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Pediatrics 2000;105;767-773
DOI: 10.1542/peds.105.4.767

A Guideline Implementation System Using Handheld Computers for Office Management of Asthma: Effects on Adherence and Patient Outcomes

Richard N. Shiffman, MD, MCIS*‡; Kimberly A. Freudigman, PhD*; Cynthia A. Brandt, MD, MPH‡; Yischon Liaw, MD‡; and Deborah D. Navedo, MSN*

ABSTRACT. *Objective.* **To evaluate effects on the process and outcomes of care brought about by use of a handheld, computer-based system that implements the American Academy of Pediatrics guideline on office management of asthma exacerbations.**

Design. **A before–after trial with randomly selected, office-based Connecticut pediatricians. In both the control and intervention phases, physicians collected data from 10 patient encounters for acute asthma exacerbations. During the intervention phase, the computer provided for structured encounter documentation and offered recommendations based on the guideline of the American Academy of Pediatrics. Patients were contacted by telephone 7 to 14 days after the visit to assess outcomes.**

Results. **Nine study-physicians enrolled 91 patients in the control phase and 74 in the intervention phase. Follow-up information was available for 93% of encounters. Use of the intervention was associated with increased mean frequency/visit of: 1) measurements of peak expiratory flow rate (2.18 vs 1.57) and oxygen saturation (1.12 vs .42), and 2) administration of nebulized β2-agonists (1.25 vs .71). Visits in the intervention phase lasted longer and fees were higher ($145.61 vs $103.11). There were no significant differences in immediate disposition or subsequent emergency department visits, hospitalizations, missed school, or caretaker's missed work during the 7 days post visit.**

Conclusion. **Use of handheld computers that provide guideline-based decision support was associated with increased physician adherence to guideline recommendations; however, visits were prolonged, fees were higher, and no improvement could be demonstrated with regard to the observed intermediate-term patient outcomes. Guideline implementers (and users) should be cautious about putting unvalidated recommendations into practice.** *Pediatrics* **2000;105:767–773;** ***guideline adherence, asthma, computer-based decision support.***

ABBREVIATIONS. AAP, American Academy of Pediatrics; PEFR, peak expiratory flow rate; ED, emergency department.

From the *Department of Pediatrics and ‡Center for Medical Informatics, Yale School of Medicine, New Haven, Connecticut.
Received for publication Mar 2, 1999; accepted Jul 28, 1999.
Reprint requests to (R.N.S.) PO Box 208009, TMP-3, New Haven, CT 06520-8009. E-mail: richard.shiffman@yale.edu

Practice guidelines have been devised for a large number of medical conditions to diminish inappropriate variations in clinical practice, to control costs, and to improve patient outcomes. However, several factors have limited the success of guideline initiatives. Some guidelines are difficult to apply because they are intrinsically unclear and incomplete.[1] Others are based on unvalidated opinion rather than a cogent evidence base; in such cases, the consequences of imposition of the policies are unknown.[2] Many physicians are resistant to the very concept of guidelines. Accustomed to functioning autonomously, they see the imposition of practice policies as a threat to the traditional doctor–patient relationship.[3] Finally, unless an effective implementation strategy is chosen, the expensive, resource-intensive guideline development process often fails to influence clinicians' behavior.[4–6]

In a meta-analysis of studies selected for methodologic rigor, Grimshaw and Russell[7] reported improvements in the process of care in 55 of 59 evaluations of guideline implementation. They found that the best predictor of successful implementation was providing guideline-based recommendations that were patient-specific at the time and place of the consultation. Computer-mediated decision support systems can process clinical data from individual patients and can offer tailored advice at the point-of-care. A structured review of evaluations of such decision support systems found improved clinician performance in 43 of 65 trials.[8]

In 1994, the American Academy of Pediatrics (AAP) published a practice parameter for management of asthma exacerbations in children who present to an office setting.[9] Asthma is the most common chronic illness in childhood accounting for 25% of school absences; the prevalence and rate of outpatient visits for asthma are rising, as is the mortality rate.[10] Total costs of illness related to asthma exceeded $5.8 billion in 1987.[11] Although effective therapy exists, there is evidence of inconsistent and suboptimal care of asthma in both children and adults.[12–14]

This report describes an investigation that evaluated the effectiveness of a handheld, computer-based decision support device in implementing the AAP asthma guideline. Specifically, we examined whether use of the device led to improved adherence to the guideline regarding: 1) measurement of peak expira-

tory flow rate (PEFR) and oxygen saturation, 2) prescription of corticosteroid, and 3) administration of oxygen.

Studies that investigate only process measures, eg, adherence to guideline recommendations, may fail to identify policies with adverse effects on health outcomes.[15] Despite the best intent of guideline developers, untested policies may have unanticipated side effects. Because the AAP guideline recommendations had not been previously validated, this study also explored whether adherence to the guideline was associated with changes in immediate outcomes, eg, improvement in the severity of the exacerbation or disposition from the office, and other indicators of functional status in the week after the office visit, including repeat office visits, delayed emergency department (ED) visits and hospitalizations, missed school days, and missed caretaker work days.

METHODS

Guideline Recommendations

The AAP practice parameter on office management of asthma exacerbations in the office setting was published in *Pediatrics* in both algorithmic and tabular formats.[9] The developers suggested that the practice parameter differed from common practice in recommending: 1) the use of physiologic measures—PEFR and oxygen saturation—to better assess the severity of asthma exacerbations, 2) increased frequency and dosage of β2-agonists, and 3) increased use of corticosteroids.[9]

This was the first AAP guideline constructed with an evidence-based development process. That process proceeds systematically through the following sequence of activities: problem definition, comparison of potential interventions, identification of health outcomes, comprehensive literature review with structured abstraction of evidence from the identified literature, development of evidence tables, meta-analysis, assessment of benefits and harms, and development of parameter recommendations (C. Herrerias, AAP, personal communication, 1997).

Selection and Randomization of Participants

Physician–subjects were drawn from a pool of 375 pediatrician listings in the *1996 Fellowship Directory* of the AAP, which categorizes members by state and city. The authors assigned a numeric identifier to each pediatrician listed in Connecticut cities and towns within a 20-mile radius of New Haven. In a rolling recruitment process, the RAND random number tables were used to select candidates, who were screened for eligibility and invited to participate until 11 participants had been recruited.

Eligibility criteria included pediatricians who: 1) actively practiced primary care pediatrics within a 20-mile radius of New Haven, Connecticut, 2) anticipated seeing 20 patients older than 5 years of age with acute asthma exacerbations within the following year, and 3) had equipment available in their offices for measurement of PEFR and for providing supplemental oxygen if needed. Pediatricians in academic practices, physicians-in-training, and subspecialists in allergy and pulmonology were excluded. To achieve a randomization by practice unit and to avoid potential contamination, only 1 physician from any group practice was eligible for participation.

Eligible patients were children between 5 and 18 years old, who presented to a nonhospital setting with acute exacerbations of asthma. Physician–subjects and patients were masked with respect to specific study hypotheses. They were told we were investigating "asthma care for Connecticut children in which we would evaluate a computer-based, decision support device and the costs of care." Data collection forms were designed to resemble superbills and included checkboxes for recording a number of items unrelated to the study hypotheses that might be examined in any comprehensive study of asthma care, eg, blood counts and chest radiographs ordered, epinephrine administered, and theophylline prescribed. The study was approved by the Yale School of Medicine Human Investigations Committee.

Study Design

The study was a randomized, prospective, before–after trial. Physician–subjects served as their own controls, thus improving statistical power. Sample size calculations with the physician as the unit of analysis indicated that a paired analysis of a sample of 10 physicians—each of whom enrolled 10 patients in the control and intervention phases—would have a power of .80 to detect a 20% difference in adherence rates. On enrollment, physician–participants provided informed consent and were instructed in the selection of patients and completion of study forms. Each pediatrician completed a questionnaire that supplied information on personal demographics, computer experience, and fees. In the control phase, each physician enrolled 10 consecutive eligible patients and managed them in the conventional manner. Next, in the intervention phase, physicians were asked to enroll 10 additional patients using the handheld, computer-based system (see below) to assist care. Physicians received $200 at the conclusion of the study in partial compensation for time spent.

The intervention (known as AsthMonitor) consisted of a Newton MessagePad 130 (Apple Computer Co, Cupertino, CA) outfitted with custom-designed software and an Apple StyleWriter 1200 inkjet printer. The system was designed for use at the point-of-care. It provided: 1) structured documentation of the clinical encounter using a pen-stylus, 2) dynamically-generated recommendations based on the AAP practice parameter, 3) assistance with calculation of predicted PEFR and medication dosages, and 4) printed encounter summaries and prescriptions. Study personnel provided in-office training in the use of the intervention.

The system provided guideline recommendations in 2 formats. Reminders for PEFR and oxygen saturation measurement were listed at the top of a window for documentation of physical findings (which also listed respiratory rate, alertness, dyspnea, retractions, color, chest sounds, subcutaneous air, and pulsus paradoxus). Recommendations for administration of oxygen, inhaled albuterol, and corticosteroids were provided on screens that appeared when appropriate combinations of findings triggered them. Null entries for PEFR and oxygen saturation measurements were permitted. Likewise, users were not obliged to follow any recommendation; physicians could deselect any recommendations and make alternate choices. Users could retrieve explanatory information that supported each recommendation by tapping an "Information Button" next to each recommendation.

Sampling of Records and Data Collection

Physicians completed a data form for each patient during both the control and intervention phases, which documented the severity of the exacerbation at presentation and discharge (mild, moderate, severe, and resolved); tests performed in the office; medications and treatment performed in the office; prescribed medications; the duration of the visit, defined as time from initial contact with a clinician until discharge from the office; immediate patient disposition; and total fee charged. Pediatricians determined the severity of the exacerbation based on a table of physical signs and physiologic measurements from the published guideline (reproduced on the data collection form). PEFR was considered to have been measured if either an actual measurement was obtained or the physician recorded that an effort was made but the child was unable to cooperate. Data forms, office notes, and (during the intervention phase) AsthMonitor encounter summaries were faxed to the study office after each encounter. Parents and/or patients were contacted by telephone 7 to 14 days after the office visit by 1 of the authors to ascertain outcomes in the 7 days after the initial office visit. A structured set of questions was read to the patient, eg, "In the 7 days after your (child's) visit to Dr_____'s office, did you miss any school? If so, how many days?" A study assistant (masked to study hypotheses) entered all data into a database and all entries were rechecked for accuracy. Each physician supplied data on customary charges for asthma-related services before beginning patient enrollment. A questionnaire was administered at the conclusion of the study to assess practitioners' reactions to AsthMonitor.

Analysis

Adherence rate was defined as the proportion of visits at which a physician performed an intervention in compliance with a guideline recommendation (eg, measured PEFR or prescribed cor-

ticosteroids) compared with the number of visits at which the intervention was appropriate. The AAP guideline recommended: 1) measurement of PEFR (and/or oxygen saturation) in all patients who presented with acute asthma exacerbations; 2) administration of supplemental oxygen to all patients who presented with moderate or severe exacerbations, and 3) consideration of prescription of steroids for any patient who presented with an asthma exacerbation. We designated the prescription rate of corticosteroids—ie, the number of encounters for which the physician prescribed steroids divided by the total number of encounters for that physician—as an adherence rate. We also tabulated the mean number of times per visit that a repeated intervention (eg, PEFR measurement or nebulization treatment) was performed.

Because guideline adherence is strongly dependent on each physician's knowledge, abilities, and acceptance of guideline recommendations, the computation of adherence rates was based on the individual physician as the unit of analysis.[16] This permitted a paired analysis of adherence data for each physician during the control and intervention phases. Continuous variables (eg, adherence rates, number of nebulization treatments, and fees) were analyzed using *t* tests and analysis of variance. Categorical variables (eg, nebulization treatment—yes or no) were analyzed using χ^2 analysis. Analysis of covariance was used to control for the effects of severity on outcome data. Patient outcomes were calculated as the proportion of patients who experienced that outcome compared with all patients in that phase of the study. All statistical calculations were 2-tailed and performed with SPSS 8.0 (Chicago, IL) and EpiInfo 5 (Centers for Disease Control and Prevention, Atlanta, GA).

RESULTS

General

Data collection began on September 30, 1996 and the study was terminated on October 1, 1998. The average time interval for each physician to complete phase I was 228 days (range: 65–361 days); the average time interval in phase II (before completion or study termination) was 192 days (range: 60–336 days). A schematic summary of the study is shown in Fig 1.

Of the 375 listings of pediatricians within a 20-mile radius of New Haven, 138 were eliminated because of categorization as residents or fellows in-training ($n = 80$) or an address at a medical center or medical school ($n = 58$). The remaining 237 were subjected to a random, rolling recruitment process. Of those selected, 28 were not in active primary care pediatric practice—22 were retired, working in administration, or practicing part-time—and 6 had moved away; 4 did not anticipate seeing 20 asthma patients in the coming year; 7 did not have required equipment; and 5 were partners of participants who had been enrolled previously. Eighteen potentially eligible physicians declined to participate in the study, 7 of whom belonged to a single multisite group practice whose administration proscribed participation despite the willingness of individual group members to take part. Of the 11 physicians who enrolled in the study, 2 dropped out during the control data collection phase—1 because of a move out-of-state, and the other because of excessive workload. Data on the 11 control phase patients they submitted were eliminated from the analysis because of our inability to make comparisons with intervention data.

During the control phase of the study, physician–participants enrolled 91 patients—each of the 9 physicians enrolled 10 patients (1 enrolled 11). In the intervention phase, 74 patients were enrolled—6 physicians each enrolled 10 patients and 3 physicians enrolled 8, 5, and 1 patient(s), respectively. In calculating changes in adherence rates, we eliminated

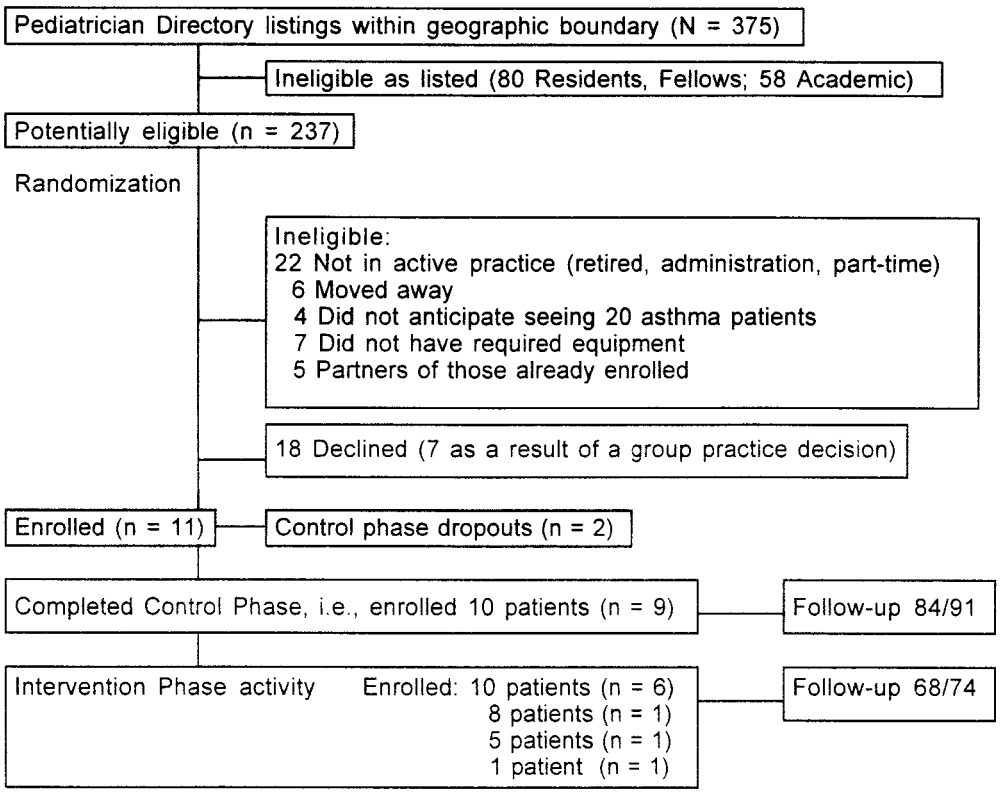

Fig 1. Schematic summary of study.

data from the single physician, who enrolled only 1 patient in the intervention phase. For each of the remaining 8 physicians, we calculated the adherence rate in each phase and performed a paired analysis. Follow-up data were collected from 92% of control patients (84/91) and 93% of intervention patients (69/74).

Characteristics of the 9 study physicians are summarized in Table 1. The distribution of practice settings seemed to fairly reflect the practice milieu in this part of New England. The majority of physicians were relatively computer-naïve by self-description. The average age of the patients enrolled during the control phase was 10.3 years (range: 5.0–17.4) and during the intervention phase was 10.8 (range: 5.0–17.8).

Guideline Adherence

Adherence to guideline recommendations for assessment of PEFR and oxygen saturation, office administration of β-agonists and oxygen, and prescription of corticosteroids increased during the intervention phase of the study (Table 2). Mean adherence rate for measurement of PEFR was .86 at baseline and rose to .94 with the intervention (P = .32). Adherence rate for measurement of oxygen saturation nearly doubled (.29–.56; P = .007). The difference between the practitioners' rates of adherence in the control and intervention phases approached statistical significance for β-agonist nebulization treatments (.73–.91; P = .064) and corticosteroid prescription (.43–.57; P = .055). As shown in Table 3, the number of measurements per visit of PEFR and oxygen saturation and the number of nebulization treatments administered per visit also rose significantly during the intervention phase.

Clinicians recorded the duration of office visits as <30 minutes, 30 to 60 minutes, and >1 hour. During the control phase, 44% of the visits lasted <30 minutes and 46% lasted 30 to 60 minutes. Only 10% lasted more than an hour. During the intervention phases, visit duration was prolonged. Only 15% of visits lasted <30 minutes, while 67% lasted 30 to 60 minutes and almost twice as many lasted >1 hour. The difference in visit duration was statistically significant (χ^2 = 15.62; P < .0004).

Use of the intervention was also associated with increased charges. The average fee charged by the study physicians during the control phase was $103.11 and rose to $145.61 during the intervention phase. This may be accounted for by charges for the increased number of interventions described above or by upcoding attributable to the more extended nature of the visits. Among the 8 physicians (from whom fee schedules were obtained at enrollment), the most commonly used *Current Procedural Terminology* code for asthma visits was 99213 for which the median fee was $65.00. The median fee for the next level of *Current Procedural Terminology* code 99214 was $77.50. The median charge for PEFR measurement was $12.50 and for oxygen saturation measurement was $30.00 (although some physicians did not bill repeatedly for physiologic measures), and for nebulization treatment was $30.00.

TABLE 1. Characteristics of Physicians

Gender
6 male/3 female
Mean age
43 y (range: 31–53)
Mean interval since completion of residency
11.6 y (range: 2–19)
Percentage of effort in practice setting
11% urban, inner-city
28% urban, not inner-city
56% suburban
5% rural
Self-assessed computer experience
2 nonuser
4 novices
3 intermediate

At presentation in the control phase, 78% (n = 71) of the patients were assessed to have mild exacerbations and 22% (n = 20) moderate exacerbations. During the intervention phase, 59% (n = 44) were judged to have mild exacerbations, 36% (n = 27) had moderate exacerbations, and 4% (n = 3) had severe exacerbations at presentation. The increased severity of illness during the intervention phase was statistically significant (χ^2 = 8.72; P = .0128) and introduced a potential confounder into the analysis. No other confounding variables were identified with univariate analysis.

To control for the potential confounding effect of the presenting severity of the exacerbation, we performed analysis of covariance and examined the effect of the intervention. The analysis showed a statistically significant effect of the intervention on the number of PEFR measurements ($F_{1,158}$ = 8.64; P < .01), the number of oxygen saturation measurements ($F_{1,159}$ = 8.5; P < .01), the number of nebulization treatments ($F_{1,153}$ = 12.3; P < .001), and fees ($F_{1,156}$ = 14.14; P = .0002).

According to the guideline, 50 patients should have received oxygen treatment because they presented with moderate or severe exacerbations—20 in the control phase and 30 in the intervention phase. Although no physicians administered oxygen to their patients during the control phase, 3 of the 30 recommendations to administer oxygen from the AsthMonitor system were heeded. In their responses to the exit questionnaire, clinicians made it clear that they often disagreed with the recommendation to prescribe oxygen: "Did not feel the need was acute enough to treat with oxygen," "I . . . feel oxygen recommendation (was) overly given," "Recommendations with regard to giving oxygen and oral steroids more conservative than what I felt necessary," "I felt oxygen prescribed too often by AsthMonitor," and "Too cumbersome to bring out oxygen tank when I know pt will improve readily with nebulization therapy."

Patient Outcomes

Comparing the physicians' assessments of each patient's asthma severity at presentation and discharge, during the control phase 43.3% of patients (n = 39) improved over the course of the office visit, whereas 57.7% (n = 41) improved during the inter-

TABLE 2. Guideline Adherence Rates for the Control and Intervention Phases of the Study

	Mean Control Phase Adherence Rate	Mean Intervention Phase Adherence Rate	Difference	*P* Value (Two-tailed; Paired *t* Test; $n = 8$)
Assessments				
PEFR	.86	.94	+8%	.320
Oxygen saturation	.29	.56	+27%	.007
Office treatments				
Metered-dose inhaler/nebulization	.73	.91	+18%	.064
Oxygen	0	.11	+11%	.139
Prescription				
Systemic corticosteroid	.43	.57	+14%	.055

TABLE 3. Mean Number of Physiologic Assessments and Treatments per Encounter During Control and Intervention Phases

Number of	Control Phase (Mean)	Intervention Phase (Mean)	*P* Value (Two-tailed)
PEFR measurements	1.6	2.2	.001
Oxygen saturation measurements	.48	1.1	.017
Nebulization treatments	.77	1.2	.026

vention phase. This relative advantage for short-term improvement approached statistical significance ($\chi^2 = 3.30$; $P = .069$).

There was no difference in immediate patient disposition from the office between control and intervention phases. Almost all patients were discharged from the hospital with only 2 in 88 control patients and 1 in 73 intervention patients requiring transfer to the ED or hospitalization directly from the office setting (Table 4).

During the week after the visit, there were no significant differences between the control and intervention phases in the number of children who missed school (or the number of days they missed), the number of their caretakers who missed work (and the number of missed workdays), and the number of children who revisited their pediatrician's office (Table 4). When we controlled for discharge severity as a potentially confounding variable, analysis of covariance showed no significant difference in missed school days ($F = .63$; $P = .42$) or missed caretaker work days ($F = .25$; $P = .62$) attributable to the intervention.

TABLE 4. The Percentage (and Number) of Encounters Associated With Immediate and Intermediate Term Outcomes

	Control % (*n*)	Intervention % (*n*)	Significance (*P*)
Changes in asthma severity			
Presentation to discharge			
Improved	57 (39)	43 (41)	.07
No change	42 (51)	58 (30)	
Immediate disposition			
Home	98 (88)	99 (73)	.86
ED/direct hospitalization	2	1	
1-wk follow-up			
Missed school	44 (37)	48 (33)	.76
Average days missed	1.29	1.04	NS
Missed work	24 (20)	23 (16)	.92
Average days missed	.56	.46	NS
Office revisit	30 (25)	26 (18)	.61
ED visits	6 (5)	0	.11
Hospitalization	4	0	.18

NS indicates not significant.

There was a small difference (not statistically significant) in the percentage of children who required ED visits and hospitalization in the week after discharge but the absolute number of patients was quite small.

Because we found no significant difference in outcomes between the control and intervention phases, we examined the statistical power of this study to detect an effect. The null hypothesis is that the outcomes are the same in both the control and intervention phases. Using the number of patients actually enrolled in the study and the observed frequencies of intermediate term outcomes during the control and intervention phases, we calculated β (the probability of a type II error) and power. We can be >90% confident that we could have detected a true difference (if it existed) between frequencies of missed school, missed work, and office revisit in the control and intervention with the sample size that we used. Power was considerably lower for avoiding a type II error with respect to ED visits (.55) and hospitalization (.62).

DISCUSSION

Use of a handheld, computer-based guideline implementation system was associated with increased adherence to the AAP guideline on office management of acute asthma exacerbations. Physicians measured PEFR and oxygen saturation more frequently, administered nebulizations more often, and there was a tendency toward more frequent prescription of systemic corticosteroids and nebulization of β-agonists when pediatricians were prompted by the system. Physicians resisted recommendations to administer oxygen to patients, however.

Not surprisingly, providing more services tended to prolong visits and was associated with higher fees. Although there was a tendency toward greater immediate clinical improvement in the children whose physicians used AsthMonitor, the additional procedures performed in compliance with the guideline recommendations did not seem to meaningfully improve intermediate-term outcomes—missed school, missed work by caretakers, office revisits, delayed ED visits, and hospitalizations in the week after the visit.

Other investigators have found similar, unanticipated side effects of successful guideline implemen-

tation. Gleason et al[17] noted that implementation of American Thoracic Society guidelines for management of community-acquired pneumonia led to 3- to 10-fold higher antimicrobial costs without any difference in patient outcomes. Suarez-Almazor et al[18] evaluated the potential impact of Agency for Health Care Policy and Research guidelines for management of acute low-back pain and found that adherence would increase the use of radiographs by 238%. Using computer technologies, Safran et al[19] showed that although electronic medical record alerts dramatically improved physicians' response times to clinical events for patients with human immunodeficiency virus, no change in admission rates, ED visits, admissions for pneumocystis, or survival could be demonstrated. A recent review of the effectiveness of guidelines in improving patient outcomes in primary care concluded that there is need for more research on guidelines implementation that includes outcome assessment.[15]

A more careful look at the specific interventions that were advised by this guideline may help to explain the apparent paradox of improved physician adherence and unchanged patient outcomes. Although measurement of arterial oxygen saturation has been shown to predict hospital admission in children who present to the ED with wheezing,[20] the value of measurement of PEFR during acute exacerbations has not been studied systematically.[21] No evidence was presented in the AAP guideline to support its recommendation for repeated assessment of physiologic functions. Likewise, it is not common practice for pediatricians to administer oxygen when children present with exacerbations of moderate severity in the office setting[22] and the guideline offered no evidence to suggest the value of oxygen therapy. Increased numbers of nebulization treatments with β-agonists during the intervention phase may have resulted in the tendency toward greater immediate clinical improvement that was observed. An increase in the frequency of prescription of corticosteroids might be expected to have an effect on intermediate term outcomes. Unfortunately, this study did not demonstrate a substantial increase in steroid prescription rate, so the potential impact of wider use of antiinflammatory agents on outcomes cannot be determined.

The AAP practice parameter—as published in *Pediatrics*—lacked explicit statements regarding evidence quality and strength of recommendations. It was supported by a technical report that was made available from the AAP for a nominal charge.[23] The technical report noted a lack of specific evidence in the medical literature to support many of the recommendations in this practice parameter. As is the case with many guideline development efforts, in which panel members struggle to produce useful products amid deficits in the evidence base, this panel relied on clinical experience and expert opinion for many of its recommendations. The technical report stated that the systematic evidence review performed during development of the guideline only addressed issues of β-agonist dosing and steroid toxicity. All other recommendations were based on expert consensus, achieved through a nominal group process.

The small number of participants in this study raises justifiable questions about the generalizability of the findings. We believe that the random sample of physicians was representative of community pediatric practice in Connecticut, but the extensive literature on practice variation suggests that any geographically limited sample may be unique. In addition, the baseline adherence rate to some recommendations was unexpectedly high suggesting the possibility of a Hawthorne effect. However, despite the small numbers, we were able to detect differences in guideline adherence that were statistically and clinically significant.

Our study describes associations between the use of the intervention and the observed behavior changes and outcomes, not cause-and-effect relationships. It is possible that the changes in behavior that were found reflect influences external to the study intervention. The time-series study design is subject to time-dependent confounding and this study did not control for secular trends in asthma management. The National Heart Lung and Blood Institute's *Expert Panel Report II* was published near the end of this study and may have influenced practice in the intervention phase.[21] However, other investigators have shown that simply publishing recommendations is often ineffective in changing physician behavior.[4,24] Moreover, the before-after approach is the most commonly applied design for evaluation of computer-based, clinical decision support systems.[25,26] Because evaluations of computer-based interventions tend to be resource-intensive and have profound impacts on organizational dynamics, the before-after design leverages the contributions of smaller numbers of participants. Innate characteristics of the participants are not merely balanced, but they are actually eliminated as confounding variables with a paired before-after design.[27]

Successful use of computer-based decision support systems to improve guideline adherence has been reported for a number of medical conditions,[8] but to our knowledge, this is the first report that evaluates the use of these technologies in the management of childhood asthma. The AsthMonitor system was designed to promote integration of guideline recommendations into clinical workflow. It provided a number of information management services—including recommendation, documentation, explanation, registration, presentation, and calculation—intended to increase its perceived value and offset the inconvenience associated with a change in work habits.[28] The vast majority of previous studies have been performed in academic settings, whereas this work investigates community-based care. In addition, this report describes the use of a handheld, pen-input device, whereas other studies of decision support tools have primarily investigated desktop computers as providers of guideline recommendations.

Implications for Clinical Practice

Although possibly flawed in terms of its claim to being evidence-based, the AAP guideline clearly described recommendations for changes in asthma man-

agement that were widely perceived as best practices. Although an ideal scenario would provide for validation of guideline recommendations before publication, this is impractical for most guideline development efforts. The development process often takes several years from topic nomination to final publication. Additional delays for extensive testing would often be associated with the appearance of new evidence that might lead to guideline revision, resulting in a continuous development process. Moreover, a budget for testing would greatly augment the already high costs of guideline development.

Computer-mediated reminders presented at the time and place of a consultation provide powerful enabling tools to improve the fidelity between physicians' intentions and actions.[29] Because of their capability to influence behavior, they must be applied wisely and responsibly. As with all sources of medical knowledge (eg, journal articles, textbooks, and consultants), guideline users should not accept statements on faith even when the guideline is described as evidence-based. Guideline developers would assist both policy implementers and end-users in the proper assessment of the quality of guideline knowledge if they annotated each recommendation with an indicator of evidence quality and/or strength of expert opinion. The AAP included such annotations in a subsequently published practice parameter.[30] Potential users—including managed care organizations, hospital systems, and individual clinicians—should critically evaluate each recommendation before implementation.[31,32]

Implementation of guideline recommendations using handheld computers seems to be an effective mechanism for influencing physicians' behavior. We believe that as the technology matures, we can look forward to the appearance of decision support applications that assist clinicians with management of a wide variety of disorders. We predict that ultimately the integration of flexible data entry, guideline-based decision support, and a comprehensive computer-based patient record will transform pediatric care.

ACKNOWLEDGMENTS

This work was supported by the Robert Wood Johnson Foundation and the National Library of Medicine through Grants 1-R29-LM 05552-01A1 and T-15-LM07056. Dr Shiffman is a Robert Wood Johnson Generalist Physician Faculty Scholar.

We gratefully acknowledge the efforts of the following physicians and their office staffs in support of this study: David Bonheim, MD; Marguerite Dillaway, MD; Greg Germain, MD; Michael Rokosky, MD; Craig Summers, MD; Juan Hernandez-Trujillo, MD; Ellen Wolfson, MD; and the other anonymous participants.

We also thank Donald Miller, MD, for his work on the initial design and programming of the AsthMonitor software.

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Richard N. Shiffman, Cynthia A. Brandt, Yischon Liaw and Deborah D. Navedo

Pediatrics 2000;105;767-773
DOI: 10.1542/peds.105.4.767