A Cost-Saving Algorithm for Children Hospitalized for Status Asthmaticus

Karen M. McDowell, MD; Robert L. Chatburn, RRT; Timothy R. Myers, RRT; Mary Ann O’Riordan, MS; Carolyn M. Kercsmar, MD

Objective: To test the ability of an assessment-driven algorithm for treatment of pediatric status asthmaticus to reduce length and cost of hospitalization.

Design: Nonrandomized, prospective, controlled trial.

Setting: Tertiary care children’s hospital.

Patients: Children aged 1 to 18 years hospitalized for status asthmaticus; 104 were treated using the asthma care algorithm (intervention) and 97 using unstructured standard treatment (control).

Intervention: Patients were treated using either an assessment-based algorithm or standard care practices. The algorithm group was treated with standard medications (aerosolized albuterol, systemic corticosteroids, epinephrine, ipratropium) administered at a frequency driven by the patient’s clinical condition. Specific criteria were outlined for decreasing or augmenting therapy, transferring to intensive care, and discharging to home. A unique patient record containing assessments, algorithm cues, and a treatment record was used. Intervention group patients were interviewed by telephone 1 week after discharge.

Main Outcome Measures: Hospital length of stay, cost per hospitalization, relapse rate, protocol adherence.

Results: Average hospital stay for intervention patients was significantly shorter than for control patients (2.0 vs 2.9 days, *P* < .001). Although intervention patients received fewer aerosolized albuterol doses than controls, there was no difference in short-term relapse rate between groups. The intervention saved more than $700 per patient in hospital charges. Adherence to the protocol was excellent, with only 8 variances per patient stay out of more than 150 opportunities.

Conclusion: An intensive, assessment-driven algorithm for pediatric status asthmaticus significantly reduces hospital length of stay and costs without increasing morbidity.


**RESULTS**

There were 104 patients in the ACA and 97 controls. Patient characteristics are shown in Table 4. By chance, there was a significant difference in age between the groups; however, both groups were of patients and physicians, with inconsistent results.\(^2\) Elimination of treatment that adds cost but not improved quality of care can be an effective strategy.\(^8\) Because asthma is so common and hospitalization for status asthmaticus so frequent, an effective predetermined algorithm could have enormous economic effects by decreasing treatment variation and improving outcomes. We report here a prospective assessment of the medical and economic effects of a newly developed assessment-driven protocol for the management of status asthmaticus in children.

Asthma is one of the most common chronic diseases of childhood, affecting more than 5% of children in the United States; recent data reveal that its prevalence is increasing.\(^3,2\) Asthma is now the most common discharge diagnosis for patients admitted to pediatric hospitals.\(^2\) Forty-three percent of the annual health care expenditures for asthma are spent on emergency department visits, hospitalizations, and costs associated with death.\(^4\)

Numerous attempts have been made to improve asthma management practices of patients and physicians, with inconsistent results.\(^2\) Elimination of treatment that adds cost but not improved quality of care can be an effective strategy.\(^8\) Because asthma is so common and hospitalization for status asthmaticus so frequent, an effective predetermined algorithm could have enormous economic effects by decreasing treatment variation and improving outcomes. We report here a prospective assessment of the medical and economic effects of a newly developed assessment-driven protocol for the management of status asthmaticus in children.
SUBJECTS, MATERIALS, AND METHODS

HYPOTHESES

It was our hypothesis that an intensive, assessment-driven algorithm for treating children hospitalized for status asthmaticus would reduce the length and cost of hospitalization without increasing relapse after hospital discharge. In addition, we expected the asthma care algorithm (ACA) would have a greater effect in reducing length of hospital stay (LOS) and costs in patients with less severe chronic disease.

DESIGN

The ACA was a clinical care algorithm for hospitalized patients with status asthmaticus. Written consent to obtain follow-up information by telephone was obtained from the parent or guardian for all patients enrolled in the ACA. The study was approved by the relevant institutional review boards of University Hospitals of Cleveland, Cleveland, Ohio.

SUBJECTS

Children aged 1 to 18 years hospitalized for the treatment of status asthmaticus and admitted to a single ward of Rainbow Babies and Childrens Hospital between September 1, 1995, through February 28, 1996, were eligible. Patients admitted to a single hospital ward were managed using the ACA. Patients admitted to other wards served as the control group. Patients were excluded if they had other underlying chronic cardiac or respiratory disease (congenital heart disease, cystic fibrosis, bronchopulmonary dysplasia), superimposed acute illness such as pneumonia, respiratory syncytial virus bronchiolitis, or were initially admitted to the intensive care unit. Three patients, 1 in the control group and 2 in the ACA group, were ultimately found to have respiratory syncytial virus but were included in the analysis. Patients in the control group were managed according to orders of the admitting physician; no ACA forms, materials, or protocols were used. The decision to admit patients to the hospital was made by emergency department physicians or by the patient’s primary pediatrician; admitting physicians were unaware of the efficacy study of the ACA. No admitting physician refused to use the ACA. Children admitted through the emergency department had failed to reach discharge criteria after receiving a standard treatment regimen of 6 aerosolized albuterol doses and oral prednisone administered over 2 hours. Decisions regarding placement within the hospital (ie, division assignment) were made according to bed availability by administrative personnel (without input from admitting physician) who were unaware of the existence of the ACA. There were no criteria for patient placement (eg, age, sex, disease acuity, or disease severity) on any given ward; all wards were staffed with registered nurses and respiratory therapists at the same patient-to-staff ratio. Staff assigned to the ACA division did not also provide care for non-ACA patients. A review of asthma LOS by hospital inpatient division in the 16 months preceding the use of the ACA revealed no significant difference among 4 patient care areas.

ALGORITHM DESIGN

After review of the current literature on asthma pathophysiology and treatment, an algorithm was designed. A multidisciplinary team including physicians, nurses, and respiratory therapists participated in its design and reached consensus on its content. Assessment measures known to correlate with acute airway obstruction were chosen (Table 1).11-19 Other measures commonly used in clinical practice (eg, wheezing, air exchange, pulse oximetry) were included to assess their correlation with rate of improvement and satisfactory outcome.20-23 The algorithm was an intensive regimen of standard therapy for asthma that was driven by the patient’s condition. Chest assessments were used to make treatment decisions and determine the frequency of therapy. Specific criteria were outlined for decreasing treatment, augmenting treatment for patients who failed to respond, and transferring patients to the intensive care unit. Criteria for discharge were also specified. Patient and family education was also an integral part of the ACA. Patients and parents were required to demonstrate knowledge of symptom recognition, trigger avoidance, and proper medication use prior to discharge; nurses and therapists documented return of demonstrated knowledge from families on data collection sheets.

A patient record (Algoform) was designed for documentation of assessments and treatments. The Algoform, which included clinical and objective assessments, algorithm cues for the next step, and a record of each treatment given, was at the bedside of each patient in the care path throughout hospitalization (Figure 1). Assessments were made by all health care providers, including physicians, primary nurses, and respiratory therapists. Providers were given lectures and demonstrations on performing chest assessments prior to initiating the care path and monthly updates; all lectures and demonstrations were given by 2 study investigators (C.M.K., T.R.M.). Community physicians and pediatric residents attended several introductory lectures describing the care path and introducing the ACA. The ACA chest assessments were not significantly different from the measures generally obtained for asthmatic children apart from the ACA. Care providers were unaware that data collected would be compared with data from nonalgorithm patients.

ASTHMA CARE ALGORITHM

Chest assessments were performed at prescribed intervals, initially every 2 hours. Wheezing severity, accessory muscle use, and air exchange were graded as good, fair, or poor according to defined criteria (Table 1). Oxygenation by pulse oximetry (Nellcor N-200, Nellcor Inc, Hayward, Calif) was recorded at least once every 8 hours (just prior to aerosolized albuterol administration). Aerosolized albuterol (2.5 mg in 2 mL of isotonic saline solution, driven by oxygen, 6 L/min) was administered only when patients failed to respond, and transferring patients to the intensive care unit. In addition, all patients received oral once-daily prednisone or methylprednisolone (1-2 mg/kg per day, maximum dose 60 mg). Intravenous methylprednisolone was administered (1-2 mg/kg per day, maximum dose 125 mg) only if oral administration was not tolerated. Supple-
mental oxygen was administered at a dose of 2 L/min by nasal cannula or 30% by face mask if the pulse oximetry readings were less than 94% in room air. Supplemental oxygen was then increased or decreased in 0.5-L/min increments to maintain saturation readings of 94% or higher.

The frequency of assessment and treatment was decreased in a stepwise fashion as indicated by improvement on chest assessment measures (Figure 2). Patients in the ACA moved through all 4 levels of assessment, but the amount of time spent at any particular phase and the amount of treatment given were determined by individual patient assessment. Patients were allowed a maximum of 12 hours at any level of treatment. Patients were advanced to the next phase (less frequent level of assessment), before the 12-hour maximum, as soon as they were rated “good” on air exchange, degree of wheezing, and accessory muscle use. In addition, patients had to maintain an oxygen saturation reading by pulse oximetry of 94% or higher on the current fraction of inspired oxygen to advance to less frequent assessment. If after 12 hours at a particular level of therapy patient condition was no worse as indicated by chest assessment scores, the patient was advanced to the next level of treatment, even without meeting the “good” criteria on chest assessment measures. The maximum interval allowed between treatments was 6 hours. Patients were discharged when they maintained a “good” rating on all chest assessment measures and an oxygen saturation reading of 94% or higher on room air while receiving treatments no more frequently than every 6 hours for a minimum of 12 hours. Thus, a patient could spend as little as 12 hours in the asthma algorithm. If patients demonstrated clinical deterioration at any point, they received an “intensified regimen,” consisting of subcutaneous epinephrine (0.01 mg/kg; maximum dose, 0.5 mg), aerosolized higher-dose albuterol (3 mg), and ipratropium (300 µg); no patient experienced any significant cardiovascular or gastrointestinal adverse effects as a result of this therapy.

Children who failed to improve with this treatment were transferred to the intensive care unit. Nurses recorded patient assessments and made algorithm decisions within a given phase; for phase changes, intensification of therapy, or significant change in patient condition, the pediatric resident confirmed the assessment and treatment. Prior to discharge, parents were required to demonstrate understanding of several basic facts about asthma, their child’s medicines, proper technique for use of a metered-dose inhaler (if applicable), asthma triggers, environmental control, and a plan for management of wheezing episodes. Written educational objectives were given to parents at admission along with a packet of simple, written materials designed to meet the above goals. A trained respiratory therapist instructed all patients and caregivers using standardized forms and visual aids. A template for an optional individualized emergency treatment plan for worsening symptoms was provided; the attending physician was urged to complete this treatment plan prior to discharge.

ADHERENCE TO THE ALGORITHM PROTOCOL

Examples of variance include failure to assess or treat patients at appropriate intervals, failure to advance to the next phase of the algorithm, documentation errors, and delay in entry to or exit from the ACA. There are 147 opportunities for variance if a patient spends the maximum amount of time in each phase of the ACA; however, many more variances are possible because there could be multiple deviations from the algorithm simultaneously.

DETERMINATION OF CHRONIC DISEASE SEVERITY

There are no universally agreed on criteria for judging asthma severity; however, most schemes include a combination of functional morbidity measures (symptoms, disruption of activities of daily living) and health care utilization.24,25 The severity of the patients’ chronic asthma (not the severity of the acute episode) was determined based on measures of functional morbidity (symptoms, sleep disruption, activity limitation) and health care utilization (unscheduled visits, hospitalizations); this definition was defined before the study onset. Patients were classified as having mild, moderate, or severe underlying disease (Table 2). Data used to determine severity were gathered prospectively by the admitting physician (pediatric residents) using a standardized history and physical examination form for both the ACA and control patients; admitting physicians were blinded as to study group assignment. Severity classification was then assigned retrospectively by review of the record after discharge.

MAIN OUTCOME MEASURES

Outcome measures included LOS, hospital charges per stay, and readmission rate or need for acute care within 72 hours of discharge. Secondary outcome measures included the number of variances from the algorithm and demonstration of acceptable asthma management behaviors after discharge by the patient’s primary care giver. Deviations from the ACA protocol were determined by review of the assessment and treatment record form after discharge, using a data collection form designed specifically for the study. Readmission rate for intervention and control group patients was determined by review of hospital and emergency department records; for the ACA group, inquiry as to emergency department use or rehospitalization was made during telephone follow-up. Asthma management behaviors were assessed by respiratory therapists using a scripted telephone questionnaire within 1 week of discharge. Acceptable asthma management behaviors were defined as recall of a specific action plan for worsening symptoms. No follow-up data were collected for patients in the control group, and information about hospital management was collected retrospectively after discharge.

STATISTICAL ANALYSIS

Graphical and univariate statistics were used initially to describe the data and determine the appropriateness of parametric or nonparametric tests of significance. Nominal variables were described as frequencies, and interval level data were described as means and SDs or medians and ranges, as appropriate. Patient characteristics were examined to determine if any baseline differences between the care path and control groups existed. Two-sided tests of significance were used and the level of significance was set at .05. Nominal variables were tested using χ² analysis or the Fisher exact test as appropriate; 2-sample t tests were used for normally
distributed data and the Wilcoxon rank sum test for skewed data. Any variable with $P < .2$ was considered for entry into a multivariate model to control for possible confounding. Characteristics relating to chronic disease severity were examined individually and as composite measures (Table 2).

Primary outcome variables were dichotomized at the overall median, and unadjusted association between outcome and group assignment were reported as relative risk with 95% confidence intervals (CIs). Multivariate logistic regression was performed using the dichotomized variables and potential confounders; adjusted odds ratios (ORs), CIs, and significant covariates were reported. Some individual severity characteristics remained significant (emergency department visits, nocturnal symptoms), while composite measures did not. Stratified analyses within severity levels indicated a possible interaction with group assignment; however, the interaction term was not significant (Table 3).

Statistical analyses were carried out using STATIT software (Statware Inc, Corvallis, Ore). Software such as SAS (SAS System, SAS Institute Inc, Cary, NC) and Splus (Stat-Sci Division, Mathsoft, Cambridge, Mass) were also used for some specific analyses.

To detect a difference in LOS of 0.5 day, the shortest interval deemed clinically significant, an a priori power analysis indicated that 64 patients would be needed in each group ($\alpha = .05, 1 - \beta = .80$).

Composed largely of school-aged, prepubertal children. The ACA group had more white patients (27.5%) than the control group (12.4%) ($P = .008$). Potential confounders (race, age) were included in a multivariate model. The majority of patients (70% for ACA group, 66% for control group) were admitted through the emergency department. The remainder were admitted from pediatricians’ offices or transferred from outlying emergency facilities. There was no difference in the number of patients in each group who used inhaled or oral corticosteroids prior to coming to the hospital; significantly more patients in the control group reported using cromolyn sodium ($45$ vs $27$, $P = .002$, $\chi^2$ test) (Table 4). The majority of patients in both groups reported Medicaid as the primary insurance type (ACA group 63%, control group 59%).

Measures of severity of acute illness included pulse oximetry in room air on admission and use of supplemental oxygen during hospitalization. The ACA patients had a significantly lower mean oxyhemoglobin saturation on admission than controls (93.2% [SD, 2.70] vs 94.7% [SD, 2.97] respectively; $P < .001$). However, there was no difference in the number of patients who required supplemental oxygen ($P = .32$).

**LENGTH OF STAY**

The median LOS for ACA patients was significantly shorter than for controls; this difference remained significant when adjusted for age, race, and sex in a multivariate model ($P < .001$) (Table 5). Controls received significantly more aerosolized albuterol doses during hospitalization than did ACA patients; however, controls were also discharged once they were stable with receipt of aerosolized albuterol doses every 6 hours. There was no difference in the albuterol or corticosteroid dosage between the ACA and control groups.

When patients were stratified according to chronic disease severity, the ACA patients had significantly shorter...
required intensive treatment had severe chronic asthma. Of the 97 patients who required intensified treatment in the control group, 5 (5%) had severe asthma. Although there was no standard regimen of intensified treatment in the control group, 5 (5%) of 97 patients received ipratropium and/or subcutaneous epinephrine. Four of the 5 patients in the control group who required intensive treatment had severe chronic asthma.

LOSs in the mild and severe disease groups (Table 5). There was no significant difference in average LOS among patients with differing disease severity within the ACA or the control groups (Table 3).

During the study period, patients treated using the ACA had shorter LOSs compared with those in the control group (Figure 3). There was a small but significant decrease in LOS in the ACA group as the study progressed; the controls showed no such decline.

Sixteen patients in the ACA group (15%) received intensified therapy. Of these patients, 8 received more intensive therapy because of worsening clinical status. The remainder were considered protocol variances because none met algorithm criteria for more aggressive therapy. Seven of the 16 patients who required intensified treatment had severe chronic asthma. No patient who received the intensified therapy experienced any adverse effects, such as tachycardia, nausea, or vomiting. Although there was no standard regimen of intensified treatment in the control group, 5 (5%) of 97 patients received ipratropium and/or subcutaneous epinephrine. Four of the 5 patients in the control group who required intensive treatment had severe chronic asthma.

The average number of hours spent in each phase of the algorithm is shown in Figure 4. Patients tended to spend less than 12 hours in any phase of the algorithm, indicating that, on average, they were usually advanced along the algorithm because of improvement rather than because they had exhausted the allowable time at the previous phase. The number of patients who spent the full 12 hours in each phase is shown in Figure 4. Because many fewer patients required intensive therapy than spent maximum time in a phase (4 in phases 1 and 2, 7 in phase 3), even patients who were advanced because they had spent 12 hours in a phase tended not to worsen. No patients in the ACA or control group were transferred to the intensive care unit.

### Table 3. Length of Stay by Chronic Asthma Severity Classification

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>ACA† (n = 104)</th>
<th>Control† (n = 97)</th>
<th>Odds Ratio</th>
<th>Confidence Interval</th>
<th>P†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>1.93 (0.23)</td>
<td>2.75 (0.28)</td>
<td>0.14</td>
<td>0.03-0.63</td>
<td>.007</td>
</tr>
<tr>
<td>Moderate</td>
<td>2.12 (0.32)</td>
<td>2.50 (0.40)</td>
<td>0.27</td>
<td>0.06-1.10</td>
<td>.08</td>
</tr>
<tr>
<td>Severe</td>
<td>1.94 (0.16)</td>
<td>2.79 (0.21)</td>
<td>0.27</td>
<td>0.13-0.56</td>
<td>.001</td>
</tr>
</tbody>
</table>

*All data are reported as mean (SE) number of days unless otherwise indicated. ACA indicates asthma care algorithm.
†χ² Analysis of the number of patients above and below the overall median.

### Table 4. Patient Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>ACA (n = 104)</th>
<th>Control (n = 97)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median ± SD age, y</td>
<td>7.3 ± 0.81</td>
<td>5.0 ± 0.73</td>
<td>.003†</td>
</tr>
<tr>
<td>Race, white/nonwhite</td>
<td>30/74</td>
<td>12/85</td>
<td>.008</td>
</tr>
<tr>
<td>Sex, F/M</td>
<td>40/64</td>
<td>43/54</td>
<td>.45</td>
</tr>
<tr>
<td>Chronic disease severity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild</td>
<td>19</td>
<td>20</td>
<td>.96</td>
</tr>
<tr>
<td>Moderate</td>
<td>15</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Severe</td>
<td>64</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Median ± SD oxygen saturation admission, %</td>
<td>93.2 ± 2.7</td>
<td>94.7 ± 2.9</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Patients requiring supplemental oxygen, %</td>
<td>49</td>
<td>41</td>
<td>.32</td>
</tr>
<tr>
<td>Medication use before hospitalization</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oral corticosteroid</td>
<td>10</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Inhaled corticosteroid</td>
<td>8</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Cromolyn sodium</td>
<td>27</td>
<td>45</td>
<td>.002</td>
</tr>
</tbody>
</table>

*Data are given as number of patients unless otherwise indicated. †Wilcoxon rank sum test; remaining values are χ² test.

The number of patients who spent the full 12 hours in each phase is shown in Figure 4. Because many fewer patients required intensive therapy than spent maximum time in a phase (4 in phases 1 and 2, 7 in phase 3), even patients who were advanced because they had spent 12 hours in a phase tended not to worsen. No patients in the ACA or control group were transferred to the intensive care unit.

### Relapse Rate

Three patients in the ACA group required readmission or an emergent visit within 72 hours of hospital discharge. One patient required readmission because of an unstable social situation unrelated to asthma. The other 2 patients were seen in outlying emergency departments and discharged. One patient in the control group required readmission at our institution within 72 hours of discharge; the controls showed no such decline. One patient in the control group required readmission or an emergent visit within 72 hours of hospital discharge. Three patients in the ACA group required readmission or an emergent visit within 72 hours of hospital discharge. One patient required readmission because of an unstable social situation unrelated to asthma. The other 2 patients were seen in outlying emergency departments and discharged.
There was no difference in relapse within 72 hours for the ACA compared with the control group (2.8% vs 1%, \( P = .62 \), Fisher exact test) given the available data.

ASTHMA KNOWLEDGE AND MANAGEMENT BEHAVIORS

Telephone surveys were completed by 41% of the ACA group; the remaining patients were not able to be contacted within the month following hospital discharge. Ninety percent of the patients or caregivers contacted were able to recall names, doses, and frequency of administration of medications prescribed at discharge. However, only 64% of patients or caregivers were able to report the home treatment plan for an acute asthma exacerbation that had been given to them at discharge, and only 17% of the patients or caregivers reported receiving the acute emergency plan from the managing physician.

COSTS

Based on financial data for our institution, the average charge for the hospital stay was more than $700 less for the ACA group. The relative risk for a charge above the median in the ACA was 0.33 (CI, 0.18-0.59) compared with the control group. These savings were realized largely due to the shortened LOS.

ADHERENCE TO THE ALGORITHM PROTOCOL

The median number of variances during hospitalization was 8 per patient. However, there are more than 150 possible variances per patient. The most common errors were un-
Large variations in acute asthma treatment result from differences in disease severity and discrepancies in the application of a relatively small number of medications. An algorithm for status asthmaticus in which interval therapy changes are determined by patient condition delivers individualized high-quality care within a standardized framework, reduces LOS, and promotes cost-effectiveness. The ACA effectively shortened the LOS for patients with status asthmaticus, reducing the LOS by nearly a full day. Patients demonstrated significant benefit in LOS regardless of chronic disease severity. We hypothesized that resources are least effectively used for mild chronic asthma and anticipated the significant reduction in LOS when it was managed according to the ACA. However, a similar finding was observed for severe chronic asthma. Frequent assessment, combined with specific criteria for decreasing treatment, may have allowed more rapid reduction of therapy in the severe subgroup. Without the specific criteria of the ACA for modifying therapy, physicians may weigh severity of underlying disease more heavily than actual clinical status when making treatment decisions. Patients in the ACA and control groups were comparable in severity of acute episode as all met criteria for admission to the general pediatric divisions; there were no clinically significant differences in degree of hypoxemia on admission and no difference in need for supplemental oxygen.

By chance, the ACA and control groups differed in age and racial composition. However, the age difference between groups was relatively small and did not cross significant developmental ranges. In addition, patients with respiratory syncytial virus bronchiolitis, a condition that could confound the response to the ACA in younger patients, were excluded from the study. Although it is possible that race could influence underlying disease severity or control, the significant difference in length of stay between ACA and control groups persisted after adjustment for race, sex, and age. Therefore, the racial and age imbalance between groups did not account for the improved length of stay in the ACA group.

Although many patients remained in a phase for the entire 12 hours, a large proportion did not (Figure 4). Moreover, less than 12% of these patients (in each phase) required more intensive therapy, and no patients required transfer to the intensive care unit. These data support an assessment-driven algorithm based on 12-hour time-limited phases. Regimens in which patients spend a fixed amount of time at a given treatment level regardless of improvement would result in overtreatment of almost half the patients. There was no difference in the frequency of therapy at discharge for ACA patients compared with controls, indicating that ACA patients were not discharged “sicker” than controls. Also, ACA patients showed no greater incidence of relapse than controls. The relapse rate of 2.9% for ACA patients is comparable to the 3% to 4% rates reported in other asthma intervention studies and surveys, although it is possible that some relapses were missed if patients received acute care or were hospitalized at other medical facilities. More important, the low incidence of relapse supports the conclusion that these cost savings are not the result of shifting the economic burden from hospitalization costs to ambulatory acute care costs after discharge.

Hospitalization for asthma constitutes failure of outpatient management. Previous studies have shown that patients often do not institute appropriate therapy prior to seeking emergent care for worsening symptoms. Analysis of pediatric emergency department visits for asthma at our institution from 1995 to 1997 revealed that 19% of patients presented having taken fewer than 2 albuterol aerosol doses and no oral steroids. Davidson et al reported that 22% of patients used the emergency department as their only management plan for worsening symptoms. Better patient management skills regarding trigger avoidance and aggressive management of early symptoms could theoretically prevent relapse. Although the data are somewhat limited by an incomplete response rate, our education program resulted in more than 90% of patients being able to recall their medications. However, fewer than two thirds could outline an emergency treatment plan for worsening symptoms. This discrepancy highlights a particularly difficult problem: knowledge of routine medications does not necessarily indicate ability to institute appropriate therapy for worsening symptoms. Because provision of a written emergency treatment plan was at the discretion of the attending physician, the low percentage of patients reporting a management plan for worsening symptoms may also reflect underrecognition by health care providers of the importance of patients’ need for such a plan. It is also possible that these data are negatively influenced by the large portion of the sample (59%) for whom data are missing. However, one study found only 28% of patients admitted for status asthmaticus had been given an action plan for an acute exacerbation by their primary care provider. Thus, teaching management of worsening symptoms and providing a written emergency treatment plan must be specifically emphasized with all patients.

The ACA also decreased hospitalization charges for status asthmaticus by reducing resource utilization: ACA patients required significantly fewer albuterol doses than controls, reducing both drug and personnel costs. Because the ACA required no additional personnel for implementation, reducing time spent administering medication allowed providers more time for other duties. The ACA also improved documentation procedures. Prior to the ACA, patient assessments were recorded inconsistently and in multiple locations in the patient record. The ACA form, which incorporated results of assessments and algorithm cues, eliminated redundancy or omissions in documentation and required treatment decisions based on patient assessment. The small but significant further decrease in the LOS in the ACA group, but not the controls, during the length of the study probably reflects increased efficiency by the staff with the ACA protocol.

Cost reductions resulting from reorganization of existing resources led to substantial savings for both the hos-
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REFERENCES


Corresponding author: Carolyn M. Kercsmar, MD, 11100 Euclid Ave. Department of Pediatrics, Rainbow Babies and Childrens Hospital, Cleveland, OH 44106 (e-mail: kercsmar@pol.net).