596 (75)	.99
Health insurance[a]			< .001
Private	150 (18)	223 (28)	
Public	534 (64)	377 (47)	
No insurance	125 (15)	140 (18)	
Current smoker	142 (17)	176 (22)	.79
Chronic asthma factors			
History of hospitalization for asthma	538 (65)	467 (58)	.01
Current use of oral corticosteroids	184 (22)	227 (28)	.003
Current use of inhaled corticosteroids	291 (35)	440 (55)	< .001
Current use of long-acting β-agonist	127 (15)	250 (31)	< .001
Current use of leukotriene receptor antagonists or modifiers	76 (9)	164 (21)	< .001
Presentation and ED/clinic course			
Duration of symptoms ≤ 24 h	47 (6)	53 (7)	.37
Vital signs			
Initial respiratory rate, breaths/min, median (IQR)	28 (24-40)	28 (7-42)	< .001
Initial oxygen saturation on room air, %, median (IQR)	94 (91-97)	95 (91-97)	.07
Initial PEF, L/min,[b] median (IQR)	150 (110-210)	230 (175-300)	.03
Concomitant medical disorders[c]	228 (27)	212 (27)	.75
Acute asthma treatment			
Systemic corticosteroids	663 (80)	715 (89)	< .001
Inhaled anticholinergic agents	402 (48)	529 (66)	< .001
IV magnesium	64 (8)	275 (34)	< .001
Mechanical ventilation[d]	22 (3)	57 (7)	< .001
Hospitalized from ED	712 (85)	759 (95)	< .001

(Continued)

TABLE 2] *(Continued)*

Characteristic	1999-2000 (n = 834)	2012-2013 (n = 800)	*P* Value
Inpatient course			
Initial admission location			.004
ED observation unit	43 (5)	67 (8)	
Hospital ward or stepdown unit	662 (79)	584 (73)	
ICU	129 (16)	149 (19)	
Hospital length of stay, d, median (IQR)	2 (1-3)	2 (1-3)	.99
Discharged to home[e]	834 (100)	777 (97)	< .001
	n = 20	n = 20	
Hospital characteristics			
No. of hospitalizations per year, median (IQR)	20,263 (18,965-29,873)	25,949 (20,282-42,064)	.08
No. of hospitalizations for asthma per year, median (IQR)	223 (125-503)	189 (113-492)	.62
Affiliated with internal medicine or pediatric residency program	20 (100)	20 (100)	…
Urban rural distinction			…
Metropolitan	20 (100)	…	
Nonmetropolitan	0 (100)	…	
Census region			…
Northeast	1 (5)	…	
Midwest	6 (30)	…	
South	7 (35)	…	
West	6 (40)	…	
Has clinical pathway on how to manage acute asthma	10 (50)	8 (40)	.34
Has standardized form for ordering asthma treatment	9 (45)	8 (40)	.51
Has protocol-based asthma education program	9 (45)	4 (20)	.13

Data are presented as No. (%) unless otherwise indicated. IQR = interquartile range; PEF = peak expiratory flow.
[a]Percentages do not equal 100 because of missing data.
[b]Analyzed for 472 adults with initial PEF data available.
[c]Including pneumonia, bronchiolitis, congestive heart failure, otitis media, sinusitis, and others.
[d]Including noninvasive positive pressure ventilation and intubation.
[e]In the 2012-2013 study, 3 patients died during hospitalization, and 20 left the hospital against medical advice.

Guideline Concordance and Hospital LOS in 2012-2013

In the 2012-2013 period, 46% of patients received care perfectly concordant with the four Level A recommendations (Table 5). These patients had a higher mean composite score compared with those who did not receive perfectly concordant inpatient care (89 vs 76; $P < .001$). In the negative binomial model adjusting for 11 patient-level characteristics and site fixed effects, delivery of perfectly concordant care was associated with a 14% shorter hospital LOS at the population level (95% CI, −23 to −4; $P = .009$), compared with nonconcordant care. Similarly, in the sensitivity analysis excluding patients who died during hospitalization or who left the hospital against medical advice, hospital LOS among patients who received perfectly concordant care remained significantly shorter than that of other patients.

Discussion

In this analysis of two large multicenter, US studies of patients hospitalized for acute asthma, we found a significant improvement in overall concordance of inpatient asthma care with the NAEPP guideline recommendations over 15 years. However, there were substantial interhospital variations in the guideline

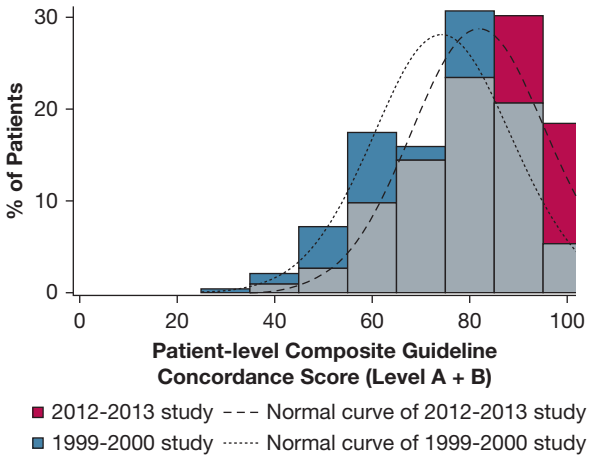

Figure 1 – *Distribution of composite guideline concordance score at the patient-level according to time period. At the patient level, the mean composite concordance score increased from 74 (SD, 14) in the 1999-2000 period to 82 (SD, 14) in the 2012-2013 period (P < .001). The superimposed curves represent the normal curve based on each sample mean and SD.*

concordance, with the widest gap between the Midwest and the Northeast hospitals. Our study also found a strong link between variability in process of care and patient outcomes. Specifically, perfect concordance with the guidelines was associated with a shorter hospital LOS.

The observed improvement in guideline concordance of inpatient asthma care is paralleled by the improvement in the ambulatory care[8] and ED[11,15] settings as well as in freestanding children's hospitals.[17] These findings collectively suggest, at least partially, the successful implementation of the NAEPP guidelines over time and support prior optimism that the quality of acute asthma care can be improved.[4,32] However, we also identified opportunities for additional improvement in quality of care. For instance, the proportion of patients who received an instruction for a follow-up asthma care appointment declined over time. In addition, 40% of hospitalized patients did not receive an individualized

TABLE 3] Performance on Quality Measures at the Patient and Hospital Level According to Time Period

	Percentage of Recommended Care Patient Received (95% CI)[a]			Mean Hospital Performance (Mean ± SD)		
Quality Measure	1999-2000	2012-2013	*P* Value	1999-2000	2012-2013	*P* Value
Recommendations based on Level A evidence						
Inhaled β-agonists in hospital	92 (91-95)	99 (98-100)	< .001	92 ± 18	99 ± 2	.07
Inhaled anticholinergic agents not given in hospital	45 (42-49)	50 (46-53)	.09	47 ± 26	50 ± 20	.70
Systemic corticosteroids in hospital	92 (90-94)	96 (94-97)	.001	92 ± 5	96 ± 5	.02
Methylxanthines not given in hospital	95 (93-96)	100 (99-100)	< .001	94 ± 5	100 ± 1	< .001
Oral corticosteroids prescribed at discharge	87 (85-89)	93 (90-94)	< .001	88 ± 7	92 ± 5	.08
Recommendations based on Level B evidence						
Inhaled corticosteroids prescribed at discharge	68 (64-71)	86 (83-88)	< .001	69 ± 14	86 ± 8	< .001
Antibiotics not given in hospital	67 (63-70)	72 (69-75)	.02	65 ± 15	73 ± 17	.07
Antibiotics not prescribed at discharge	71 (68-75)	82 (79-85)	< .001	68 ± 15	83 ± 12	< .001
Written action plan at discharge	36 (33-40)	61 (58-65)	< .001	36 ± 27	61 ± 36	.01
Follow-up asthma appointment at discharge	87 (84-89)	80 (77-83)	< .001	87 ± 9	80 ± 13	.08
Composite Score	Patient Level (Mean ± SD)		*P* Value	Hospital Level (Mean ± SD)		*P* Value
Composite guideline concordance score (overall)	74 ± 14	82 ± 14	< .001	74 ± 6	82 ± 7	< .001
Composite guideline concordance score (Level A evidence)	82 ± 15	87 ± 12	< .001	83 ± 5	87 ± 4	.01
Composite guideline concordance score (Level B evidence)	70 ± 23	78 ± 23	< .001	69 ± 11	78 ± 11	.01

[a]Denominator and numerator for each quality measure according to the time period are included in e-Table 2.

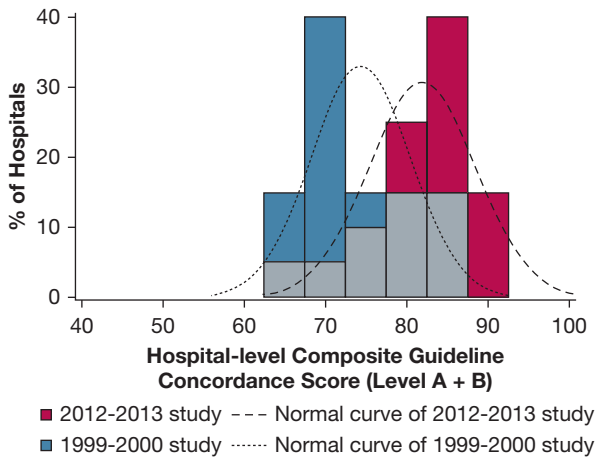

Figure 2 – *Distribution of composite guideline concordance score at the hospital-level according to time period. At the hospital level, the mean composite concordance score increased from 74 (SD, 6) in the 1999-2000 period to 82 (SD, 7) in the 2012-2013 period (P < .001). The superimposed curves represent the normal curve based on each sample mean and SD.*

action plan at hospital discharge in the 2012-2013 period. These observations support prioritization of these activities by quality improvement efforts in acute asthma management (eg, through the use of clinical pathways, decision support, and multifaceted interventions[38]). Hospitalization can be an opportune setting for reevaluating the adequacy of outpatient asthma care and initiating prevention measures with seamless transition of care.

We also found that the variability in guideline concordance remained wide across the hospitals in the 2012-2013 period. The reasons for this wide practice variation are likely multifactorial. Although the number of participating hospitals was relatively small, the observed variation was partially explained by geographic region. Similarly, in our previous 48-center and 64-center observational studies of ED patients with acute asthma,[11,14] we also found variations in the guideline concordance of emergency asthma care across these same regions. However, the link between geographic regions and guideline concordance is undoubtedly complex; for example, geography might have served as an identifiable proxy for a number of patient, provider, and health system factors associated with the process measures that are difficult to isolate quantitatively. Our data should encourage researchers to identify barriers to the delivery of high-quality asthma care in underperforming hospitals. In addition, because of the complexity of providing high-quality inpatient asthma care, health-care providers and policy makers in collaboration with other stakeholders will need to continue to bridge quality chasms.

Establishing process measures and identifying interventions have become important to improve patient outcomes.[39] However, few studies have linked the guideline concordance of inpatient asthma care with a corresponding improvement in patient outcomes. There have been two single-center studies of hospitalized children reporting an association of higher performance on the Children's Asthma Care measures with reduced readmission rates.[19,20] Our multicenter study extends these findings by demonstrating the association of perfectly concordant inpatient care with a shorter hospital LOS. Our encouraging finding is mirrored by our previous multicenter ED-based studies that reported the association of perfectly concordant asthma care in the ED with a reduced risk of subsequent hospitalization.[11,14] Despite different populations, settings, and designs, several studies have arrived at similar conclusions, supporting the use of an all-or-none quality measurement. Because asthma is a common public health problem,[1] clinicians and hospitals have accountability to use best practices. However, to improve the quality of asthma care throughout the nation, our findings underscore the importance of continued collective efforts with patient advocacy organizations, professional societies, and federal/state agencies.

This study has several potential limitations. First, because data collection in the studies relied on medical record review, some of the apparent deficit in guideline concordance might be attributable to measurement errors. However, we used a previously applied standardized data collection system with uniform definitions and training, which had achieved high interobserver agreement in our previous study.[28] Second, our method was able to show associations but unable to prove causation. In addition, the association of higher guideline concordance with shorter LOS might be explained by residual confounders (eg, physicians' practice patterns). Third, one may surmise that the observed 14% reduction in hospital LOS is not meaningful. However, as the public health burden of asthma-related hospitalizations is substantial (347,000 hospitalizations with $2 billion direct cost each year),[2] a 14% decline would be substantial nationally. Accordingly, our findings should be relevant to many stakeholders, such as policy makers, quality agencies, and hospitals. Fourth, our study did not measure postdischarge events (eg, readmissions). These important outcomes will be the focus of future investigation by the MARC investigators. Fifth, our study did not include patients who were treated and

TABLE 4] Unadjusted and Multivariable-Adjusted Hospital-Level Predictors of Composite Guideline Concordance Score in the 2012-2013 Study

Hospital-Level Variable	Unadjusted Model		Adjusted Model[a]		Sensitivity Analysis[b]	
	Difference in Score (95% CI)	*P* Value	Difference in Score (95% CI)	*P* Value	Difference in Score (95% CI)	*P* Value
Annual hospitalizations for asthma per 100-hospitalization increase	−0.13 (−0.21 to −0.04)	.003	−0.25 (−0.33 to −0.16)	< .001	−0.26 (−0.35 to −0.17)	< .001
Census region						
Northeast	Reference	…	Reference	…	Reference	…
Midwest	−6.30 (−9.21 to −3.38)	< .001	−7.86 (−11.4 to −4.34)	< .001	−9.20 (−12.7 to −5.68)	< .001
South	−3.19 (−6.32 to −0.06)	.047	−4.10 (−7.89 to −0.31)	.03	−5.25 (−9.07 to −1.43)	.007
West	−0.11 (−3.39 to 3.17)	.95	−0.13 (−3.56 to 3.20)	.94	−0.80 (−4.13 to 2.53)	.64
Has clinical pathway on how to manage acute asthma	1.67 (−0.10 to 3.46)	.06	0.66 (−1.45 to 2.78)	.58	0.87 (−1.28 to 3.01)	.43
Has protocol-based asthma education program	−1.71 (−3.44 to 0.02)	.06	−2.00 (−4.62 to 0.62)	.13	−2.32 (−4.93 to 0.29)	.08

[a]Mixed-effects linear regression model using random intercepts for hospitals, with adjustment for 11 patient-level variables (age, sex, race/ethnicity, insurance, primary care physician status, current use of systemic corticosteroids and inhaled corticosteroids, comorbidities, and respiratory rate, oxygen saturation, and initial peak flow at hospitalization) (n = 1,000).
[b]Sensitivity analysis that excluded patients who died during the hospitalization course and those who left the hospital against medical advice (n = 976).

TABLE 5] Unadjusted and Multivariable Associations of Guideline-Concordant Care With Hospital LOS in the 2012-2013 Study

Guideline-Concordant Care (All-or-None Metric)	Patients With Acute Asthma (n = 1,000)	Unadjusted Model[a]		Adjusted Model[b]		Sensitivity Analysis[c]	
		% Change (95% CI)	*P* Value	% Change (95% CI)	*P* Value	% Change (95% CI)	*P* Value
Received all 4 types of guideline-recommended care when eligible[d]	464 (46%)	−19% (−29 to −8)	.001	−14% (−23 to −4)	.009	−13% (−22 to −3)	.02
Did not received all 4 types of guideline-recommended care when eligible	536 (54%)	Ref	…	Ref	…	Ref	…

LOS= length of stay.
[a]Negative binomial model only adjusting for dummy variables for the 25 participating sites (n = 1,000).
[b]Negative binomial model adjusted for 11 patient-level variables (age, sex, race/ethnicity, insurance, primary care physician status, current use of systemic corticosteroids and inhaled corticosteroids, comorbidities, and respiratory rate, oxygen saturation, and initial peak flow at hospitalization) and dummy variables for the 25 participating sites (n = 1,000).
[c]Sensitivity analysis with excluded patients who died during the hospitalization course and those who left the hospital against medical advice (n = 976).
[d]The elements of care represented 4 Level A guideline-recommended treatments in the hospital: use of inhaled β-agonists and systemic corticosteroids, nonuse of inhaled anticholinergic agents and methylxanthines during inpatient course.

discharged at the ED or other ambulatory care settings. Finally, the hospitals that comprised this sample were urban teaching hospitals. This composition may make our findings less generalizable to other settings (eg, rural, community hospitals).

Conclusions

This multicenter analysis, based on two large observational studies, found a significant improvement in concordance of inpatient asthma care with the NAEPP guideline recommendations over 15 years. However, it also identified interhospital variations in the guideline concordance in the 2012-2013 period. In addition, the data demonstrated a significant link between variability in process of asthma care and patient outcomes. Specifically, perfect concordance with the guideline recommendations was associated with a shorter hospital LOS.

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