

# Towards Effective Implementation of a Pediatric Asthma Guideline: Integration of Decision Support and Clinical Workflow Support

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*Successful local implementation of national guideline recommendations requires attention to factors that promote clinician compliance. Design of a computerized system is described that will implement recommendations from a recently published guideline for outpatient management of childhood asthma exacerbations. Logical analysis of the guideline shows that it is incomplete and contains several ambiguities that must be addressed before the guideline can be operationalized. Once the user-audience is defined guideline decision points are examined and a structured data entry system is devised. Support of clinicians' workflow is provided by an integrated capability for encounter documentation, dosage calculation, and prescription-writing. A pen-based, graphical interface represents an appropriate platform for implementation of the system because of its ease of use and portability.*

A clinical practice guideline can only be considered to be effectively implemented if its knowledge content is faithfully transmitted to healthcare providers and its recommendations are incorporated into their clinical practices. National policies are unlikely to influence the practice of individual practitioners if they are merely published and allowed to diffuse [1]. Grimshaw and Russell reported that guidelines are most effective when they incorporate patient-specific information and provide decision support concurrent with decision making [2].

A goal of this project is to develop a replicable process by which clinical guideline knowledge can be extracted, verified, and incorporated into a system that will influence the behavior of physicians toward adherence to the guideline. Knowledge, published recently in a clinical practice guideline, is reused and recommendations are integrated into a system that facilitates physician work patterns.

## BACKGROUND

Clinical practice guidelines are being produced by a wide array of organizations in an effort to reduce inappropriate variations in clinical practice and to reduce unnecessary costs [3]. These clinical policies frequently embody high quality knowledge that is intended for implementation by a broad range of users including healthcare practitioners, quality assurance bodies, third party payers, and governmental

policy makers. Well-crafted guidelines contain knowledge that is evidence-based, representative of the best current thinking in a given domain, and sanctioned by the sponsoring organization.

Guideline knowledge, therefore, represents a valuable resource that can be reused for the development of new knowledge-based systems. Such knowledge sharing requires translation of guideline knowledge into a form that is usable by knowledge based systems [4]. We have previously found that logical analysis using decision table techniques facilitates this translation process and may enhance the knowledge by ensuring its completeness and logical consistency [5].

Shortliffe defined a decision support system as any computer program designed to help health professionals make clinical decisions [6]. Such a system may include tools for information management (i.e., for storing and retrieving clinical knowledge), tools for focusing attention (i.e., for reminding users about problems that might otherwise be overlooked) and tools for patient-specific consultation (i.e., for providing tailored diagnostic and treatment advice). Successful use of decision tools is dependent on their integration into routine data-management tasks [7].

*Clinical workflow support* includes activities embedded in the process of patient care that enhance that care without directly affecting decision making. Workflow support is a critical factor in the acceptance and use of all computer systems. Automation of any activity is unlikely to be successful unless it produces a net benefit to offset the costs associated with its implementation.

## APPROACH

### Selection of practice parameter

Guidelines are most frequently published as text-based narratives or as clinical algorithms. This work applies logical analysis techniques to a recently published guideline from the American Academy of Pediatrics for management of asthma in practitioners' offices [8]. The guideline knowledge is presented primarily in algorithm format with appended annotations. A clinical algorithm is a stepwise procedure for making decisions about the diagnosis and treatment of a clinical problem that is published in a graphic format [9]. It represents the logic of clinical decisions concisely and explicitly and focuses

clinicians' attention on relevant issues by defining a world of restricted breadth and depth [10].

This guideline for office management of childhood asthma exacerbations was chosen for a number of reasons, including:

- Asthma is a major health problem in pediatrics. It affects 5-10% of children and accounts for almost 1/4 of school absences. The hospitalization rate and the death rate from childhood asthma are rising and there is considerable variation in treatment [8]. Early, appropriate management of asthmatic patients may significantly decrease morbidity and mortality.
- The asthma management guideline was published recently and therefore reflects current thinking of asthma experts in the pediatric community. Much of the knowledge in the guideline is evidence-based.
- The guideline has been sanctioned by the American Academy of Pediatrics. Additionally, the American Medical Association Specialty Society Practice Parameters Partnership reviewed the guideline and found that it conformed to AMA attributes.
- The complexity of the guideline knowledge content is intermediate, i.e., more complicated than a one-line recommendation—e.g., premenopausal women should have Pap smears every 3 years—yet less intricate than a guideline that specifies comprehensive management of chronic disease over many years. The short timeline of encounters governed by the asthma guideline simplifies its implementation and makes compliance assessable.

### Overview of guideline content

The guideline is intended to apply to children over 5 years of age with signs of airway obstruction, wheezing, and/or persistent cough who present to an office setting. It includes several recommendations that "may vary from common practice" including use of peak expiratory flow rate (PEFR) measurements and pulse oximetry, altered frequency and dosage of  $\beta$ -2 agonists, and increased use of corticosteroids. The algorithm proceeds through 7 decision boxes and 13 action boxes to a disposition of each patient either by transfer to a hospital setting or discharge home with appropriate medication and follow-up.

The asthma guideline was published both in flowchart form (with appended annotations) and in a table. The algorithmic representation more clearly expresses the recommended sequence of clinical activities while the table modularizes the guideline into 5 groups of related activities ("Initial Assessment and Emergency Management", "Initial Treatment", "Follow-up Treatment", "Additional Treatment or Transfer to ED or Direct Admission to Appropriate

Hospital Unit", "Additional Treatment and/or Hospitalize"). One might expect that translation of a flowchart-based guideline to a set of rules would be straightforward but several unanticipated problems required remediation.

### Assessment of guideline logical integrity

Before a practice guideline can be effectively operationalized, it should be demonstrated to be logically comprehensive and consistent [5, 8, 11]. This requires analysis and extraction of relevant clinical decision and action variables.

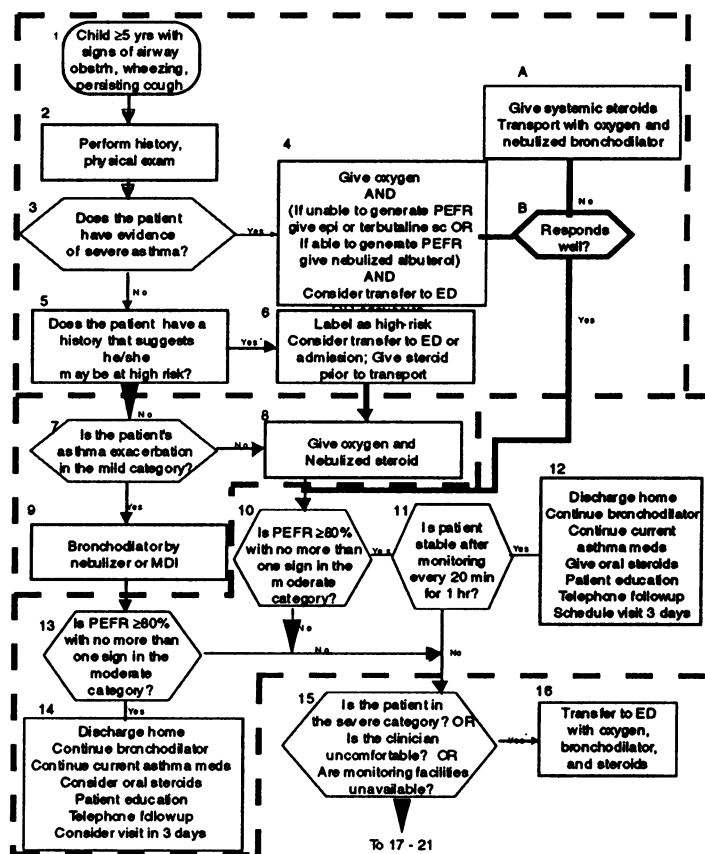


Figure 1. Flowchart display adapted from the published guideline for initial management of children with acute asthma in office settings. Three modules are indicated by dashed lines. Decision node and arcs added by the author are defined by heavy lines. (Reproduced by permission of *Pediatrics* Volume 93 page 123 ©1994)

The analysis is facilitated by modularization of the algorithm into cohesive and functionally independent blocks as shown in Figure 1. Such partitioning is an effective technique for simplification of complex decision problems [12, 13]. In this manner the number of variables pertinent

to any single phase of the management sequence is limited, thereby decreasing the number of clinical rules that must be constructed. Also, activities within a single module occur contemporaneously so that temporal sequencing issues are ameliorated [14]. Only the sequencing relationships of whole modules needs to be considered.

In each module, an exhaustive set of possible values for each variable is determined and a Cartesian product defines all mathematically possible combinations of decision variables [5]. According to guideline recommendations, actions are appended to all combinations that are semantically possible to form rule sets. These rule sets are then subjected to decision table analysis to assess the guideline's logical integrity.

For this guideline, logical analysis identified several issues that required attention:

**1. Incomplete logical expression.** Despite its configuration as a flowchart, the guideline failed to explicitly indicate all the decision branches. As published, the algorithm incorporated 2 decisions within action box 4. The choice of subcutaneously injected vs. inhaled bronchodilators depends on "If the patient is able to generate a PEFr". The action box recommends that "If the patient responds well to the initial ... treatment" management should continue in box 10 although no linking arrow is included in the algorithm.

Likewise, action box 6 implies a linking arrow to box 8 that is not shown. It labels a group of patients as "High-Risk" but no subsequent decision box incorporates the high risk categorization in its decision making.

To remedy these problems, the algorithm was reformulated to indicate an additional decision box and its outcome actions. Linkage arrows were added to show the logical flow.

**2. Ambiguous definition.** Although this guideline is generally quite explicit with regard to test specification, medication dosing, and outcome measurements, it is logically compromised by several ambiguous definitions. Decision boxes 4 and 5 contain lists of parameters that respectively assess the severity of an attack and the risk status of the patient. They are each phrased: "Does the patient have...?" followed by a list of 7-9 parameters. There is no indication whether these assessments are combined by ANDs or ORs or "2 (or more) of the aboves".

In decision box #7 the user is asked to answer whether the asthma exacerbation is "in the mild category"? The published practice parameter includes a table from the National Asthma Education Program (NAEP) that characterizes 9 manifestations as mild, moderate, or severe, which presumably

should be used for this determination. However, the guideline provides no criteria for interpretation of combinations of manifestations [15]. Is a patient with 6 manifestations in the mild category and 3 in the moderate category having a mild exacerbation? Examination of the original NAEP publication provides limited clarification: "(W)ithin each category, the presence of several parameters, but not necessarily all, indicate the general classification of the exacerbation".

To operationalize the guideline, precise definitions are necessary. Decision box 11 tests whether the patient is "stable after monitoring every 20 minutes for 1 hour", however stability is not explicitly defined. Also, the decision "If the patient responds well to the initial ... treatment" is considerably less rigorous than the later test (#10) "Is PEFr >80% with no more than one sign in the moderate category".

Finally, the published algorithm contains 2 ambiguities that are apparently due to typographical errors. Decision box 13 tests "PEFr >90%" whereas the equivalent section of the tabular representation tests for "PEFr >80%". Similarly, decision box 3 assesses PEFr "≥50%" for a finding of severe asthma whereas the tabular representation makes the more plausible test of "<50%".

After these logical deficiencies were corrected by consultation with local experts, decision table evaluation demonstrated that the guideline was logically complete and consistent. Input parameters were defined in the condition stub and potential outputs were specified in the action stub. Each column in the decision tables represents a rule that may be used to trigger pertinent decision support activities. The algorithm itself provides a view of the guideline pathway that facilitates decisions regarding workflow support.

**Devise decision support that will facilitate adherence to guideline recommendations**  
**Define the intended users.** A specification regarding the intended audience for the application helps to determine the level and types of decision support required. Physicians and nurses have different needs, as do medical students and residents, and generalists and specialists. For example, medical students might find hypertext access to definition of terminology and a multimedia presentation of abnormal breath sounds in asthma to be pedagogically useful, while subspecialists probably would not. For this application, support was considered to be aimed at practicing, generalist pediatricians.

**Examine the decision points in the guideline to determine potentially useful decision support information.** Every decision in this guideline—except for the determination of risk

level by consideration of historical factors—is based on an assessment of the patient’s respiratory status. This uniformity facilitates design of a structured data entry system.

A graphical layout of all the clinical decision parameters and potential choices provides a useful reminder of the entire range of assessments that must be made at each decision point (Figure 2). Multiple factors are weighed (PEFR, respiratory rate, alertness, dyspnea, accessory muscle use, color, auscultatory findings, pulsus paradoxus, and evidence of extrapulmonary air) and an estimate of severity is formulated. Similarly, a list of criteria that determine high-risk situations (decision box #5) can be provided. McDonald, et al., have postulated that such reminders reduce oversights, i.e., they "improve the fidelity between a physician's actions and his intentions" [16].

Joe Patient 10/8/94 4:45PM			
PEFR	70-90%	50-70%	<50%
Resp Rate	< Mean + 30%	Mean + 30-50%	Mean + 50%
Alertness	Normal	Normal	Decreased
Dyspnea	Absent	Moderate	Severe
Retractions	≤ Mild	Moderate	Moderate + Flaring
Color	Good	Pale	Cyanotic
Auscultation	End-exp wheeze	Insp & Exp wheeze	BS inaudible
P paradoxus			≥ 20 mm
Subcut air			Present

Figure 2. Input screen for assessment and documentation of asthma severity.

Entering the measured PEFR allows comparison with predicted values (which can be calculated from the patient’s age and height). A clock function triggers reminders that reassessment is due.

Decision logic is used to trigger the appearance of alerts that indicate a variance from guideline recommendations. For example, printing discharge instructions for a patient who presents with moderate asthma that do not include a prescription for steroids prompts a reminder.

Additional decision support might include citations to relevant papers in the medical literature that support a given recommendation or indications of

quality of evidence that support a particular recommendation.

### Support workflow

Potential users were observed as they provided care for asthma exacerbations and surveyed regarding their needs. Perhaps the most valuable workflow support would come from automated documentation of interval clinical assessments. As each parameter is assessed at each decision point the program can maintain a record of the clinical evaluations. This information is useful for sequential comparisons of individual patient progress and can be a valuable source of data for retrospective evaluation of guideline adherence and effectiveness.

Examination of action boxes suggests additional areas for workflow support. This guideline recommends alternative dosages of bronchodilator based on the severity of the exacerbation. Medication dosages in pediatrics are adjusted based on the size of the child. The correct dosage for a given patient can be calculated based on weight and then automatically converted into a volume of bronchodilator solution to be dispensed into a nebulizer. Reminders of maximal dosages and frequency of repetition can be provided.

For patients who are discharged, materials can be printed including prescriptions for bronchodilators and steroids, patient education information, and follow-up instructions. For patients who fail to improve, software can provide the clinician with convenient phone listings for referral to emergency departments and ambulance services, and offer the possibility of electronic transmission of admission orders.

### Interface and platform considerations

Implementation of this system would be facilitated by a platform that permits clinician mobility, is user-friendly, and is available at relatively low cost. The Newton PDA platform (Apple Computer Co., Cupertino, Calif.) provides an appealing graphical interface and intuitive pen-based input to help reduce physician reluctance to enter data.

Even with current technological restrictions these devices are capable of meeting the limited demands posed by this application. Most choices can be made by “tapping” gestures; for example, documentation of respiratory status can be performed by tapping on pertinent descriptor buttons (Figure 2) [17]. Text entry will be minimized since handwriting recognition capabilities remain limited. Wherever possible, known entries will be entered automatically, e.g., date and time. Choosing from drop-down menus (called “pickers”) or slider “gauges” provides more accurate data input without introducing inefficiency.

## DISCUSSION

Design of a system that brings about successful implementation of clinical practice guidelines recommendations is a challenge for medical informatics. Simply providing users with paper-based or on-line representations of published guidelines will likely produce less compliance than will integration of guideline information into the decision-making and documentation process. This paper describes the design of a system that deals with patient-specific information in real time and is intended to overcome the natural reluctance of many clinicians to use computer devices.

Furthermore, users must embrace and trust the guideline knowledge that is being implemented. Evidence-based, officially sanctioned guidelines provide a useful starting point; but this study re-emphasizes the fact that many current guidelines contain logical deficiencies that must be addressed and remedied [18].

If healthcare providers are to be expected to sacrifice some degree of professional autonomy to comply with guideline recommendations, some new benefit must accrue. Currently, for this asthma guideline and many others, data has not yet confirmed that compliance will improve patient outcomes. Therefore, to optimize user acceptance, the decision and workflow support that is provided must offset perceived disadvantages and inconveniences brought about by the new system.

The system described here will permit collection of data to facilitate outcome studies. Evaluation of the success of this project will require testing of hypotheses that use of this system does, in fact, promote compliance, change physician behavior, and improve patient outcomes.

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