Impact of a Bronchiolitis Guideline on ED Resource Use and Cost: A Segmented Time-Series Analysis

OBJECTIVE: Bronchiolitis is a major cause of infant morbidity and contributes to millions of dollars in health care costs. Care guidelines may cut costs by reducing unnecessary resource utilization. Through the implementation of a guideline, we sought to reduce unnecessary resource utilization and improve the value of care provided to infants with bronchiolitis in a pediatric emergency department (ED).

METHODS: We conducted an interrupted time series that examined ED visits of 2929 patients with bronchiolitis, aged 1 to 12 months old, seen between November 2007 and April 2013. Outcomes were proportion having a chest radiograph (CXR), respiratory syncytial virus (RSV) testing, albuterol or antibiotic administration, and the total cost of care. Balancing measures included admission rate, returns to the ED resulting in admission within 72 hours of discharge, and ED length of stay (LOS).

RESULTS: There were no significant preexisting trends in the outcomes. After guideline implementation, there was an absolute reduction of 23% in CXR (95% confidence interval [CI]: 11% to 34%), 11% in RSV testing (95% CI: 6% to 17%), 7% in albuterol use (95% CI: 0.2% to 13%), and 41 minutes in ED LOS (95% CI: 16 to 65 minutes). Mean cost per patient was reduced by $197 (95% CI: $136 to $259). Total cost savings was $196,409 (95% CI: $135,592 to $258,223) over the 2 bronchiolitis seasons after guideline implementation. There were no significant differences in antibiotic use, admission rates, or returns resulting in admission within 72 hours of discharge.

CONCLUSIONS: A bronchiolitis guideline was associated with reductions in CXR, RSV testing, albuterol use, ED LOS, and total costs in a pediatric ED. Pediatrics 2014;133:e227–e234

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KEY WORDS bronchiolitis, guidelines, pediatric emergency, resource utilization, costs

ABBREVIATIONS AAP—American Academy of Pediatrics CI—confidence interval CXR—chest radiograph ED—emergency department LOS—length of stay QI—quality improvement RSV—respiratory syncytial virus

Dr Akenroye was involved in the conceptualization of the study, development of the initial study design, data analyses, and drafted the initial manuscript; Dr Baskin was involved in the development of the final study design, contributed to the interpretation of the data, and provided critical revisions of the manuscript; Dr Samnaliev was involved in the development of the final study design and data analyses, retrieved the financial data, and provided critical revisions of the manuscript; Dr Stack was involved in the conceptualization of the study and development of the initial study design, contributed to the interpretation of the data, and provided critical revisions of the manuscript; and all authors approved the final manuscript as submitted.

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Bronchiolitis is a major reason for ambulatory visits and hospitalizations in patients <2 years old. It is 1 of the top 10 emergency department (ED) diagnoses during the late fall and winter. Viral bronchiolitis, although self-limited with testing and/or therapies offering little or no benefit for most healthy infants, contributes to millions of dollars in annual health care costs.\textsuperscript{2,4}–\textsuperscript{10} The high cost of health care in the United States, currently >17% of gross domestic product, continues to promote extensive discussion among policy makers, payers, health care providers, and consumers.\textsuperscript{11,12} Evidence suggests that >30% of health care utilization is unnecessary and avoidable and includes frequent overuse of screening or diagnostic services.\textsuperscript{12,13} Whereas many approaches have been suggested to rein in health care costs, reduction in the use of unnecessary services has been a recurring theme.\textsuperscript{14} However, to identify what services are unnecessary, and to avoid the potential problem of reducing the quality of medical care while reducing costs, it is important that providers are equipped with the right evidence based on well-executed research. Care guidelines provide a way of integrating best-available knowledge into a concise format and may make it easier for individual providers to use best practices. In 2006, the American Academy of Pediatrics (AAP) bronchiolitis guideline was introduced to aid clinician decision-making in the management of patients with bronchiolitis.\textsuperscript{2} Despite publication of the guideline, many studies across the United States,\textsuperscript{10,15–19} have shown wide variation in resource utilization and ED management of patients with bronchiolitis. Through internal quality assurance efforts, we found wide variation across providers in the management of bronchiolitis. To improve the management of patients with bronchiolitis in our setting, we adapted the AAP recommendations and implemented a bronchiolitis guideline. We hypothesized that adherence to a well-implemented guideline would result in reductions in resource utilization and costs without a worsening of other outcomes.

**METHODS**

The study was approved by the hospital’s institutional review board. An informed consent waiver was obtained for a quality improvement (QI) study. Data were deidentified and presented on the aggregate level.

**Study Design and Setting**

This was a retrospective study of a QI intervention to standardize care for patients with bronchiolitis. The setting was the ED of a tertiary, university-affiliated pediatric hospital with 60,000 annual visits. ED providers consist of 48 board-certified pediatric emergency medicine physicians, 26 general pediatrics, up to 100 registered nurses or nurse practitioners, and >200 rotating residents and fellows.

**Intervention**

**Description of the Guideline**

Due to the variation and potential for improved efficiency in the management of patients with bronchiolitis, a guideline was developed. The guideline was developed by a team chaired by a pediatric emergency physician and nurse and occurred over the 9-month period from October 2010 to June 2011. Implementation occurred at the start of the bronchiolitis season in November 2011. Through an iterative process, early versions were evaluated by 5 pediatric emergency medicine attending physicians with a mean of 12 years of experience after subspecialty training. The nurse provided support for inclusion of nursing-sensitive measures. The major recommendations, adapted from the AAP guideline, were as follows: no routine viral testing, chest radiograph (CXR), and albuterol or antibiotic administration. A trial of bronchodilator to assess for effect was an option.

**Implementation of the Guideline**

Implementation was led by the ED Guideline Implementation Team, made up of 7 individuals: 2 physicians, 2 nurses, a QI expert, a data analyst, and an administrator. Before implementation, electronic order set and discharge instructions were created. In line with the Pathman model,\textsuperscript{20} the goals of implementation were to stimulate awareness of the guideline, promote agreement with recommendations, improve adoption, and support adherence. We used multifaceted strategies, which included the following:

- Guideline introduction and discussion of major recommendations at weekly division conference. At this well-attended conference, providers were allowed to openly agree or disagree with recommendations. The evidence supporting the guideline recommendations was discussed extensively.
- E-mail to ED providers highlighting the major recommendations with a copy of the guideline algorithm attached.
- Display of copies of the algorithm in the ED charting area. Laminated copies of the algorithm and online copies were also available.
- Monthly monitoring of performance on the major recommendations with the use of control charts. These were shared with the clinical chief of the department, the nurse manager, and the guideline physician and nurse leader. Control charts were shared at staff meetings every 2 to 3 months. Booster doses of reinforcement were sent to providers as appropriate.
Annual feedback from the Division Chief to individual attending physicians on their compliance with the major recommendations. As part of this confidential report, individual physicians were also able to compare their performance with (deidentified) peers.

Other strategies included the use of a pocket pamphlet outlining major recommendations, posters (eg, informing providers of the cost of a respiratory syncytial virus [RSV] test), graphical display of performance in the ED conference room, and one-on-one discussions with providers.

Data Collection

Eligible patients were infants between 1 and 12 months of age with a primary diagnosis of bronchiolitis (International Classification of Diseases, Ninth Revision, code 466.11 or 466.19) seen in the ED during the months of November through April 2007–2013. Patients were studied during 6-month period because this is the peak bronchiolitis season in North America.21 The bronchiolitis guideline (Supplemental Fig 2) directed providers in making a clinical diagnosis of bronchiolitis as well as indicating patients who should be excluded. All patients who presented to the ED were eligible regardless of disposition at initial visit. Data on utilization of resources, cost of services, and length of stay were obtained from the administrative and financial databases of the hospital. The hospital’s costing system integrates financial, clinical, and administrative information and uses either internally developed or industry-derived Relative Value Units to accurately assign the costs to individual procedures and activities. Total costs, in 2012 dollars, include the cost of clinical care and the cost of supplies and materials (eg, the costs of diagnostic tests, medications, and procedures and the cost of the ED visit if discharged from the hospital and the ED visit and inpatient costs if admitted). We modeled the change in the total costs associated with the entire episode of care to capture the overall impact of the guideline.

Our primary outcomes, chosen a priori, were rates of CXR, RSV testing, administration of antibiotic or albuterol, and total cost of care. Albuterol was billed by dose (eg, a patient nebulized twice was billed for 2 units). RSV tests include both the point-of-care test and the laboratory direct fluorescent antigen test. Balancing measures, to identify unintended consequences of the guideline, were rates of admission at initial visit, return ED visit resulting in admission within 72 hours of discharge, mortality rate, and the ED length of stay (LOS). We did not define a clinically relevant change in the outcome variables. Because the AAP recommends against obtaining these tests or prescribing albuterol and anti-biotics routinely, we considered any statistically significant change in the primary outcomes as a relevant change. For the balancing measures, we looked for a steadiness in these rates from pre– to post–guideline implementation.

Data Analysis and Statistical Methods

Segmented regression analysis of interrupted time series was conducted to assess the impact of the bronchiolitis guideline. The model compares the preintervention with the postintervention rates while accounting for preexisting trends, the preintervention rates of these outcomes, and the magnitude of the decrease. We adjusted for the following covariates: age, gender, race and ethnicity, oxygen saturation, initial temperature, and disposition.

For all outcomes, the mean monthly rates were modeled, with the exception of ED LOS for which the median was modeled due to its skewed distribution. Serial autocorrelation between error terms was assessed by using the Durbin-Watson statistic, and the Prais-Winsten transformation was applied to adjust for first-order autocorrelation when evidence of autocorrelation was found. Stationarity of segments (in which trends are stable over a given period) were assessed by using the augmented Dickey-Fuller test.22,23

Cost savings after implementation of the guideline were estimated by multiplying the average cost saved per patient by the total number of patients seen. We conducted subgroup analyses for patients who were admitted compared with those who were not. Because the estimated effects of the guideline on all outcomes and costs were in the same direction and of similar magnitude, only the aggregate results are presented. Analyses were conducted in Stata version 12 (StataCorp, College Station, TX).

RESULTS

A total of 2929 patients with bronchiolitis were treated in the ED during the 6 seasons studied (4 seasons pre– and 2 seasons post–guideline implementation). The groups of patients seen during both periods were similar in baseline characteristics, with the exception of race and ethnicity and initial triage temperature. Before guideline implementation, more than one-quarter of patients were categorized as having “other race/ethnicity.” We, however, believe this difference is reflective of coding adjustments in race/ethnicity options. The difference in temperature between the patients seen before and after guideline implementation, although statistically significant, was not clinically meaningful (Table 1).

Primary Outcomes

The unadjusted rates of CXR use, RSV testing, albuterol or antibiotic administration, and average cost per patient during the study periods are shown in Fig 1 A–E. There were no significant
TABLE 1 Characteristics of Patients with Bronchiolitis Seen in the ED Before and After EBG Implementation

<table>
<thead>
<tr>
<th></th>
<th>Before ED EBG (November to April, 2007–2011, n = 1932)</th>
<th>After ED EBG (November to April, 2011–2013, n = 997)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female, n (%)</td>
<td>758 (39.2)</td>
<td>372 (37.3)</td>
<td>.31</td>
</tr>
<tr>
<td>Age, median (IQR), d</td>
<td>153 (81–238)</td>
<td>165 (95–253)</td>
<td>.15</td>
</tr>
<tr>
<td>Asian, n (%)</td>
<td>57 (2.9)</td>
<td>26 (2.6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Black/African American, n (%)</td>
<td>433 (22.4)</td>
<td>194 (19.5)</td>
<td></td>
</tr>
<tr>
<td>White, n (%)</td>
<td>733 (37.9)</td>
<td>357 (35.8)</td>
<td></td>
</tr>
<tr>
<td>Hispanic, n (%)</td>
<td>215 (11.1)</td>
<td>43 (4.3)</td>
<td></td>
</tr>
<tr>
<td>Other race/ethnicity, n (%)</td>
<td>395 (20.6)</td>
<td>257 (26.8)</td>
<td></td>
</tr>
<tr>
<td>Declined or unable to collect, n (%)</td>
<td>99 (5.1)</td>
<td>110 (11.0)</td>
<td>.33</td>
</tr>
<tr>
<td>Oxygen saturation, median (IQR), %</td>
<td>98 (86–99)</td>
<td>98 (86–99)</td>
<td></td>
</tr>
<tr>
<td>Initial temperature, median (IQR), °C</td>
<td>57.3 (36.8–37.7)</td>
<td>37.3 (36.9–37.8)</td>
<td>.008</td>
</tr>
</tbody>
</table>

EBG, evidence-based guideline; IQR, interquartile range

Balancing Measures

The ED LOS was reduced by 41 minutes (95% CI: 16 to 65 minutes) post–guideline implementation. There were no differences in the percentage of patients who had a return ED visit resulting in admission within 72 hours of discharge or in the admission rates at the initial ED encounter (Table 2). There were no deaths during either period.

DISCUSSION

We implemented a bronchiolitis guideline in an effort to improve efficiency while maintaining high-quality care. After guideline implementation, there were statistically significant reductions in diagnostic testing, bronchodilator use, ED LOS, and total cost. Of a total of 997 patients, these changes led to 229 fewer children having a CXR, 110 fewer having a RSV test, and 70 fewer receiving albuterol after guideline implementation. The cost savings of $197 per patient represent ~17% of the total cost of care before guideline implementation and translate into total savings of ~$200 000 for the patients seen postimplementation. Importantly, there was no change in the rates of hospital admission or return to the ED resulting in admission within 72 hours.

For albuterol use, we found only a modest reduction in utilization, but there was a significant downward trend post–guideline implementation. This finding might be indicative of the relative ease of reducing the use of a diagnostic test as opposed to a therapeutic intervention. Physicians may perhaps require more convincing to abandon the use of a relatively safe medication. A recent national study of ED visits also revealed that after the publication of the 2006 AAP bronchiolitis guideline, CXR rates decreased by one-quarter nationally, whereas there was no change in the use of antibiotics and bronchodilators.

The choice to use albuterol was also likely indicative of the strength of the evidence and resulting recommendation. In the guideline, the recommendation is qualified with a “may” as in “trial dose of albuterol may be considered” in contrast to one that says “CXR not routinely recommended.”

Our findings, like those in previous studies, reveal that bronchiolitis guidelines may be associated with reductions in resource utilization. However, most of these studies were in the inpatient setting, with the extent of reduction in CXRs, viral testing, and bronchodilator use widely varying between studies.

Furthermore, studies on the cost impact of bronchiolitis guidelines have been mixed and mostly in the inpatient setting. To our knowledge, no previous study has quantified the cost impact of a bronchiolitis guideline in an ED. This study provides the magnitude of potential cost savings that may be associated with implementation of a bronchiolitis guideline in an ED. By evaluating actual cost savings, and not just reductions in resource use, we assessed for the possible effects of cost shifting. For example, an ED provider might not order a CXR but admit the patient. Furthermore, the study provides a foundation for future studies on the cost-effectiveness of guideline adoption in the ED, which is increasingly being used to optimize the use of health care resources.
Previous studies have shown that guideline adoption is usually slower and more challenging in outpatient compared with inpatient settings. We believe the speed of adoption of the guideline recommendations after implementation and the sustainability of improvements in our ED are probably indicative of the robustness of our implementation strategy. Despite similar ED volumes during both periods, ED LOS also decreased by 41 minutes.

FIGURE 1
Utilization of CXR (A), RSV testing (B), antibiotics (C), and albuterol (D) and average cost per patient (E). Vertical red dashed lines represent the point at which the bronchiolitis guideline was implemented. The x-axis shows the 6 seasons studied (November to April 2007–2013). Labels for alternate months were eliminated for better display.
than those with RSV-induced bronchiolitis. These patients could therefore benefit from further testing. However, we do not expect the percentage of instances when these tests were justified to have changed significantly from pre- to post-guideline implementation given the similar patient populations as well as the multivariate adjustment for patient-level covariates. Fourth, we do not account for the initial costs of developing or implementing the guideline. However, these were relatively small and entirely in kind. Finally, we rely on only a few quantifiable balancing measures. Health care quality may have been affected in other ways not captured in this evaluation. For instance, patients may have presented to another hospital for a return visit.

The cost savings, although they appear to be associated with the specific guideline recommendations, may be indirectly linked to reductions in additional resource utilization. For example, patients who have a CXR may be more likely to receive additional therapies such as antibiotics due to findings on the CXRs that may be more representative of atelectasis than bacterial pneumonia. Reduction in unnecessary utilization may therefore have an impact far beyond the direct savings from the specific resource.

Although these savings could be considered relatively modest, cost reductions at the microsystem level (hospitals, clinics, etc.) may translate into large savings if implemented more broadly. In the United States, children <2 years old represent >200,000 ED visits for bronchiolitis annually. Successful implementation of bronchiolitis guidelines in ED settings with similar cost savings could therefore save up to $40 million annually. This estimate, however, could be conservative because several studies have shown that, in general, regardless of severity, patients with bronchiolitis are more likely to receive resource-intensive and costly care (eg, have a CXR and be prescribed antibiotics) if seen in a general ED as opposed to the ED of a children’s hospital.

From this effort, we have learned that guideline implementation can be successful even in a busy setting such as the ED. More important, we found that provider buy-in is crucial to successful implementation. To seek agreement with recommendations, the evidence supporting each guideline recommendation was discussed extensively. As in this study, it is also important to note that clinical outcomes might not necessarily change after improvement activities, especially in instances in which effectiveness of care is optimal before the improvement activity. Nonetheless, even if outcomes are perfect, because higher

Our findings must be viewed in the light of several limitations. First, this is a single-center study and other contextual factors might have aided successful implementation. However, our implementation strategies are clear and could be easily translated to other EDs. Second, although interrupted time-series analyses are considered a strong quasi-experimental design, changes occurring at the same time as the bronchiolitis guideline could have affected our outcomes. However, to our knowledge, there were no interventions that could have accounted for the magnitude and consistency in change across these outcomes. Third, we did not perform chart reviews to identify patients with significant comorbidities or instances when the utilization of the tests or therapies was justified. We realize that bronchiolitis is a heterogeneous disease with different viral causes and a subset of patients may have benefited from further testing and/or therapies: for instance, patients with human rhinovirus—associated bronchiolitis have been shown to have a different clinical course and may convey a higher risk of childhood asthma than those with RSV-induced bronchiolitis.

### TABLE 2

<table>
<thead>
<tr>
<th>Primary outcomes</th>
<th>Pre-EBG Utilization and Costs (Adjusted)</th>
<th>Change in Utilization and Costs From Pre- to Post-EBG (95% CI)</th>
<th>Pre-EBG Trend per Month (95% CI)*</th>
<th>Change in Trend per Month From Pre- to Post-EBG (95% CI)*</th>
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<tbody>
<tr>
<td></td>
<td>39</td>
<td>−23 (−11 to −34)*</td>
<td>+0.2 (−0.2 to 0.6)</td>
<td>−0.3 (−1.3 to 0.6)</td>
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<td></td>
<td>33</td>
<td>−11 (−6 to −17)*</td>
<td>−0.2 (−0.5 to 0.1)</td>
<td>−0.2 (−0.5 to 0.9)</td>
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<tr>
<td></td>
<td>11</td>
<td>−4 (−9 to 0.7)</td>
<td>+0.02 (−0.5 to 0.1)</td>
<td>−0.4 (−1.1 to 0.3)</td>
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<td>Antibiotics utilization, %</td>
<td>11</td>
<td>−7 (−0.2 to −13)*</td>
<td>+0.2 (−0.2 to 0.5)</td>
<td>−0.9 (−0.2 to −1.6)*</td>
</tr>
<tr>
<td>Albuterol utilization, %</td>
<td>54</td>
<td>−197 (−158 to −259)*</td>
<td>−5 (−11 to 1.3)</td>
<td>−8 (−4 to 20)</td>
</tr>
<tr>
<td>Total cost per patient, $</td>
<td>1178</td>
<td>−213 (−176 to −251)*</td>
<td>−6 (−12 to −1)</td>
<td>−13 (−7 to −18)</td>
</tr>
<tr>
<td>Balancing measures*</td>
<td></td>
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<tr>
<td>Admission rate, %</td>
<td>26</td>
<td>+0.8 (−2 to 3)</td>
<td>+0.1 (−0.1 to 0.3)</td>
<td>−0.2 (−0.5 to 0.2)</td>
</tr>
<tr>
<td>Return ED visit rate, %</td>
<td>2</td>
<td>−1.1 (−3.9 to 1.7)</td>
<td>+0.1 (−0.1 to 0.3)</td>
<td>−0.1 (−0.4 to 0.3)</td>
</tr>
<tr>
<td>ED LOS, min</td>
<td>240</td>
<td>−41 (−16 to −65)*</td>
<td>−0.6 (−2.2 to 1.1)</td>
<td>+1.7 (−1.3 to 4.7)</td>
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Covariates were adjusted for age, gender, race/ethnicity, oxygen saturation, initial temperature, and disposition. EBG, evidence-based guideline. *Significant (P value <.05) after adjustment for preexisting trends and covariates.

* Trend (slope): “+” indicates increasing trend; “−” indicates decreasing trend.

“Change in trend” indicates testing for a significant difference between the pre-EBG and post-EBG slopes. For instance, the albuterol utilization rate revealed no significant pre-EBG trend. Post-EBG, however, the rate decreased at an additional 0.9% per month.

* No deaths occurred during either period.
value health care should be the goal (improved quality, lower costs), we could strive for improved performance in other areas of care, such as efficiency and costs, without jeopardizing the outcomes of care.

Other EDs could improve the uptake of various evidence-based guidelines to improve care in their setting by applying similar principles of implementation as we have done here, such as visible leadership involvement, fostering peer support, and leveraging available resources. However, when embarking on improvement activities, it is important to consider what is feasible. In our case, it was easier to significantly reduce a commonly used diagnostic test than to reduce antibiotics where the rate was already relatively low (10%) and possibly justified before guideline implementation, such as for treatment of concomitant otitis media. It is also harder to increase a high-performance intervention. These floor and ceiling effects might therefore affect QI activities. Also, associated cost savings after implementation of a bronchiolitis guideline will depend on the number of patients with bronchiolitis seen. EDs with low utilization of these tests or therapies and/or with fewer patients with bronchiolitis might not be able to demonstrate significant reductions in resource utilization and costs.

To summarize, in the ED setting, a successfully implemented bronchiolitis guideline can help reduce costs through the reduction of unnecessary utilization of testing and treatment, without a reduction in the quality of care. With the savings of ~$200 per patient, there may be potential for substantial savings in the management of bronchiolitis across the United States, especially in centers with high utilization of testing and/or therapies.

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