

## Quality of Care for Acute Asthma in Emergency Departments in Japan: A Multicenter Observational Study

Kohei Hasegawa, MD, MPH<sup>a</sup>, Takuyo Chiba, MD<sup>b</sup>, Yusuke Hagiwara, MD, MPH<sup>c</sup>, Hiroko Watase, MD, MPH<sup>d</sup>, Yusuke Tsugawa, MD, MPH<sup>e,f</sup>, David F. M. Brown, MD<sup>a</sup>, and Carlos A. Camargo, Jr, MD, DrPH<sup>a</sup>, on behalf of the Japanese Emergency Medicine Network Investigators *Boston, Mass; Portland, Ore; and Fukui and Tokyo, Japan*

**What is already known about this topic?** North American studies have highlighted gaps in the quality of acute asthma care in emergency departments. However, little is known about the quality of care and the association between process of care and outcomes in other industrialized nations.

**What does this article add to our knowledge?** This multicenter study showed that the concordance of acute asthma care with evidence-based guidelines was suboptimal in Japan. Greater concordance with guideline-recommended management might reduce unnecessary hospitalizations.

**How does this study impact current management guidelines?** Greater concordance with guideline-recommended management might reduce unnecessary hospitalizations. Knowledge translation initiatives aimed at increasing concordance are likely to improve patient outcomes internationally.

**BACKGROUND:** Little is known about the quality of acute asthma care in emergency departments (EDs) outside of North America.

**OBJECTIVE:** We evaluated concordance of acute asthma management in Japanese EDs with recommendations in the

2007 National Institutes of Health asthma guidelines and investigated whether guideline concordance was associated with risk of hospital admission.

**METHODS:** We conducted a multicenter chart review study in 23 EDs across Japan. We identified ED patients aged 18 to 54 years with acute asthma between 2009 and 2011. Concordance with evidence-based guideline recommendations was evaluated by using item-by-item quality measures and composite concordance scores both at patient and ED levels. These scores ranged from 0 to 100.

**RESULTS:** Among 1380 patients, the median age was 35 years and 11% were hospitalized. Overall guideline concordance score was suboptimal both at the patient level (mean  $\pm$  SD, 72  $\pm$  14) and ED level (mean  $\pm$  SD, 72  $\pm$  6). Specifically, asthma care at the patient level was suboptimal in several areas: inhaled anticholinergics in ED (2%), systemic corticosteroid in ED (56%) and at discharge (36%), and peak flow assessment (9%). A multivariable model that adjusted for severity at presentation and several ED characteristics showed that higher guideline concordance was associated with significantly lower risk of hospital admission (odds ratio, 0.70 per 10-unit increase in composite score; 95% CI, 0.62-0.79 per 10-unit increase in composite score).

**CONCLUSION:** The management of acute asthma in Japanese EDs is suboptimal. Greater concordance with guideline-recommended management might reduce unnecessary hospitalizations. Knowledge translation initiatives are warranted to increase adherence with best practice in acute asthma management. © 2013 American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol: In Practice 2013;1:509-15)

<sup>a</sup>Department of Emergency Medicine, Massachusetts General Hospital, Harvard Medical School, Boston, Mass

<sup>b</sup>Department of Emergency Medicine, Obama Municipal Hospital, Obama, Fukui, Japan

<sup>c</sup>Department of Pediatric Emergency and Critical Care Medicine, Tokyo Metropolitan Children's Medical Center, Fuchu, Tokyo, Japan

<sup>d</sup>Department of Public Health and Preventive Medicine, Oregon Health and Science University, Portland, Ore

<sup>e</sup>Division of General Medicine and Primary Care, Beth Israel Deaconess Medical Center, Boston, Mass

<sup>f</sup>Center for Clinical Epidemiology of St Luke's Life Science Institute, Tokyo, Japan Supported by a grant from St Luke's Life Science Institute (Tokyo, Japan) and by National Institutes of Health grant U01 AI-87881 (C.A.C.). The study sponsor had no involvement in the study design; in the collection, analysis, and interpretation of data; in the writing of the article; or in the decision to submit the article for publication.

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Corresponding author: Kohei Hasegawa, MD, MPH, Department of Emergency Medicine, Massachusetts General Hospital, Harvard Medical School, 326 Cambridge St, Ste 410, Boston, MA 02114. E-mail: [khasegawa1@partners.org](mailto:khasegawa1@partners.org). 2213-2198/\$36.00

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**Key words:** Acute asthma; Quality of care; Guidelines; Hospitalization; Emergency department

**Abbreviations used**

ED- Emergency department

JEMNet- Japanese Emergency Medicine Network

NIH- National Institutes of Health

PEF- Peak expiratory flow

Asthma is an important public health problem worldwide, with an estimated 300 million affected persons.<sup>1,2</sup> The World Health Organization has estimated that 22 million disability-adjusted life years are lost annually because of asthma, representing 1% of the total global disease burden.<sup>3</sup> The most recent estimates indicated that asthma affected 4% (5 million) of Japanese adults in 2007<sup>4</sup> and 8% (25 million) of Americans in 2009.<sup>5</sup>

Evidence-based recommendations for acute asthma management exist within international guidelines.<sup>1,6</sup> However, ensuring that practitioners provide optimal care is challenging; publication of guidelines does not necessarily lead to improved patient outcomes.<sup>7,8</sup> Indeed, North American studies have highlighted ongoing gaps in the quality of acute asthma care provided.<sup>9-13</sup> Furthermore, a multicenter US study reported that better guideline concordance of emergency department (ED) processes of care was associated with a reduction in hospital admissions by 46%.<sup>9</sup> Despite the significant global burden of acute asthma, little is known about the quality of acute asthma care and the association between process of care and outcomes in other industrialized nations. Replication of care gaps in acute asthma management in differing health care settings and professional training systems would show the need to move beyond guideline publication and to focus on international implication of guidelines.

In this context, our study objectives were 1) to evaluate concordance of acute asthma management in Japanese EDs with recommendations in the 2007 National Institutes of Health (NIH) asthma guidelines,<sup>6</sup> 2) to identify ED characteristics associated with higher ED guideline concordance, and 3) to investigate whether better guideline concordance was associated with improved patient outcomes (ie, decreased risk of hospital admission).

## METHODS

### Study design and setting

We performed a multicenter chart review study to characterize the acute asthma management in Japanese EDs. This study was coordinated by the Japanese Emergency Medicine Network (JEMNet) in collaboration with the US-based Emergency Medicine Network ([www.emnet-usa.org](http://www.emnet-usa.org)). JEMNet is a consortium of 23 academic and community medical centers from different geographic regions across Japan ([jemnet.asia/wp](http://jemnet.asia/wp)). During the period of this study, all 23 EDs were staffed by ED-based attending physicians. All patients were managed by at the discretion of the treating physician. The institutional review board of each participating center and the Massachusetts General Hospital approved the study with a waiver of written informed consent.

### Selection of participants

With the use of the *International Classification of Diseases, Tenth Revision, Clinical Modification*<sup>14</sup> code J45.xx, each site

identified all charts with a principal ED or hospital discharge diagnosis of asthma from hospital administrative records between January 2009 and December 2011. Inclusion criteria were visits made by patients aged 18 to 54 years and a history of physician-diagnosed asthma before the index visit.

We excluded (1) visits made by patients with a history of physician-diagnosed chronic obstructive pulmonary disease, emphysema, or chronic bronchitis; (2) transfer visits; (3) repeat visits by the same subject; or (4) visits not prompted largely by an asthma exacerbation. In the case of repeat visits, only the first ED visit during the study period was included.

### Data collection

Onsite chart abstractors reviewed 60 randomly selected ED charts from January to December 2011. For sites with <60 charts during this period, eligible charts from the calendar year 2009 and 2010 were also reviewed to reach the target number of 60 charts. All chart abstractors were emergency physicians or emergency medicine residents. Abstractors were trained with a 1-hour lecture, and then the abstractors completed practice charts, which were assessed with a "criterion standard." If an abstractor's accuracy was <80% per chart, the person was retrained. To assess inter-rater reliability, we re-abstracted charts from a randomly selected 100 samples. For the process measures, the  $\kappa$  statistics ranged from 0.56 to 1.00 (moderate to perfect agreement; see Table E1 in this article's Online Repository at [www.jaci-inpractice.org](http://www.jaci-inpractice.org)). For the outcome measure, the inter-rater agreement was almost perfect ( $\kappa = 0.95$ ).

**ED-level measurements.** We distributed a key informant survey at each site to collect data on ED characteristics, such as annual volume of ED visits, annual volume of asthma-related ED visits, number of beds in the ED, number of full-time equivalent ED physicians in the past year, affiliation with an emergency medicine residency program, rural and urban distinction, and presence of electronic ED visit notes and peak expiratory flow (PEF) meter in ED.

**Patient-level measurements.** Data abstraction was done with a standardized form and included patients' demographics, past asthma history, current asthma medications, patient presentation, PEF, treatment (in the ED or at discharge), and disposition. This standardized form was used in multiple US-based studies conducted by the Emergency Medicine Network.<sup>15-22</sup>

### Quality measures

**Process measures.** On the basis of common recommendations contained in the 2007 NIH asthma guidelines<sup>6</sup> and using methods similar to those in the National Emergency Department Safety study with acute asthma,<sup>9</sup> we derived *a priori* 8 explicit process measures, which included 5 level A and 3 level B evidence-based treatments (see Table E2 in this article's Online Repository at [www.jaci-inpractice.org](http://www.jaci-inpractice.org)). We did not use timeliness measures, given substantial missing values in the Japanese ED charts. We summarized the 8 evidence-based process measures (levels A and B) by using a patient composite concordance score, which was calculated as the sum of guideline-concordant care provided from the patient's total number of eligible opportunities.<sup>23</sup> These scores were then averaged across patients at the ED level to obtain ED composite scores. These scores ranged from 0 to 100, with a score of 100 indicating perfect concordance.<sup>24</sup> To assess whether the concordance varied

by strength of evidence, we computed the scores for level A evidence-based measures separately.

**Outcome measures.** The primary outcome measure was hospital admission, which was defined as admission to an observation unit, an inpatient unit, or intensive care unit.

### Data analysis

We assessed the associations between ED characteristics and ED composite concordance scores by using multivariable linear regression, conditioning on a predefined set of aggregate patient mix at the ED level (ie, age, sex, duration of symptoms, oxygen saturation, and initial respiratory rate at ED presentation).

To examine the associations between the risk of hospital admission and patient composite concordance scores, we fitted 2 regression models with the use of generalized estimating equations to account for the effects of clustering patients within each ED. First, we developed an unadjusted model that included only patient composite score as the independent variable. Second, we examined the association between patient composite score and the risk of hospital admission with multivariable linear regression. We adjusted for both patient-level variables (age, sex, history of intubation for asthma, duration of symptoms, chronic use of inhaled corticosteroids, and initial oxygen saturation) and ED-level variables (annual ED visit volume, annual ED asthma volume, number of beds in ED, number of emergency physicians, affiliation with an emergency medicine residency program, location, and presence of electronic ED visit notes). For the model of hospital admission, only level A guideline-recommended care in the ED was used for calculating the composite scores (ie, inhaled  $\beta$ -agonists, inhaled anticholinergics, systemic corticosteroids, and not receiving methylxanthines) to give more weight to the treatments that have been shown to reduce hospitalizations.<sup>6,9,25</sup>

We then conducted a series of sensitivity analyses to assess the robustness of our findings. First, we stratified the analysis of patient- and ED-level concordance scores by a PEF measurement. Second, we generated the ED-level composite concordance scores by using the “opportunity-based” method (ie, the patient-level composite scores were summated at the ED level).<sup>24</sup> Third, for the hospital admission model, we constructed a random effects model with binomial response that accounted for the clustering of persons at the hospital level.<sup>26</sup> Analyses were performed with SAS statistical software version 9.3 (SAS Institute, Cary, NC). All tests were 2-tailed, and  $P < .05$  was regarded as statistically significant.

## RESULTS

### ED and patient characteristics

We created a cohort of 1380 patients with acute asthma who presented to the 23 EDs between 2009 and 2011, with 91% of the ED visits made in 2011. Participating EDs had a median annual visit volume of 29,000 and number of asthmatic patients of 107 (Table I). Most sites were affiliated with an emergency medicine residency program, in the urban setting, and used electronic ED visit notes. By contrast, only 57% had peak flow meters available in the ED.

The median age of the patients was 35 years and most patients were women. Disease burden was relatively high, with 6% admitted for acute asthma in the past year and 16% having visited an ED for acute asthma care. Almost one-third of the

**TABLE I.** ED and patient characteristics\*

|                                                         | Value                  |
|---------------------------------------------------------|------------------------|
| ED characteristics (n = 23)                             |                        |
| No. of ED visits per year, median (IQR)                 | 29,000 (20,000-38,000) |
| No. of ED visits for asthma per year, median (IQR)      | 107 (80-123)           |
| No. of ED beds, median (IQR)                            | 13 (11-20)             |
| No. of emergency physicians, median (IQR)               | 10 (4-13)              |
| Residency affiliated (%)                                | 91                     |
| Urban location (%)                                      | 91                     |
| Electronic ED visit notes (%)                           | 83                     |
| Standardized order sets in ED (%)                       | 26                     |
| PEF in ED (%)                                           | 57                     |
| Patient characteristics (n = 1380)                      |                        |
| Demographics                                            |                        |
| Age (y), median (IQR)                                   | 35 (26-43)             |
| Female sex (%)                                          | 58                     |
| Chronic asthma factors (%)                              |                        |
| Admitted for asthma in past year                        | 6                      |
| ED visit for asthma in past year                        | 16                     |
| Ever intubated for asthma                               | 2                      |
| Current use of inhaled corticosteroids                  | 30                     |
| Current use of oral methylxanthines                     | 11                     |
| Current use of leukotriene modifiers                    | 11                     |
| Duration of symptoms (%)                                |                        |
| ≤3 h before ED arrival                                  | 16                     |
| >3 h                                                    | 80                     |
| Unknown                                                 | 4                      |
| ED presentations                                        |                        |
| Initial respiratory rate (breaths/min), median (IQR)    | 20 (18-24)             |
| Initial oxygen saturation on room air (%), median (IQR) | 96 (94-98)             |
| Initial PEF (L/min), median (IQR)                       | 200 (150-280)          |
| Concomitant bacterial infection diagnosis (%)           |                        |
| Pneumonia                                               | 2                      |
| Sinusitis                                               | 1                      |
| ED disposition (%)                                      |                        |
| Sent home                                               | 89                     |
| Admission (hospital ward/observation unit)              | 10                     |
| ICU admission                                           | 1                      |
| Other (eg, left against medical advice)                 | <1                     |

ICU, Intensive care unit.

\*Number and proportion of missing values for each variable included in Table E3.

patients were on inhaled corticosteroids; 11% were on oral methylxanthines. On presentation to the ED, the median respiratory rate was 20 breaths per minute, oxygen saturation was 96%, and PEF was 200 L/min. However, initial PEF measurement was not documented in 92% of patients (see Table E3 in this article's Online Repository at [www.jaci-inpractice.org](http://www.jaci-inpractice.org)). After ED management, 10% of patients were admitted to the hospital ward or observation unit, and 1% was admitted directly to the intensive care unit.

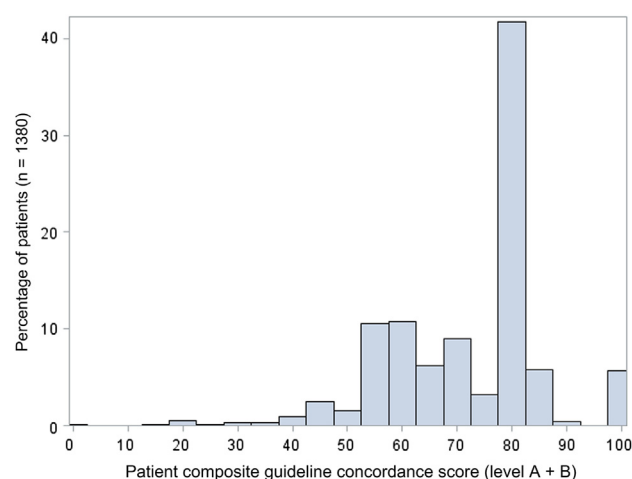
### Performance on quality measures

Table II shows the item-by-item guideline-recommended management and the overall concordance scores. At the patient

**TABLE II.** Performance on quality measures at the patient and ED level

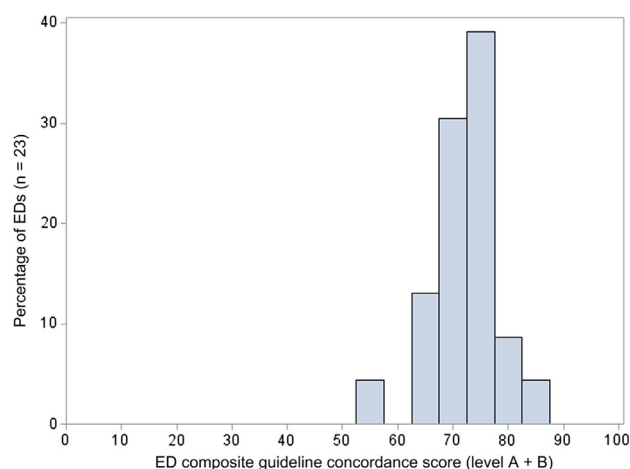
| Quality measure                              | No. of patients eligible | No. of times care was delivered | Percentage of recommended care patient received (95% CI) | Median ED performance (IQR) |
|----------------------------------------------|--------------------------|---------------------------------|----------------------------------------------------------|-----------------------------|
| <b>Process of care*</b>                      |                          |                                 |                                                          |                             |
| Inhaled $\beta$ -agonists in ED              | 1380                     | 1185                            | 86 (84-88)                                               | 90 (85-93)                  |
| Inhaled anticholinergics in ED               | 198                      | 3                               | 2 (0-3)                                                  | 0 (0-0)                     |
| Systemic corticosteroids in ED               | 627                      | 352                             | 56 (52-60)                                               | 55 (46-71)                  |
| Methylxanthines not prescribed in ED         | 1380                     | 1300                            | 94 (93-95)                                               | 97 (90-100)                 |
| Prescribed oral corticosteroids at discharge | 474                      | 173                             | 36 (32-41)                                               | 33 (17-54)                  |
| Antibiotics not prescribed in ED             | 1345                     | 1326                            | 99 (98-99)                                               | 100 (97-100)                |
| Oral antibiotics not prescribed at discharge | 1199                     | 1151                            | 96 (95-97)                                               | 98 (94-100)                 |
| Assessment of PEF                            | 1216                     | 112                             | 9 (8-11)                                                 | 2 (0-15)                    |

\*Composite guideline concordance score (level A + B evidence) was  $72 \pm 14$  for patient level and  $72 \pm 6$  for ED level. Composite guideline concordance score (level A evidence) was  $79 \pm 24$  for patient level and  $79 \pm 9$  for ED level.

**FIGURE 1.** Distribution of composite guideline concordance score at the patient-level.

level, the overall concordance with the guideline recommendations was suboptimal, with a mean  $\pm$  SD score of  $72 \pm 14$  (Figure 1). The level of concordance varied widely by quality measure but was often suboptimal. For example, inhaled anticholinergics were used for 2% of the eligible patients, systemic corticosteroids in ED for 56%, oral corticosteroids prescription at discharge for 36%, and assessment of PEF for 9%. In the sensitivity analysis, the wide variation in the level of concordance and suboptimal care persisted with stratification by use of a PEF measurement (see Table E4 in this article's Online Repository at [www.jaci-inpractice.org](http://www.jaci-inpractice.org)).

At the ED level, the overall ED concordance with the guideline recommendations was also suboptimal, with a mean ED composite score of  $72 \pm 6$  (Figure 2). Similar to the findings at the patient level, the quality of care delivered in the ED varied considerably but was often suboptimal. The best-performing ED scored at 84, whereas the worst-performing ED scored at 55. Item-by-item measures indicated that the variation in ED performance was greatest in systemic corticosteroid at ED [interquartile range (IQR), 46-71] and prescription of oral corticosteroid at discharge (IQR, 17-54).

**FIGURE 2.** Distribution of composite guideline concordance at the ED level.

### ED characteristics and ED-level guideline concordance

The ED characteristics associated with ED-level guideline concordance are shown in Table E5 (in the Online Repository available at [www.jaci-inpractice.org](http://www.jaci-inpractice.org)). Higher annual asthma volume was associated with higher unadjusted composite concordance scores ( $P = .004$ ). This positive association persisted after adjusting for aggregated patient mix ( $P = .003$ ) and with sensitivity analysis that used the opportunity-based method ( $P = .002$ ).

### Patient-level guideline concordance and risk of hospital admission

The associations between patient-level guideline composite concordance scores and risk of hospital admission are shown in Table III. In the unadjusted model, a higher concordance with guideline recommendations was associated with a lower risk of admission (odds ratio (OR) per 10-unit increase in composite score, 0.79; 95% CI, 0.73-0.84 per 10-unit increase in composite score;  $P < .001$ ). After adjustment for patient and ED characteristics, the risk of admission remained significantly lower among patients who received highly concordant care (OR, 0.70;

**TABLE III.** Bivariable and multivariable associations between guideline-concordant care and hospital admission among ED patients with acute asthma

|                                                       | Hospital admission as the dependent variable, OR (95% CI) |                        |                   |
|-------------------------------------------------------|-----------------------------------------------------------|------------------------|-------------------|
|                                                       | Unadjusted analysis*                                      | Multivariable analysis |                   |
|                                                       |                                                           | Model 1*               | Model 2†          |
| Guideline-concordant score (OR per 10-unit increase)‡ | 0.79 (0.73-0.84)§                                         | 0.70 (0.62-0.79)§      | 0.72 (0.66-0.79)§ |
| Age, decile                                           | —                                                         | 1.15 (1.01-1.32)§      | 1.51 (1.25-1.82)§ |
| Male (vs female)                                      | —                                                         | 0.83 (0.61-1.13)       | 1.03 (0.70-1.53)  |
| History of intubation for asthma                      | —                                                         | 1.76 (0.74-4.17)       | 2.14 (0.71-6.49)  |
| Duration of symptoms ( $\leq 3$ h vs others)          | —                                                         | 0.72 (0.43-1.19)       | 0.75 (0.43-1.30)  |
| Current use of inhaled corticosteroid                 | —                                                         | 1.04 (0.64-1.20)       | 1.05 (0.70-1.59)  |
| Oxygen saturation at triage (OR per 1% increase)      | —                                                         | 0.76 (0.70-0.83)§      | 1.00 (1.00-1.00)  |
| Annual ED visits for asthma per 100-visit increase    | —                                                         | 0.91 (0.31-2.64)       | 0.92 (0.35-2.34)  |
| Annual ED visits per 1000-visit increase              | —                                                         | 1.00 (0.97-1.03)       | 1.00 (0.97-1.02)  |
| No. of ED beds                                        | —                                                         | 1.07 (0.97-1.19)       | 1.05 (0.96-1.15)  |
| No. of emergency physicians                           | —                                                         | 0.98 (0.91-1.05)       | 1.01 (0.12-2.92)  |
| Residency affiliated                                  | —                                                         | 0.52 (0.18-1.50)       | 0.60 (0.12-2.92)  |
| Urban location                                        | —                                                         | 2.80 (0.51-15.88)      | 2.41 (0.44-13.1)  |
| Electronic ED visit notes                             | —                                                         | 1.36 (0.50-3.49)       | 1.51 (1.25-1.82)§ |

—, Not applicable.

\*Models were fit by using generalized estimating equations to account for the effects of clustering of patients within EDs.

†Random effects model.

‡The elements of care represented 4 level A guideline-recommended treatments in ED: inhaled  $\beta$ -agonists, inhaled anticholinergics, systemic corticosteroids, and not receiving methylxanthines.

§Statistically significant.

95% CI, 0.62-0.79;  $P < .001$ ). The magnitude of the protective association was similar in the random effects model (OR, 0.70; 95% CI, 0.62-0.79;  $P < .001$ ).

## DISCUSSION

Among 1380 randomly sampled patients who presented with acute asthma to 23 Japanese EDs, we found the overall concordance of acute asthma care with NIH guideline recommendations was suboptimal. Substantial variations in the quality of care were observed across EDs, and the only identified predictor of higher guideline concordance was annual number of ED visits for acute asthma; the higher the visit volume, the better the asthma care. Our study also showed a strong association between variation in processes of care for acute asthma and patient outcomes. More specifically, higher concordance with NIH guidelines was associated with lower risk of hospitalization.

The patient-level performance on quality measures identified several opportunities to improve quality of care by addressing problems of underuse and overuse of asthma-related process measures. In particular, only 9% of ED patients with acute asthma underwent a PEF measurement during their ED course, although objective lung function measurements that use PEF are known to be useful for categorizing the severity of acute asthma and for determining who will require hospital admission and who is likely to have sufficient response to treatment to allow continued ED care.<sup>6,27,28</sup> In addition, only 56% received systemic corticosteroid therapy in the ED and only 36% received a prescription for oral corticosteroids at discharge, despite a body of literature describing that systemic corticosteroids speed the resolution of airflow obstruction, reduce the rate of relapse, and may reduce hospitalizations.<sup>6,29-33</sup>

The observed quality gaps in acute asthma care were consistent with but substantially larger than prior North American

studies that used similar chart abstraction forms.<sup>9-12</sup> For example, the National Emergency Department Safety Study found that only 52% of ED patients with acute asthma underwent a PEF assessment and only 66% received oral corticosteroids at discharge. Similarly, our finding of the association between the use of evidenced-based ED asthma management and reduced hospital admissions was large and consistent with the previous study.<sup>9</sup> Thus, multiple studies from highly developed health care settings are arriving at similar conclusions despite differing populations, health care settings, and professional training systems. Our data support ongoing efforts to focus on more successful global implementation of evidence-based guidelines. To that end, several studies have shown that quality improvement programs for ED asthma management improve adherence to evidence-based management, improve patient outcomes, and reduce hospitalization.<sup>11,34-36</sup> To increase adherence with best practices in acute asthma management in the real world, such knowledge translation initiatives were warranted.

Similar to earlier studies in North America,<sup>9-11,13</sup> we were struck with the high degree of variation in quality of care across the 23 EDs. The reasons for the observed practice variations are unclear and likely are multifactorial. Potential explanations include regional differences in access to services, knowledge of emergency asthma management guidelines and recent literature, and systems of care such as standardized order sets and automatic referrals.<sup>10</sup> In our study, the practice variation was partly explained by annual number of asthma-related ED visits after adjusting for annual ED visits, residency affiliation, location of ED, and patient mix. Thus, the association between the higher asthma volume and better quality of care might result from the factors other than ED and patient characteristics, such as greater provider experience and possible interest in asthma-related evidence. However, the relationship between volume and process

of care is complex. Volume of patients is an identifiable surrogate marker for a number of patient, physician, and systems variables that affect quality measures but are difficult to quantify individually. The benefit of volume on quality of care was also noted on health conditions that involve a systems-based approach, such as traumatic injury and acute myocardial infarction.<sup>37,38</sup> Because asthma is a common public health problem and any ED, regardless of its patient volume, has accountability to provide best practice, our findings call for development and implementation of systems of care for patients with acute asthma. This effort must address not only evidence-based ED care but also comprehensive ED discharge education and referral systems.<sup>7</sup>

Our study has several potential limitations. First, the study relied on medical record review for quality assessment, and some of the apparent quality deficit might be due to underdocumentation. However, previous studies showed that the rates of ED assessments and treatments for asthma by chart abstraction were similar to those by direct observation, with  $\kappa$  coefficients ranging from 0.6 to 0.9 (substantial to almost perfect).<sup>39</sup> In addition, underdocumentation cannot explain the observed inappropriate use of methylxanthines in 6% of patients with asthma.

Second, the minimal use of PEF measurements in the EDs likely led to an underestimation of the number of patients eligible for systemic corticosteroids and inhaled anticholinergics. Indeed, the PEF criteria were used for only 15% of the patients who were classified as eligible for systemic corticosteroids in the ED. However, the undertreatment with these medications persisted with stratification by use of a PEF measurement, suggesting suboptimal quality care overall in the Japanese EDs.

Third, this study was not designed to measure patient outcomes after ED disposition such as ongoing symptoms and subsequent relapse. More accurate analyses of those end points would require follow up with patients. These important topics will be the focus of future research by JEMNet investigators.

Fourth, as with any observational studies, the association between guideline concordance and reduced hospitalizations does not necessarily prove causality and might be explained, at least partly, by unmeasured confounders, such as outpatient management for patients with asthma. Nevertheless, even a modest reduction in asthma hospitalizations would provide substantial benefits and is worthy of further investigation.

Finally, our sample consisted predominantly of EDs affiliated with emergency medicine residency programs in urban areas. Therefore, these results may not represent acute asthma management practices in nonacademic or rural EDs, where emergency asthma care might be significantly better or worse than these academic institutions. Either way, we believe our results are highly relevant from a policy standpoint, because these institutions train most emergency physicians in Japan. These institutions thus have a disproportionate effect on the quality of current and future acute asthma care.

In summary, our multicenter study indicated that the overall concordance of acute asthma care with guideline recommendations was suboptimal in Japan. Substantial variations were observed in the quality of care across EDs, suggesting a widespread need for successful knowledge translation initiatives. We believe that greater adherence to evidence-based guideline recommendations will advance excellence in patient care, which, in turn, will improve outcomes of acute asthma. This inference is supported by our finding of a strong association between better guideline concordance and reduced hospital admissions.

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**TABLE E1.** Inter-rater reliability by quality measure from 100 randomly selected samples

| Quality measure                                  | No. of agreement | No. of disagreement | $\kappa$ Statistic | Strength of agreement |
|--------------------------------------------------|------------------|---------------------|--------------------|-----------------------|
| Process measure                                  |                  |                     |                    |                       |
| Treatment with inhaled $\beta$ -agonists in ED   | 100              | 0                   | 1                  | Perfect               |
| Treatment with inhaled anticholinergics in ED    | 100              | 0                   | 1                  | Perfect               |
| Treatment with systemic corticosteroids in ED    | 96               | 4                   | 0.90               | Almost perfect        |
| Treatment with methylxanthines in ED             | 97               | 3                   | 0.56               | Moderate              |
| Treatment with oral corticosteroids at discharge | 97               | 3                   | 0.87               | Almost perfect        |
| Treatment with antibiotics in ED                 | 100              | 0                   | 1                  | Perfect               |
| Treatment with oral antibiotics at discharge     | 100              | 0                   | 1                  | Perfect               |
| Assessment of airflow limitation                 | 98               | 2                   | 0.67               | Substantial           |
| Outcome measure                                  |                  |                     |                    |                       |
| Hospital admission                               | 99               | 1                   | 0.95               | Almost perfect        |

**TABLE E2.** Description of quality measures for acute asthma care

| Process measure                                  | Level of evidence according to the 2007 NIH guidelines | Numerator                               | Denominator                                                                                                                                                                                                                                                                                                                                                                             |
|--------------------------------------------------|--------------------------------------------------------|-----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Treatment with inhaled $\beta$ -agonists in ED   | A                                                      | Inhaled $\beta$ -agonist given in ED    | Patients presenting to the ED with an asthma exacerbation                                                                                                                                                                                                                                                                                                                               |
| Treatment with inhaled anticholinergics in ED    | A                                                      | Inhaled anticholinergics given in ED    | Patients presenting to the ED with a severe asthma exacerbation, defined as any of the following criteria: (1) admitted to hospital, ICU, or observation unit; (2) PEF <200 L/min for women and <250 L/min for men; exclusion of the mildest exacerbations (oxygen saturation = 100% on room air and RR <18/min)                                                                        |
| Treatment with systemic corticosteroids in ED    | A                                                      | Systemic corticosteroids given in ED    | Patients presenting to the ED with a moderate-to-severe asthma exacerbation, defined as any of the following criteria: (1) admitted to hospital, ICU, or observation unit; (2) using any type of corticosteroids at time of ED visit; (3) PEF <300 L/min for women and <400 L/min for men; exclusion of the mildest exacerbations (oxygen saturation = 100% on room air and RR <18/min) |
| Treatment with methylxanthines in ED             | A                                                      | Not given methylxanthines in ED         | Patients presenting to the ED with an asthma exacerbation                                                                                                                                                                                                                                                                                                                               |
| Treatment with oral corticosteroids at discharge | A                                                      | Oral corticosteroids given at discharge | Asthmatic patients who meet the criteria to receive systemic corticosteroids in the ED (see above) and are discharged home                                                                                                                                                                                                                                                              |
| Treatment with antibiotics in ED                 | B                                                      | Not given antibiotics in ED             | Patients presenting to the ED with an asthma exacerbation; exclusion of infections that are generally of bacterial origin, such as pneumonia and otitis media                                                                                                                                                                                                                           |
| Treatment with oral antibiotics at discharge     | B                                                      | Not given oral antibiotics at discharge | Asthmatic patients who do not meet the criteria to receive antibiotics in the ED (see above) and are discharged home                                                                                                                                                                                                                                                                    |
| Assessment of airflow limitation                 | B                                                      | At least 1 PEF measured in ED           | Patients presenting to the ED with an asthma exacerbation; exclusion of respiratory extremis (oxygen saturation <90% or RR >30/min)                                                                                                                                                                                                                                                     |

ICU, Intensive care unit; RR, respiratory rate.

**TABLE E3.** Missing data for ED- and patient-level variables

| Variable                                     | No. missing (%) |
|----------------------------------------------|-----------------|
| ED characteristic (n = 23)                   |                 |
| No. of ED visits per year, median            | 0 (0)           |
| No. of ED visits for asthma per year, median | 0 (0)           |
| No. of ED beds, median                       | 0 (0)           |
| No. of emergency physicians, median          | 0 (0)           |
| Residency affiliated                         | 0 (0)           |
| Urban location                               | 0 (0)           |
| Electronic ED visit notes                    | 0 (0)           |
| Patient characteristics (n = 1380)           |                 |
| Age                                          | 0 (0)           |
| Sex                                          | 0 (0)           |
| Admitted for asthma in past year             |                 |
| ED visit for asthma in past year             | 378 (27)        |
| Ever intubated for asthma                    | 542 (39)        |
| Current use of inhaled corticosteroids       | 73 (5)          |
| Current use of oral methylxanthines          | 70 (5)          |
| Current use of leukotriene modifiers         | 72 (5)          |
| Duration of symptoms                         | 47 (3)          |
| Initial respiratory rate                     | 658 (48)        |
| Initial oxygen saturation                    | 138 (10)        |
| Initial peak expiratory flow                 | 1271 (92)       |
| Concomitant bacterial infection diagnosis    | 24 (2)          |
| ED disposition                               | 0 (0)           |

**TABLE E4.** Performance on quality measures at the patient and ED levels, stratified by use of a peak expiratory flow measurement

| Quality measure                              | No. of patients eligible | No. of times care was delivered | Percentage of recommended care patient received (95% CI) | Median ED performance (IQR)* |
|----------------------------------------------|--------------------------|---------------------------------|----------------------------------------------------------|------------------------------|
| Patients with PEF measurement†               |                          |                                 |                                                          |                              |
| Process of care                              |                          |                                 |                                                          |                              |
| Inhaled $\beta$ -agonists in ED              | 122                      | 116                             | 95 (91-99)                                               | 100 (93-100)                 |
| Inhaled anticholinergics in ED               | 65                       | 0                               | 0 (0-0)                                                  | 0 (0-0)                      |
| Systemic corticosteroid in ED                | 110                      | 42                              | 38 (29-47)                                               | 40 (22-50)                   |
| Methylxanthines not prescribed in ED         | 122                      | 121                             | 99 (98-100)                                              | 100 (100-100)                |
| Prescribed oral corticosteroids at discharge | 95                       | 54                              | 54 (44-64)                                               | 40 (22-50)                   |
| Antibiotics not prescribed in ED             | 119                      | 116                             | 98 (95-100)                                              | 100 (100-100)                |
| Oral antibiotics not prescribed at discharge | 105                      | 104                             | 99 (97-100)                                              | 100 (100-100)                |
| Assessment of PEF                            | 112                      | 112                             | 100 (100-100)                                            | 100 (100-100)                |
| Patients without PEF measurement‡            |                          |                                 |                                                          |                              |
| Process of care                              |                          |                                 |                                                          |                              |
| Inhaled $\beta$ -agonists in ED              | 1258                     | 1069                            | 85 (87-83)                                               | 89 (82-93)                   |
| Inhaled anticholinergics in ED               | 133                      | 3                               | 2 (0-5)                                                  | 0 (0-0)                      |
| Systemic corticosteroid in ED                | 517                      | 310                             | 60 (56-64)                                               | 62 (48-74)                   |
| Methylxanthines not prescribed in ED         | 1258                     | 1179                            | 94 (92-95)                                               | 97 (90-100)                  |
| Prescribed oral corticosteroids at discharge | 378                      | 122                             | 32 (28-37)                                               | 31 (18-54)                   |
| Antibiotics not prescribed in ED             | 1226                     | 1210                            | 99 (98-99)                                               | 100 (97-100)                 |
| Oral antibiotics not prescribed at discharge | 1094                     | 1047                            | 96 (95-97)                                               | 94 (97-100)                  |
| Assessment of PEF                            | 1104                     | 0                               | 0 (0-0)                                                  | 0 (0-0)                      |

\*Restricted to 11 sites with peak expiratory flow measurements.

†Composite guideline concordance score (level A + B evidence) was  $79 \pm 12$  at the patient level and  $79 \pm 6$  at the ED level. Composite guideline concordance score (level A evidence) was  $66 \pm 20$  at the patient level and  $64 \pm 11$  at the ED level.‡Composite guideline concordance score (level A + B evidence) was  $72 \pm 4$  at the patient level and  $72 \pm 6$  at the ED level. Composite guideline concordance score (level A evidence) was  $80 \pm 24$  at the patient level and  $80 \pm 9$  at the ED level.**TABLE E5.** Unadjusted and multivariable-adjusted predictors of higher ED composite guideline concordance score (level A + B)

| ED-level variable                                  | Unadjusted $\beta$ -coefficient (95% CI) | Multivariable-adjusted $\beta$ -coefficient (95% CI)* |
|----------------------------------------------------|------------------------------------------|-------------------------------------------------------|
| Annual ED visits for asthma per 100-visit increase | 6.7 (2.4 to 10.9)†                       | 10.0 (4.4 to 15.6)†                                   |
| Annual ED visits per 1000-visit increase           | 0.03 (−0.2 to 0.2)                       | −0.001 (−0.2 to 0.2)                                  |
| No. of ED beds                                     | 0.0005 (−0.4 to 0.4)                     | −0.6 (−1.3 to 0.1)                                    |
| No. of emergency physicians                        | −0.1 (−0.6 to 0.4)                       | 0.05 (−0.5 to 0.6)                                    |
| Residency affiliated                               | −1.3 (−10.4 to 7.7)                      | −6.1 (−17.3 to 5.1)                                   |
| Urban location                                     | 0.1 (−8.9 to 9.2)                        | −1.3 (−10.6 to 7.9)                                   |
| Electronic ED visit notes                          | 5.4 (−0.9 to 11.7)                       | 3.9 (−3.0 to 10.7)                                    |

\*Model adjusted for all variables shown in the table and aggregated patient mix (age, sex, duration of symptoms, oxygen saturation, and respiratory rate at ED presentation).

†Statistically significant.