Using an Asthma Control Questionnaire and Administrative Data To Predict Health-Care Utilization*

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Objective: To examine the merits of the Asthma Therapy Assessment Questionnaire (ATAQ) control index together with prior asthma health-care utilization from administrative data in predicting future acute asthma health-care utilization.

Design: Prospective cohort study.

Population: A total of 4,788 adult asthma patients aged 17 to 93 years who completed a baseline evaluation and had at least 6 months of follow-up data.

Statistical methods: Classification and regression tree methodology to predict future risk of acute health-care utilization events.

Results: These results show that the ATAQ control index and administrative data are jointly useful for predicting future health-care utilization. The utility of the ATAQ control index in the presence of information about prior health-care utilization is to further stratify risk among the subset of younger individuals who did not have any prior acute health-care utilization. While administrative health-care utilization data served as the strongest predictor of future health-care utilization, the ATAQ control index helped to identify 1% of individuals without recent acute care that had approximately a sixfold elevated risk (95% confidence interval, 4.2 to 8.4) of future acute health-care utilization. This is an important result since only a small fraction of individuals with acute events in a given year will have had acute events in the previous year.

Conclusion: These findings should assist the practicing clinician and organizations interested in population-based asthma disease management.

(CHEST 2006; 129:918–924)

Key words: asthma; asthma disease management; health-care utilization; level of control; severity

Abbreviations: ATAQ = Asthma Therapy Assessment Questionnaire; CART = classification and regression tree; ED = emergency department; PR = prospective risk

Asthma is a common health condition affecting approximately 16 million Americans.1 Despite advances in our understanding of asthma, the development of better medications for treating it, and national guidelines for the diagnosis and management of asthma, morbidity from asthma continues to be an important health problem. As interest in population-based asthma disease management programs has grown in recent years, so has the need for simple, office-based tools that can be used to identify the patient who is at risk for future exacerbations that will require the use of acute care services.

Prior health-care utilization and other administra-
tive data have been used in a variety of studies to predict future hospitalization and emergency department (ED) care for asthma. Additionally, a number of questionnaire-based measures have been developed in studies of short duration, ≤ 9 weeks, allowing for an assessment of responsiveness of the measures to changes in patient symptoms over short time frames. Associations between simple questionnaire items and ED visits were found in a retrospective case-control study, while two questionnaire-based indexes have been shown to predict health-care utilization in (12-month) prospective studies. One of these latter instruments, the five-question control domain of the Asthma Therapy Assessment Questionnaire (ATAQ), has been shown to be highly correlated with self-reported quality of life and can identify subsets of the population with up to a threefold increased risk of requiring acute health-care services in the following year. ATAAQ measures have also been used more generally to assess asthma symptoms and other asthma management issues.

In a previous report, the use of the ATAQ control index was recommended as a "vital sign" that clinicians could use in the office setting, and also as a tool that could be used by groups such as large health maintenance organizations who are interested in population-based disease management. The ATAQ control index can be used alone, such as when administrative data are not available, or it can be used in conjunction with administrative data to identify high-risk groups.

This report uses classification and regression tree (CART) methodology to examine the merits of the joint use of the ATAQ control index and administrative data in predicting future acute health-care utilization. The results can be used to better understand the relative roles of these two sources of information in identifying at-risk individuals and to identify clinical subgroups at differential risk for future acute health-care utilization. Some of the results of these studies have been previously reported in the form of an abstract.

**Materials and Methods**

**Study Population**

In the fall of 1997, with approval from the institutional review board, we surveyed 13,964 adult members of a large managed-care organization to obtain information on current level of asthma control, health status, and quality of life. Those surveyed had received at least two doses of antiasthma medications in the previous year and/or had a hospital or ED visit for asthma in 1994, 1995, or 1996. Sixty-two percent responded; of these, 5,172 persons reported having a doctor diagnosis of asthma and were currently receiving antiasthma medications and were thus eligible for the study. The focus for model development is the 4,788 individuals (93% of those screened as eligible) who had ≥ 6 months of health plan eligibility (mean, 11.8 months) in 1998. We also report on the subset of 3,075 individuals who did not report having comorbid COPD, defined as chronic bronchitis, emphysema, or COPD, and had a full 12 months of follow-up.

**Study Variables**

Level of asthma control was measured in the survey using the ATAQ control index, a brief self-administered questionnaire that asks individuals to assess whether or not they had problems due to asthma in the last 4 weeks with regard to the following: (1) asthma control in general; (2) missing work, school, or normal daily activities; (3) nighttime waking; and (4) need for quick reliever medication. The ATAQ control score identifies the number of these control problems (0 to 4) experienced. As relatively few individuals experienced four control problems, these individuals were combined with those reporting three control problems for all analyses. Health-care utilization data from administrative and clinical databases in 1997 and 1998 were used to obtain the following variables: number of inpatient admissions for asthma, number of ED visits for asthma, number of urgent (after hours) care visits for asthma, number of nonurgent outpatient visits for asthma, and total number of dispensings of asthma medication.

**Statistical Methods**

We used CART analysis to predict acute asthma care events in calendar year 1998 (hospitalizations or ED visits or other acute care contacts) based on 1997 health-care utilization, reported level of control in the fall of 1997, gender, and age (18 to 34 years, 35 to 54 years, ≥ 55 years). The CART methodology uses a binary splitting algorithm to build the regression “tree.” At each stage, the CART algorithm considers all possible dichotomizations of each predictor variable to find the one that best separates individuals with the event of interest from those without the event of interest. This process is then independently repeated for each of the new branches of the tree, with the process stopping when the degree of separation between subsequent branches does not surpass a user-defined threshold. For each terminal branch of the CART model, we computed the prospective risk (PR) as the proportion of individuals in that branch who had an acute health-care encounter during 1998. All CART models were constructed using specialized software (Answer Tree 3.0; SPSS: Chicago, IL).

The CART methodology is particularly well suited for identifying complex interactions among variables that connote unusually high (or low) risk and that may not be readily identified via more traditional modeling techniques such as logistic regression. In regression modeling, multifactor interactions are often excluded due to difficulties in interpretation, power limitations, and lack of prior information regarding the existence of such interactions. CART methodology, however, is explicitly designed for exploration of interactions involving many factors.

**Results**

Study participants ranged in age from 17 to 93 years (mean, 52 years) [Table 1]. Two thirds were female, and 33% reported having, in addition to asthma, a doctor diagnosis of chronic bronchitis,
emphysema, or COPD. Ten percent of both the full study cohort and the subset without comorbid COPD had at least one acute encounter during the follow-up year. Compared to those excluded from the analysis due to lack of health plan eligibility in 1998, those included were significantly older (52 years vs 44 years, p < 0.001) and more likely to report use of inhaled corticosteroids (38% vs 28%, p < 0.001).

Figure 1 illustrates the CART methodology by presenting the regression tree from an analysis in which the presence or absence of any acute asthma health-care encounter in 1998 (either ED, hospitalization, or other urgent care) was predicted on the basis of the ATAQ control index, age, and gender. The initial cut was into those with none to two control problems (PR, 9.1%) vs those with three to four control problems (PR, 19.3%). The former group was further subclassified into those with no control problems (PR, 7.7%) vs one to two control problems (PR, 10.8%; for simplicity, Fig 1 shows a single classification into the three groups). Both the middle and higher risk control categories were further subclassified based on age, with the middle risk
group (one to two control problems) splitting into two age strata, and the higher risk group (three to four control problems) eventually splitting into three age strata. In both cases, the pattern was for the ATAQ control index to be more predictive in younger adults. Gender entered last but did not provide clinically meaningful added separation and so was dropped from the model.

The terminal branches (nodes) of this model are summarized in Table 2. The model identified a relatively small subset of the asthmatic population (those with three to four control problems and < 35 years old, approximately 2% of the overall sample) who had a fivefold increased risk of having an acute asthma health encounter during 1998 compared to the lowest risk group (essentially those with no control problems regardless of age and those ≥ 55 years old with only one to two control problems, approximately two thirds of the overall sample). The next highest risk group (with approximately 2.5-fold increased risk and comprising approximately 5% of the sample) consisted of individuals reporting three to four control problems and aged 35 to 54 years. The remaining two groups were at approximately 50% increased risk and comprised 28% of the sample. Qualitatively similar results were observed when we applied this same model to the subset of individuals without comorbid COPD (Table 2).

Figure 2 illustrates the CART model that resulted when we added prior asthma health-care utilization to our set of possible predictors (once again, multiple splits of a single variable are shown as a single division into multiple categories for ease of presentation). The initial split in this new model was zero ED visits (PR, 8.9%) vs one or more ED visits (PR, 34.6%), with the latter group further splitting into those with one vs two or more ED visits (PR, 29.0% and 52.3%, respectively). The group with no ED visits in 1997 further was subdivided into those with zero vs one or more urgent care visits (PR, 7.9% and 24.1%, respectively), and it was only in those with no ED or urgent care visits that the ATAQ control index added further insight, splitting into those with none to two control problems vs three to four control problems (PR, 7.1% and 14.3%, respectively). Finally, those with three to four control problems were further classified into those ≤ 34 years old (PR, 42.0%) vs those aged ≥ 35 years (PR, 10.9%).

Interestingly, although the ATAQ control index only entered into the model for those with no ED or urgent care visits, the model was able to find a subset (those < 35 years with three to four control problems) with the second highest estimated prospective risk. For practical use, this model might be further simplified by grouping these six terminal branches into just three groups, nominally representing those at high, medium, and low (relative) risk for a future acute health-care encounter (Table 3). Similar to the initial model summarized in Table 2, the highest risk group represents approximately 2% of the population, and in this case has a risk 6.4 times higher than that of the low-risk group, which now comprises about 87% of the population. Once again, qualitatively similar results were observed when we applied this same model to the subset of individuals without comorbid COPD.

Table 4 examines what happens when we replace administrative data on health-care utilization with self-reported data. Since the self-report data available for this cohort included urgent care, but not specifically ED visits, the health-care utilization categories are reduced to simply “0,” “1,” and “2 or more” urgent care visits. Although the relative risks are smaller in magnitude, the patterns are similar to those seen in Table 3.

Similar patterns were seen when we built models to predict the specific types of acute care contacts (hospitalization, or ED, or other urgent care) that comprised the composite “any acute care” outcome. The administrative data on prior acute asthma encounters provided the initial discrimination in each case, the ATAQ control index generally only entered the models for those with no prior acute encounters.

Table 2—Summary of CART Model for Predicting Any Acute Asthma Care as a Function of ATAQ Control Index and Age

<table>
<thead>
<tr>
<th>Description of Terminal Branch</th>
<th>Full Cohort (n = 4,788)</th>
<th>Subset Without COPD (n = 3,075)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% of Sample</td>
<td>PR, %</td>
</tr>
<tr>
<td>No control problems</td>
<td>49</td>
<td>7.7</td>
</tr>
<tr>
<td>One to two control problems and age ≥ 55 yr</td>
<td>17</td>
<td>8.6</td>
</tr>
<tr>
<td>One to two control problems and age &lt; 55 yr</td>
<td>22</td>
<td>12.5</td>
</tr>
<tr>
<td>Three to four control problems and age ≥ 55 yr</td>
<td>6</td>
<td>11.9</td>
</tr>
<tr>
<td>Three to four control problems and age 35 to 54 yr</td>
<td>5</td>
<td>20.9</td>
</tr>
<tr>
<td>Three to four control problems and age &lt; 35 yr</td>
<td>2</td>
<td>39.5</td>
</tr>
</tbody>
</table>
and the predictive power of the ATAQ control index was greatest in younger, as opposed to older, adults.

**Discussion**

These results suggest that asthma control predicts prospective acute asthma health-care utilization even after controlling for prior asthma-related health care obtained from administrative data. Although previous research had provided support for both the use of prior utilization and the ATAQ control index for prediction of future risk, groups for which ATAQ clearly added to the identification of high-risk individuals had not been identified. The CART methodology used here illustrates that the added utility of the ATAQ control index, in the presence of information about prior health-care utilization, is to further stratify risk among the subset of individuals who did not have any prior acute health-care utilization. In our study population, two thirds of the asthmatics having acute events in 1998 had no acute care visits in 1997. Similar reports indicate that only a small fraction of ED users in a given year exhibit persistent ED use from year to year.25 Having a simple tool to help identify who will comprise ED/urgent care users without recent prior acute visits could be of great value to individuals and organizations interested in population-based disease management.

For the individual clinician who may not have access to administrative data on prior asthma-related health care utilization, self-reported data can be used. Although self-reported health-care utilization does not always agree with chart-confirmed utilization,26 our results suggest that the two approaches provide similar discrimination.

The finding that the ATAQ control index works
best in younger adults when previous utilization is available may reflect the fact that some of our older subjects may have unreported coexisting chronic bronchitis or emphysema that may be confounding these associations. In younger adults, the issue of coexisting COPD is less of an issue. Although our younger subjects had a lower risk of hospitalization than the older groups, the youngest group did have proportionally more ED and other urgent care visits than the older subjects and these acute visits were more likely to occur for those with ATAQ control scores of 3 to 4. Regardless of the reason for the utility of the ATAQ control index in younger patients, the results may be important for disease management. ATAQ requires primary data collection that, while not extensive, in most settings is not part of the current system of care. It is always difficult to add data collection to managed-care environments or busy practice settings. As a result, the targeted use of the ATAQ instrument in younger patients with asthma may produce the best return on this investment of time, particularly if the health plan has access to a strong administrative database that can track resource utilization. While the proportion of individuals identified by the ATAQ control index as being at highest risk is small (1 to 2% of those studied overall), their risk for future acute exacerbations is quite high and they should clearly benefit from more aggressive disease management approaches, including potentially care management. Providing increased attention to high-risk individuals is feasible when these individuals comprise a small fraction of all patients. Identification of such groups can be particularly useful for population-based disease management practices.

Additional measures of communication, self-efficacy, and attitude/behavior included in the broader ATAQ instrument provide added value to disease management. A previous study of patient dissatisfaction with asthma treatment measured via ATAQ found a significant association between treatment dissatisfaction and asthma control. We did not incorporate these additional ATAQ measures in the CART modeling reported here, as earlier CART models suggested that these measures did not add additional predictive capabilities for the identification of the high-risk group once administrative data, age, and the ATAQ control index were included.

Earlier approaches we have used to predict the risk of subsequent acute events relied on Poisson regression models. The CART methodology used here is an alternative, nonparametric approach that is particularly well suited for identifying combinations of factors that convey especially high (or low) risk that might easily be missed by classical parametric models. In this case, while the CART model

### Table 3—Summary of Simplified CART Model for Predicting Any Acute Asthma Care as a Function of ATAQ Control Index, Age, and Administrative Variables

<table>
<thead>
<tr>
<th>Description of Terminal Branch</th>
<th>Full Cohort (n = 4,788)</th>
<th></th>
<th></th>
<th>Subset Without COPD (n = 3,075)</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>No ED or urgent care and [one to two control problems or [three to four control problems and age ≥ 35 yr]]</td>
<td>87</td>
<td>7.5</td>
<td>1.0</td>
<td>88</td>
<td>7.2</td>
<td>1.0</td>
</tr>
<tr>
<td>One ED visit or (no ED visits but one or more urgent care visit)</td>
<td>10</td>
<td>26.2</td>
<td>3.5</td>
<td>10</td>
<td>25.6</td>
<td>3.6</td>
</tr>
<tr>
<td>Two or more ED visits or (no ED or urgent care, three to four control problems, and age &lt; 35 yr)</td>
<td>2</td>
<td>47.8</td>
<td>6.4</td>
<td>2</td>
<td>50.0</td>
<td>6.9</td>
</tr>
</tbody>
</table>

### Table 4—Summary of Simplified CART Model for Predicting Any Acute Asthma Care as a Function of ATAQ Control Index, Age, and Self-Reported Health-Care Utilization

<table>
<thead>
<tr>
<th>Description of Terminal Branch</th>
<th>Full Cohort (n = 4,788)</th>
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<th>Subset Without COPD (n = 3,075)</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No urgent care and [none to two control problems or [three to four control problems and age ≥ 35 yr]]</td>
<td>77</td>
<td>7.5</td>
<td>1.0</td>
<td>80</td>
<td>6.8</td>
<td>1.0</td>
</tr>
<tr>
<td>One urgent care visit</td>
<td>13</td>
<td>15.1</td>
<td>2.0</td>
<td>12</td>
<td>15.6</td>
<td>2.3</td>
</tr>
<tr>
<td>Two or more urgent care visits or (no urgent care, three to four control problems, and age &lt; 35 yr)</td>
<td>9</td>
<td>26.8</td>
<td>3.6</td>
<td>8</td>
<td>34.6</td>
<td>5.1</td>
</tr>
</tbody>
</table>
generally confirmed previous findings that the ATAQ control index has predictive value even after adjusting for prior health-care utilization and that it works best in younger adults, it provided the additional insight that the added value of the ATAQ was in further stratifying risk among individuals not identified on the basis of prior health-care utilization. In addition to targeting individuals with prior acute visits as being of high risk, the combined use of administrative data and the ATAQ control index allows for identification of a small high-risk group among those without prior urgent events.

In summary, these results illustrate that one of the best predictors of future acute health-care utilization for asthma is past acute care utilization, and that the more acute the utilization, the better is the prediction. However, since current users of acute care comprise only a fraction of future users of acute care, additional measures are needed to determine those at risk. Our results also illustrate that, even in the absence of prior asthma health-care utilization, knowledge about one’s level of asthma control can have, particularly in younger adults, surprisingly high predictive value. These findings should have use both for the practicing clinician and for individuals and organizations interested in population-based asthma disease management.

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