**Classification of Asthma Severity in Children**

*The Contribution of Pulmonary Function Testing*

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**Background:** Despite increasing awareness of the National Asthma Education and Prevention Program guidelines, the relative contribution of symptom frequency or pulmonary function to the recommended asthma severity levels remains poorly understood.

**Objective:** To determine whether adding lung function measurements to clinical history substantially changes the asthma severity classification, thereby influencing treatment decisions.

**Design:** Baseline data were studied from children enrolled in 2 multicenter studies: phase 1 of the National Cooperative Inner-City Asthma Study (1992-1994) (cohort 1) and the Inner-City Asthma Study (1998-2001) (cohort 2).

**Setting:** Fifteen (8 for cohort 1 and 7 for cohort 2) major metropolitan inner-city areas in the United States.

**Participants:** Inner-city children aged 8 through 11 years with asthma.

**Main Outcome Measures:** Proportion of children reclassified from less severe asthma categories based on symptom frequency into more severe categories because of lung function.

**Results:** Of children with symptoms of mild intermittent asthma, 22.8% in cohort 1 and 27.7% in cohort 2 would be reclassified as having either moderate or severe persistent asthma. Of children with symptoms of mild persistent asthma, 31.2% in cohort 1 and 33.3% in cohort 2 would be similarly reclassified.

**Conclusions:** In 2 different studies of inner-city children with asthma, approximately one third of the participants were reclassified into higher National Asthma Education and Prevention Program asthma severity categories when pulmonary function was considered in addition to symptom frequency. This may have direct implications for the undertreatment of asthma.

Arch Pediatr Adolesc Med. 2006;160:844-850

The National Asthma Education and Prevention Program (NAEPP) guidelines recommend that medical professionals use a combination of clinical findings and objective measurement of lung function for the diagnosis of asthma.2 According to these guidelines, asthma is classified into 4 levels at initial diagnosis: mild intermittent, mild persistent, moderate persistent, and severe persistent based on symptom frequency and either spirometric (forced expiratory volume in 1 second [FEV1]) or peak expiratory flow (PEF) measurements (Table 1). Despite increasing awareness of these guidelines, the relative contribution of symptom frequency and pulmonary function to the recommended asthma severity levels remains poorly understood.

Choice of therapy depends on an accurate determination of asthma severity because underestimation will result in suboptimal treatment and increased morbidity.25 In a study of more than 4000 asthmatic patients in managed care, Wolfenden et al24 found that physicians systematically underestimate asthma severity. In addition, Baker et al25 provided 24 board-certified allergists and pulmonologists with 8 asthma case summaries and found low levels of agreement for NAEPP guideline asthma severity classification.

In a sample of more than 200 hospitalized asthmatic patients, Warman et al26 showed that 83% should be classified as having persistent asthma but that only 35% were receiving daily anti-inflammatory agents. They reported ascertainment of severity using symptom frequency. The potential contribution of pulmonary function was not addressed.

Peak expiratory flow and FEV1 are commonly used measures of lung function, and they are used particularly for assessment of the airway obstruction typically seen with asthma. Both are recommended in the NAEPP guidelines as measures of severity assessment. The PEF meter is a simple and inexpensive device that is widely available...
but has several limitations compared with the spirometer. Peak expiratory flow is effort dependent, and several studies7-10 have shown that it underestimates the degree of airway obstruction. Eid et al11 found that PEF had poor negative predictive value for patients with air trapping as determined by elevated residual volume/total lung capacity. Patients with air trapping can generate a peak burst of airflow, yielding a normal PEF measurement, but as exhalation continues, abnormalities in measurements such as FEV1 and forced expiratory flow between 25% and 75% are detected. The spirometric measurement, FEV1, is reliable and has good correlation with degree of airway obstruction.12

Despite the NAEP guidelines to assess lung function by means of FEV1 or peak flow, these measurements, particularly FEV1, which requires a spirometer, are not routinely determined.13 Picken et al14 reported that when primary care physicians were given the opportunity to adapt the NAEP guidelines for their own local use, they included clinical criteria and PEF measurement. Spirometry was recommended only for patients with an incomplete response to inhaled corticosteroids as determined by clinical examination, for “unusual” patients, or for patients in whom an alternate diagnosis was suspected. In a survey13 of primary care physicians, only 21% reported using FEV1 to establish the diagnosis of asthma, and only 8% used FEV1 measurements in routine follow-up. In contrast, 75% reported using PEF in the initial diagnosis or follow-up.15 In a study by Diette et al,13 only half of the patients reported ever undergoing pulmonary function testing.

The NAEP guidelines organize asthma severity into 4 categories, using “or” criteria for daytime and nighttime symptom frequency, office-based pulmonary functions (FEV1 or PEF rate [PEFR]), and home-based diurnal variability in PEFR (Table 1). The purpose of this study is to determine whether asthma severity classification based on clinical history alone is changed by the addition of spirometric measures of lung function. If more patients needing treatment are identified in this manner, it could reduce the problem of undertreatment of asthma.

METHODS

To increase the generalizability of the findings, we included children enrolled in 2 separate but related multicenter studies: Phase 1 of the National Cooperative Inner-City Asthma Study (NCICAS), conducted between January 2, 1993, and November 12, 1994, and the Inner-City Asthma Study (ICAS), conducted between July 24, 1998, and August 9, 2001. For both studies, each participating site received approval from the human subjects review committee at their institution. Informed consent was obtained from all the parents or legal guardians, and the children provided age-appropriate assent.

Pulmonary function findings are based on predicted values for height, race, and for certain measures, the sex of the child, and the findings are expressed as a percentage of the predicted value. We chose the third National Health and Nutrition Examination Survey normative data set for the study population’s pulmonary function values.16 These spirometric reference values include data from 7429 asymptomatic nonsmoking participants and compare white, African American, and Mexican American individuals aged 8 to 80 years. Of the available normative data sets, these comparisons are the most relevant to our study populations. Because of the age range of the reference values, our analyses are restricted to children aged 8 to 11 years.

NATIONAL COOPERATIVE INNER-CITY ASTHMA STUDY

Phase 1 of the NCICAS (cohort 1) enrolled 1528 children aged 4 to 9 years who resided in 8 major metropolitan inner-city areas in the United States.17 The NCICAS asthma inclusion criteria were a combination of physician diagnosis and symptom history (Table 2). Participants in the NCICAS sample resided in census tracts in which approximately 20% to 40% of the households had incomes below the 1990 federal poverty level. Of the 1376 previously diagnosed asthmatic children, 327 children aged 8 to 9 years attempted spirometry. Acceptable measurements for FEV1 and PEFR were available for 257 participants.

INNER-CITY ASTHMA STUDY

The ICAS (cohort 2) enrolled 937 children aged 5 to 11 years with moderate to severe asthma using inclusion criteria intended to result in participants with more severe asthma than those in the NCICAS sample. Children and their families were eligible for the ICAS if the child had at least 1 hospitalization or 2 urgent care visits for asthma during the 6 months before screening and had a positive skin test reaction to at least 1 of 11 common indoor allergens (Table 2).18 Except for 1 site, where alternate criteria for poverty were used, children enrolled in the ICAS had to live in a census tract in which at least 20% of households reported a household income below the federal poverty level, and they had to sleep in the intervention home at least 3 nights of every week. Of the 453 participants aged 8 to 11 years, complete data were available for 383.

For both study cohorts, a comprehensive baseline evaluation was conducted at enrollment. A variety of questions were asked of the caregiver, including the child’s medication use and adherence, home environment and smoking history, perceived stress and stressful life events, mental health measures for the caregiver and the child participant, and recent morbidity. Morbidity measures included asthma symptoms in the past 2 weeks, school days missed in the past 2 weeks, and use of health care services in the past 2 months. In addition, each child answered questions regarding stress and quality of life and underwent allergy skin testing. In the NCICAS, pulmonary function testing was performed using a Pulmonary Screen 11E/VRS system (S&H Instrument, Doylestown, Pa), and in the ICAS, a Renaissance II spirometer (Nellcor Puritan Bennett, Pleasanton, Calif) was used. The pulmonary function measures reported in this article, including PEFRs, were obtained from these respective instruments. All test-
ing was performed by trained technicians and followed American Thoracic Society guidelines.19

We classified the asthma severity of study participants according to the Expert Panel Report 2 national asthma guidelines.1 Using the symptom frequency categories given in Table 1, we placed participants into 3 severity levels: mild intermittent, mild persistent, and moderate and severe persistent asthma. Using 14-day reports, children who had 0 to 4 days with symptoms and 0 to 1 night with symptoms were classified as mild intermittent. Children who had 5 to 13 days with symptoms or 2 nights with symptoms were classified as mild persistent. Children who had 14 days with symptoms or 3 to 14 nights with symptoms were classified as moderate or severe persistent. The 2 most severe categories (moderate and severe persistent asthma) were collapsed into 1 because with this data set we could not reliably differentiate moderate from severe persistent asthma based on patient symptom frequency self-report alone (ie, differentiating between “daily” and “continual” daytime symptoms or defining “frequent” nights with symptoms).1,20

We examined the pulmonary function test results at the baseline evaluation for each study to determine the proportion of children in each asthma severity category who would be reclassified from symptom-only severity categories based on the addition of these lung function results. Consistent with the NAEP guidelines, we examined FEV₁ and PEFR separately and together as “or” criteria along with symptom frequency so that the addition of lung function could result either in no change in asthma severity categories if pulmonary function was normal or in an increase in asthma severity categories if pulmonary function findings were abnormal.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Cohort 1 (National Cooperative Inner-City Asthma Study)</th>
<th>Cohort 2 (Inner-City Asthma Study)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>4-9</td>
<td>5-11</td>
</tr>
<tr>
<td>Residence</td>
<td>Selected census tracts with &gt;40% of household incomes below the 1990 poverty level</td>
<td>Selected census tracts with at least 20%-40% of household incomes below the 1990 poverty level and sleeps overnight at 1 address ≈5 times per week</td>
</tr>
<tr>
<td>Recruitment sites</td>
<td>Emergency departments and community primary care sites</td>
<td>Hospitals, emergency departments, and clinics</td>
</tr>
<tr>
<td>Definition of asthma</td>
<td>1. Physician diagnosis of asthma and asthma symptoms (cough, wheeze, shortness of breath, or whistling or tightness in the chest) for &gt;3 d in the past 12 mo or 2. Asthma symptoms (cough, wheeze, or shortness of breath) for &gt;6 wk in the past 12 mo and that met 3 of the 5 following conditions: a. Cough, wheeze, or shortness of breath was present more than half the days and nights during the 6-wk period b. Cough, wheeze, or shortness of breath was aggravated by exercise or cold air c. There is a parent or sibling with asthma d. Child does not have a history of antibiotic therapy for sinusitis accompanying the cough e. Cough, wheeze, or shortness of breath that resulted in disturbance of the child’s sleep</td>
<td>1. At least 1 hospitalization related to asthma in the past 6 mo or 2. At least 2 unscheduled visits to an emergency department or clinic related to asthma in the past 6 mo</td>
</tr>
<tr>
<td>Other</td>
<td>None</td>
<td>Positive allergen skin test reaction to at least 1 indoor allergen (eg, dust mites, cockroaches, mold, rodents, or pets)</td>
</tr>
</tbody>
</table>

Table 2. Eligibility Criteria for Cohorts 1 and 2

RESULTS

CHARACTERISTICS OF THE STUDY SAMPLES

The NCICAS population is designated cohort 1, and the ICAS population is cohort 2. For this analysis, cohort 1 included 257 children, and cohort 2 included 383 children. The study samples for both cohorts were demographically similar (Table 3). The mean age for cohort 1 was 8.5 years and for cohort 2 was 9.5 years, reflecting their different age inclusion criteria. Approximately 60% of the participants in both cohorts were boys. In cohort 1, most study participants (74.4%) were African American. In cohort 2, Hispanic and African American children were enrolled in similar proportions (almost 40% for each). In both cohorts, approximately 70% of the caregivers reported graduating from high school, and almost 60% of respondents in each study reported household incomes of less than $15,000. Caregivers in cohort 2 were more likely to report being married (35.2% vs 23.4%) and, consistent with recent reforms in welfare legislation, were also more likely to report at least 1 currently employed household member (76.1% vs 50.2%).

ASTHMA SEVERITY ACCORDING TO SYMPTOM FREQUENCY

We first examined the distribution of participants into asthma severity categories based on symptom frequency categories alone and on daytime symptoms and nighttime symptoms separately and together as “or” criteria, consistent with the NAEP guidelines (Table 4). As expected, given the eligibility criteria, a greater proportion of cohort 1 children fell into the mild intermittent category compared with cohort 2 children (47.9% vs 38.6%; P = .02) (Table 4). The proportion of children in the mild persistent category was similar in cohorts 1 and 2 (18.7% vs 18.8%; P = .97). Finally, a smaller proportion of cohort 1 vs cohort 2 children were in the moderate or severe persistent category (33.5% vs 42.6%; P = .02).

For both cohorts, consideration of nighttime symptoms alone places more participants in the moderate or severe persistent categories than use of daytime symptoms alone (cohort 1: 29.6% vs 10.1%; cohort 2: 36.3% vs 19.8%; P < .001 for both).
We then examined the distribution of children into normal (≥80% of predicted) or abnormal (<80% of predicted) categories of FEV₁ and PEFR according to the NAEPP guidelines. For FEV₁, a smaller proportion of children in cohort 1 vs cohort 2 had abnormal lung function (16.7% vs 28.2%; P<.001) (Table 5). The PEFR was less sensitive to differences in cohort severity, with the difference between cohorts only approaching significance (19.5% vs 25.3%; P = .08). When either FEV₁ or PEFR was considered (the recommended NAEPP guidelines approach), 24.5% of children in cohort 1 had abnormal lung function compared with 35.8% in cohort 2 (P = .003).

INFLUENCE OF PULMONARY FUNCTION IN CHANGING THE SEVERITY CLASSIFICATION

To address the main study question, we examined how the severity distribution would change when abnormal pulmonary function—either FEV₁ or PEFR—is also considered (Table 5). Among children with symptoms consistent with mild intermittent asthma, 22.8% in cohort 1 and 27.7% in cohort 2 would be reclassified as having moderate or severe persistent asthma. Among children with symptoms consistent with mild persistent asthma, 31.2% in cohort 2 would be reclassified as having moderate or severe persistent asthma. Among children who were already classified as having moderate or severe persistent asthma by symptoms alone, 23.3% in cohort 1 and 44.2% in cohort 2 had abnormal pulmonary function. Figure 1 shows the overall distribution of severity classifications when using the differing criteria.

COMMENT

These 2 cohorts of inner-city children with asthma differed somewhat in severity, reflecting the differences in eligibility criteria. Regardless, approximately one third of the children in each cohort were reclassified to higher NAEPP asthma severity categories when pulmonary function was considered in addition to symptom frequency. These results demonstrate that the NAEPP severity assessment algorithm is highly dependent on the availability of symptom frequency and pulmonary function data.

The findings are from 2 populations of relatively severe asthmatic children living in an inner-city environment and may not be generalizable to all asthmatic children. The participants from the ICAS, for example, were included only if they had 1 hospitalization or 2 acute care visits for asthma in the past 6 months (Table 2). Most of the children in this analysis were in the moderate and severe asthma categories, which is consistent with our strategy to enroll children with significant and active asthma morbidity for this study.

It may be that, at least for some patients, PEF and FEV₁ are not the most sensitive indicators of small-airway obstruction. Klein et al²¹ found that some children with symptoms suggestive of moderately severe asthma had normal PEF and FEV₁ measurements but decreased forced expiratory flow between 25% and 75%. Moy and colleagues²² found that intensity of shortness of breath was...
Other studies have shown the weakness of symptoms alone as a predictor of asthma severity. For example, Osborne et al\textsuperscript{24} found that a 2-year review of medical records, including exacerbations, urgent care visits, hospitalizations, and medications, correlated well with pulmonary function and glucocorticoid use but not with asthma symptoms.

There are inherent limitations with the assessment of asthma, a dynamic chronic illness, at any given point. Callhoun et al\textsuperscript{25} found that in repeated assessments of asthma severity based on symptoms and PEF, a single point-in-time classification of asthma was highly unreliable. Unfortunately, initial therapeutic decisions must be based on such limited information.

Within the symptom frequency categories, many more participants in this study were classified as severe according to nighttime vs daytime symptoms, a finding corroborated by Colice et al.\textsuperscript{26} This raises the importance of a careful nocturnal symptom history, realizing that this history may be an underestimate of what is really occurring. For example, variables such as the location of the historian's (ie, parent’s) bed to the patient’s bed and whether the historian is a deep sleeper can affect the accuracy of recall and thus the accuracy of asthma severity classification and the resulting treatment.

### Table 5. Children With Abnormal Lung Function by Symptom Category: National Cooperative Inner-City Study (Cohort 1) and Inner-City Asthma Study (Cohort 2)*

<table>
<thead>
<tr>
<th>Severity Classification by Symptoms</th>
<th>Participants, No.</th>
<th>FEV\textsubscript{1}</th>
<th>PEF</th>
<th>Either FEV\textsubscript{1} or PEF</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cohort 1 Symptoms (n = 257)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severity by daytime symptoms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild intermittent</td>
<td>180</td>
<td>12.8</td>
<td>15.6</td>
<td>20.6</td>
</tr>
<tr>
<td>Mild persistent</td>
<td>51</td>
<td>27.4</td>
<td>31.4</td>
<td>35.3</td>
</tr>
<tr>
<td>Moderate or severe persistent</td>
<td>26</td>
<td>23.1</td>
<td>23.1</td>
<td>30.8</td>
</tr>
<tr>
<td>Severity by nighttime symptoms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild intermittent</td>
<td>148</td>
<td>15.5</td>
<td>21.0</td>
<td>25.7</td>
</tr>
<tr>
<td>Mild persistent</td>
<td>33</td>
<td>15.2</td>
<td>18.2</td>
<td>24.2</td>
</tr>
<tr>
<td>Moderate or severe persistent</td>
<td>76</td>
<td>19.7</td>
<td>17.1</td>
<td>22.4</td>
</tr>
<tr>
<td>Severity by daytime + nighttime symptoms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild intermittent</td>
<td>123</td>
<td>14.6</td>
<td>17.9</td>
<td>22.8</td>
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<tr>
<td>Mild persistent</td>
<td>48</td>
<td>18.8</td>
<td>27.1</td>
<td>31.2</td>
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<tr>
<td>Moderate or severe persistent</td>
<td>86</td>
<td>18.6</td>
<td>17.4</td>
<td>23.3</td>
</tr>
<tr>
<td>Overall</td>
<td>257</td>
<td>16.7</td>
<td>19.5</td>
<td>24.5</td>
</tr>
<tr>
<td><strong>Cohort 2 Symptoms (n = 383)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Severity by daytime symptoms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild intermittent</td>
<td>199</td>
<td>23.6</td>
<td>21.1</td>
<td>30.6</td>
</tr>
<tr>
<td>Mild persistent</td>
<td>108</td>
<td>26.8</td>
<td>22.2</td>
<td>33.3</td>
</tr>
<tr>
<td>Moderate or severe persistent</td>
<td>76</td>
<td>42.1</td>
<td>40.8</td>
<td>52.6</td>
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<tr>
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<tr>
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<td>196</td>
<td>22.4</td>
<td>20.4</td>
<td>28.1</td>
</tr>
<tr>
<td>Mild persistent</td>
<td>46</td>
<td>35.4</td>
<td>27.1</td>
<td>41.7</td>
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<tr>
<td>Moderate or severe persistent</td>
<td>139</td>
<td>33.8</td>
<td>31.6</td>
<td>44.6</td>
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<tr>
<td>Severity by daytime + nighttime symptoms</td>
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<tr>
<td>Mild intermittent</td>
<td>148</td>
<td>22.3</td>
<td>19.6</td>
<td>27.7</td>
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<tr>
<td>Mild persistent</td>
<td>72</td>
<td>27.8</td>
<td>22.2</td>
<td>33.3</td>
</tr>
<tr>
<td>Moderate or severe persistent</td>
<td>163</td>
<td>33.7</td>
<td>31.9</td>
<td>44.2</td>
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<tr>
<td>Overall</td>
<td>383</td>
<td>28.2</td>
<td>25.3</td>
<td>35.8</td>
</tr>
</tbody>
</table>

Abbreviations: FEV\textsubscript{1}, forced expiratory volume in 1 second; PEF, peak expiratory flow.

*Data are given as percentages.
Bacharier et al described a weak relationship among symptom frequency, medication use, and FEV1. However, they also demonstrated a decrease in the FEV1/forced vital capacity ratio as asthma severity increased.Their findings underscore the imperfect overlap between symptom frequency and pulmonary function at a moment in time, and the value of using multiple domains when diagnosing and assessing asthma.

Nair et al recently corroborated our finding, demonstrating that the use of spirometry identified a large proportion of asthmatic children with abnormal lung function who otherwise had mild asthma based on history or physical examination findings alone. Fuhlbrigge et al demonstrated a strong association between decreased FEV1 and risk of an asthma attack in the subsequent year. Juniper et al demonstrated via factor analysis that airway caliber (ie, pulmonary function) was 1 of 4 distinct domains of asthma health status, along with quality of life, daytime symptoms and β-agonist use, and nighttime symptoms.

These findings support the use of spirometry when assessing patients with asthma. Administering the forced expiratory maneuver requires good patient coaching, which in turn requires careful and adequate support staff and provider training. If well-trained personnel are in place and quality criteria are diligently used, the increased availability of reliable and user-friendly spirometers may make possible the incorporation of pulmonary function testing in primary care settings. Spirometry is often problematic for children, and 16% to 21% of our curves were unacceptable, underscoring the importance of ensuring that a good-quality flow volume curve is being interpreted.

Approximately the same number of children with “abnormal” lung function were identified using PEFR as using FEV1. However, these 2 subsets of children do not overlap completely. The FEV1 and FEV1/forced vital capacity, when performed and interpreted properly, provide an objective view of the expiratory phase that may help identify patients with airway obstruction otherwise missed by history and physical examination. A single value obtained using an automated spirometer and may differ from peak flow determined using an automated peak flowmeter. In the lowest ranges (<200 L/min), our data show a significant discrepancy between values obtained using these 2 methods. The findings from an inner-city population may or may not be generalizable to other populations. It is also possible that findings from children in a limited age range (8-11 years) may not be generalizable to other age groups. The inclusion criterion of a recent hospitalization or 2 acute care visits was meant to identify asthmatic children with significant morbidity. This recruitment strategy partially explains the high proportion of these participants who were in the more severe asthma categories.

We show that using symptom frequency alone to classify asthma severity underestimates the number of children with moderate to severe persistent asthma. This finding suggests that the often described phenomenon of undertreatment of more severe asthma with controller medications, most notably inhaled corticosteroids, may be due, in part, to an underestimate of asthma severity. Increased use of spirometry may lead to better identification of asthma severity and thereby improve treatment with daily anti-inflammatory medication.

Accepted for Publication: March 3, 2006.
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