Utility of the Breathing Reserve Index at the Anaerobic Threshold in Determining Ventilatory-Limited Exercise in Adult Cystic Fibrosis Patients*

William P. Sexauer, MD, FCCP; Ho-Kan Cheng, MD; and Stanley B. Fiel, MD, FCCP

Objectives: Cardiopulmonary exercise testing in cystic fibrosis (CF) patients is useful to assess functional status and prognosis. Using the current interpretation guidelines, the utility of this testing will be limited in those patients who cannot exercise to a near-maximal level. This study investigates the utility of the breathing reserve index at the anaerobic threshold (BRIAT), which is defined as minute ventilation at the anaerobic threshold (AT)/maximum voluntary ventilation (MVV), to distinguish ventilatory-limited (VL) CF patients from nonventilatory-limited (NVL) CF patients.

Design: Exercise studies on 53 adult CF patients at baseline clinical status performed from 1993 to 1999 were reviewed, of which 40 met the inclusion criteria. The studies were performed via ramp protocol to the symptom-limited maximum on a cycle ergometer with breath-by-breath expired gas analysis. AT was determined noninvasively via the V-Slope method. The patients were classified as VL if they had abnormal spirometry findings, reduced exercise capacity, and a breathing reserve index at maximum exercise (BRImax) of $>0.7$. NVL patients had a normal BRImax and met the criteria for a maximal study.

Results: VL patients (21 patients) had significantly lower FVC, FEV1, MVV, and body mass index than NVL patients (19 patients). The BRIAT for the VL group was significantly higher than that for the NVL group ($p < 0.001$). Logistic regression analysis revealed that BRIAT discriminated VL patients from NVL patients better than a variety of nonexercise variables tested. The BRIAT correlated extremely well with BRImax ($r = 0.89; p < 0.001$), FVC ($r = -0.67; p < 0.001$), FEV1 ($r = -0.76; p < 0.001$), and FEV1/FVC ratio ($r = -0.683; p < 0.001$). A BRIAT value of 0.29 distinguished VL CF patients from NVL CF patients with 95.2% sensitivity and 84.2% specificity.

Conclusions: The BRIAT assessed noninvasively correlates well with commonly used measurements of pulmonary function and accurately distinguishes CF patients with and without a ventilatory limitation to exercise. The BRIAT may have utility in the interpretation of exercise studies in CF patients who are unable to exercise to a maximal level.

(CHEST 2003; 124:1469–1475)

Key words: anaerobic threshold; cystic fibrosis; exercise testing; ventilation

Abbreviations: AT = anaerobic threshold; BMI = body mass index; BRIAT = breathing reserve index at the anaerobic threshold; BRImax = breathing reserve index at maximum exercise; CF = cystic fibrosis; HR = heart rate; MVV = maximum voluntary ventilation; NVL = non-ventilatory-limited; RV = residual volume; TLC = total lung capacity; $\dot{V}e$ = minute ventilation; VL = ventilatory-limited; $\dot{V}O_{2}\max$ = maximum oxygen uptake

Maximal cardiopulmonary testing has increased in practice and importance in the cystic fibrosis (CF) population in recent years. It may be used to evaluate functional capacity, to assess for oxyhemoglobin desaturation, to guide exercise prescription for subjects entering an exercise/rehabilitation program, and to assess outcomes to therapeutic interventions or clinical trials. In addition, maximal exercise capacity has been shown to be one of the best markers of prognosis and mortality in CF patients.1

Exercise limitation in CF patients is primarily a function of the following two parameters: pulmonary function; and skeletal muscle dysfunction. Multiple factors likely contribute to the skeletal muscle dysfunction in CF patients, among them malnutrition.
and deconditioning.\textsuperscript{2–4} Maximal exercise testing is useful in determining the cause of exercise limitation and perhaps prognosis in individual patients.

The value of exercise testing, however, is tempered by a number of limitations. The interpretation of exercise testing by current published criteria necessitates a maximal or near-maximal exercise effort on the part of the patient. Many patients either cannot or will not exercise to a level sufficient to allow interpretation. Examples of reasons for the premature termination of exercise include anxiety, lack of motivation, pain/discomfort of exercise, and seat discomfort (for cycle ergometers). By most conventional criteria, such early termination of exercise will render this valuable tool uninterpretable, and perhaps useless.

In an attempt to address this issue, new criteria have been proposed that will allow the interpretation of a pulmonary mechanical limitation at a less effort-dependent level of exercise. Medoff et al\textsuperscript{5} showed that measurement of the breathing reserve at the anaerobic threshold (BRIAT), defined as minute ventilation ($V_e$) at the anaerobic threshold (AT)/maximum voluntary ventilation (MVV), correlated well with the breathing reserve measured at end exercise, and discriminated a pulmonary limitation to exercise in COPD patients from exercise limitation in patients with cardiac disease and healthy subjects with a high degree of sensitivity and specificity.

The study by Medoff et al\textsuperscript{5} demonstrated the utility of the BRIAT in discriminating a ventilatory limitation to exercise in very different populations of patients, one of which had an underlying primary pulmonary pathology. We hypothesized that the BRIAT also may have utility in a single patient population such as the CF population, in which exercise limitation may be due to two or more underlying mechanisms. The purpose of this study was to determine whether the BRIAT accurately distinguishes ventilatory-limited (VL) adult CF patients from non-ventilatory-limited (NVL) adult CF patients.

**Materials and Methods**

Patients attending the Adult Cystic Fibrosis Center at Drexel University College of Medicine (formerly MCP Hahnemann University School of Medicine) undergo full pulmonary function studies and cardiopulmonary exercise testing as part of their annual evaluation. All patients had CF confirmed by a sweat chloride level of $>$ 60 mEq/L, as determined by quantitative pilocarpine iontophoresis. A review of the records of 53 patients who had undergone at least one exercise study between October 1993 and December 1999 was performed. All patients were at or close to their clinical baseline (nonexacerbated) state at the time of the exercise study, as judged by the attending physician (WS or SF). Prior to exercise testing, all patients underwent measurement of spirometry, including FVC, FEV\textsubscript{1}, MVV, lung volumes by body plethysmography, and single-breath diffusing capacity for carbon monoxide (model 6200; SensorMedics; Yorba Linda, CA). The reference equations used for pulmonary function testing were those of Morris\textsuperscript{6} and Polgar and Promadhat.\textsuperscript{7} MVV also was calculated for each patient as FEV\textsubscript{1} multiplied by 35.\textsuperscript{8} The higher value between the measured and calculated MVV was designated as the MVV for that patient and was used in the calculation of the breathing reserve indexes (see below).

All patients underwent cardiopulmonary exercise testing in the exercise physiology laboratory at the Medical College of Pennsylvania Hospital. Patients performed progressive exercise on an electronically braked cycle ergometer (Ergo line, model 800S; SensorMedics) via a ramp protocol to a symptom-limited maximum. Work increments were individualized for each patient based on clinical factors (e.g., history, pulmonary function test results, and comorbidities) to provide an estimated maximal exercise level at between 8 and 10 min of exercise.\textsuperscript{9} Oxygen uptake, carbon dioxide production, and $V_e$ were measured breath by breath with results condensed over a 10-s time average (model 2900; SensorMedics). Oxygen saturation (N-200 pulse oximeter; Nellcor; Pleasanton, CA), ECG, and heart rate (HR) [model MAX-1; SensorMedics] were measured continuously throughout exercise. BP was measured at baseline, at 60 s intervals throughout exercise, and at termination of exercise. Maximum oxygen uptake ($V_{O_{2max}}$) and maximum $V_e$ were defined as the highest 10-s, time-averaged values obtained within the last minute of exercise.

The AT was determined noninvasively by the V-slope method.\textsuperscript{10} $V_e$ at the AT was recorded. The breathing reserve index at maximum exercise (BRImax) was calculated by dividing the maximum $V_e$ by the MVV. The BRIAT was calculated using $V_e$ at the AT divided by MVV.

Subjects were classified as VL if they demonstrated all of the following: (1) abnormal spirometry (defined as FEV\textsubscript{1} of $<$ 80% predicted or an FEV\textsubscript{1}/FVC ratio of $<$ 70%); (2) reduced exercise capacity (defined as a $V_{O_{2max}}$ of $<$ 85% predicted); and (3) reduced breathing reserve (defined as a BRImax of $\geq$ 0.70).\textsuperscript{11} The equations used for predicted $V_{O_{2max}}$ were those of Jones.\textsuperscript{12}

Subjects were classified as NVL if they had a normal breathing reserve (defined as a BRImax of $<$ 0.70) while demonstrating a maximal effort. A study was considered to be at or near the maximal level if any one of the following criteria were met: normal exercise capacity (defined as a $V_{O_{2max}}$ of $\geq$ 85% predicted); achievement of at least 85% of the predicted maximum HR; or a respiratory exchange ratio of $\geq$ 1.09.\textsuperscript{11}

Studies were excluded from analysis for the following reasons: (1) AT was indeterminate; (2) the study was submaximal; (3) exercise capacity was normal or elevated with a reduced breathing reserve (possibly indicating a high level of fitness); and (4) breathing reserve was reduced with normal spirometry. If patients had undergone multiple studies, the study with the highest $V_{O_{2max}}$ that met all other inclusion/exclusion criteria was included in analysis. The fact that most patients had undergone multiple exercise studies due to annual testing likely accounts for the low number of exclusions due to submaximal effort.

**Statistical Analysis**

The data are expressed as the mean $\pm$ SEM. Normally distributed variables were compared using the unpaired Student two-tailed $t$ test. The Mann-Whitney $U$ test was used to compare variables that were not normally distributed. The relationships between measured variables were analyzed using the Spearman rank correlation test. Multivariate logistic regression was employed to determine which of a variety of selected parameters.
independently predicted a ventilatory limitation to exercise. A p
value of < 0.05 was considered to be statistically significant.

RESULTS

Of the 53 exercise studies initially reviewed, 13 were excluded from analysis for the reasons outlined in Figure 1. Of the 40 remaining subjects, 21 were found to be VL and 19 had nonventilatory limitations to exercise. The baseline characteristics of the study population are summarized in Table 1. The NVL group had a higher male/female ratio than the VL group. The age and height of the two groups were similar, but the VL group had a significantly lower weight and body mass index (BMI). Pulmonary function studies of the two groups are summarized in Table 2. The VL group had a significantly lower FVC percent predicted, FEV₁ percent predicted, and FEV₁/FVC ratio than did the NVL group. The VL group also had a greater degree of air trapping than the NVL group, as assessed by the residual volume (RV) percent predicted and the RV/total lung capacity (TLC) ratio.

Table 3 summarizes the major exercise variables for both groups. The VL group had a lower absolute \( \dot{V}O_2 \)max than did the NVL group, but the difference did not reach statistical significance (p = 0.273). There was no significant difference between the groups in AT, HR, or \( O_2 \) pulse. VE values at maximum exercise and at the AT were also not significantly different between the two groups. However, the BRImax and BRIAT in the VL group were greater than those in the NVL group, with a high degree of statistical significance due to the much higher MVV in the NVL group (Table 2).

For the BRIAT to be valid as a discriminatory variable for a ventilatory limitation to exercise, it should bear a close relationship to other commonly used ventilatory variables. Of the variables tested, BRIAT most strongly correlated with BRImax (Fig 2, top), but also had strong correlations with FEV₁ percent predicted (Fig 2, middle), FVC percent predicted (Fig 2, bottom), and FEV₁/FVC ratio (not shown) [\( r = -0.683; p < 0.001 \)].

BRIAT will be useful only if it predicts a ventilatory limitation to exercise better than more commonly used ventilatory parameters. Using multivariate logistic regression, BRIAT was found to be the

---

Table 1—Study Population*

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>VL (n = 21)</th>
<th>NVL (n = 19)</th>
<th>p Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>19–42</td>
<td>19–39</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>29 ± 1.3</td>
<td>29 ± 1.2</td>
<td>NS</td>
</tr>
<tr>
<td>Height, cm</td>
<td>168 ± 2</td>
<td>171 ± 3</td>
<td>NS</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>59 ± 2</td>
<td>67 ± 2</td>
<td>0.027</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>20.9 ± 0.6</td>
<td>22.9 ± 0.6</td>
<td>0.019</td>
</tr>
</tbody>
</table>

*Values given as mean ± SEM, unless otherwise indicated. NS = not significant.
only independent predictor of a ventilatory limitation
to exercise of the parameters assessed (Table 4). The
odds ratio for BRIAT are multiplied by a factor of 22
for each 0.10 increase, not for every 1.0 increase
(Table 4). For the population studied, a BRIAT value
of 0.29 distinguished VL CF patients from NVL CF
patients with 95.2% sensitivity and 84.2% specificity.

**Discussion**

Impaired exercise capacity in CF patients is com-
mon, with multiple factors potentially contributing to

**Table 2—Pulmonary Function Studies**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>VL Group (n = 21)</th>
<th>NVL Group (n = 19)</th>
<th>p Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FVC</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>3.02 ± 0.20</td>
<td>4.18 ± 0.28</td>
<td>0.002</td>
</tr>
<tr>
<td>% predicted</td>
<td>68 ± 4</td>
<td>85 ± 4</td>
<td>0.002</td>
</tr>
<tr>
<td><strong>FEV</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F/L</td>
<td>1.70 ± 0.14</td>
<td>2.95 ± 0.25</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>% predicted</td>
<td>48 ± 4</td>
<td>75 ± 5</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>FEV/FVC ratio</td>
<td>56 ± 3</td>
<td>70 ± 3</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>TLC</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>5.76 ± 0.38</td>
<td>6.15 ± 0.30</td>
<td>NS</td>
</tr>
<tr>
<td>% predicted</td>
<td>98 ± 6</td>
<td>97 ± 3</td>
<td>NS</td>
</tr>
<tr>
<td><strong>RV</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>2.63 ± 0.29</td>
<td>1.92 ± 0.20</td>
<td>0.042</td>
</tr>
<tr>
<td>% predicted</td>
<td>161 ± 17</td>
<td>109 ± 11</td>
<td>0.009</td>
</tr>
<tr>
<td>RV/TLC ratio</td>
<td>44 ± 3</td>
<td>32 ± 3</td>
<td>0.003</td>
</tr>
<tr>
<td>MVV, L/min</td>
<td>69 ± 5</td>
<td>132 ± 11</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

*pValues given as mean ± SEM, unless otherwise indicated. See Table 1 for abbreviation not used in the text.

**Table 3—Exercise Data**

<table>
<thead>
<tr>
<th>Variables</th>
<th>VL Group</th>
<th>NVL Group</th>
<th>p Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>V˙O₂ max</td>
<td>1.434 ± 94</td>
<td>1.712 ± 132</td>
<td>NS</td>
</tr>
<tr>
<td>mL/kg/min</td>
<td>24.3 ± 1.3</td>
<td>25.4 ± 1.7</td>
<td>0.7 NS</td>
</tr>
<tr>
<td>% predicted</td>
<td>64 ± 3</td>
<td>65 ± 4</td>
<td>0.7 NS</td>
</tr>
<tr>
<td><strong>AT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mL/min</td>
<td>753 ± 54</td>
<td>884 ± 77</td>
<td>NS</td>
</tr>
<tr>
<td>% predicted</td>
<td>33 ± 2</td>
<td>34 ± 2</td>
<td>NS</td>
</tr>
<tr>
<td><strong>HRmax</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>beats/min</td>
<td>165 ± 4</td>
<td>167 ± 5</td>
<td>NS</td>
</tr>
<tr>
<td>% predicted</td>
<td>89 ± 2</td>
<td>92 ± 2</td>
<td>NS</td>
</tr>
<tr>
<td>O₂ pulse, mL/beat</td>
<td>9.1 ± 0.6</td>
<td>10.5 ± 0.7</td>
<td>NS</td>
</tr>
<tr>
<td>Maximum RER value</td>
<td>1.24 ± 0.04</td>
<td>1.29 ± 0.05</td>
<td>NS</td>
</tr>
<tr>
<td><strong>VE, L/min</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>64.7 ± 4.6</td>
<td>72.1 ± 5.6</td>
<td>NS</td>
</tr>
<tr>
<td><strong>AT</strong></td>
<td>28.4 ± 2.0</td>
<td>28.5 ± 1.7</td>
<td>NS</td>
</tr>
<tr>
<td><strong>BRImax</strong></td>
<td>0.96 ± 0.07</td>
<td>0.56 ± 0.02</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td><strong>BRIAT</strong></td>
<td>0.43 ± 0.03</td>
<td>0.23 ± 0.01</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

*pValues given as mean ± SEM, unless otherwise indicated. RER = respiratory exchange ratio; HRmax = maximum HR. See Table 1 for abbreviation not used in the text.

**Figure 2.** BRIAT correlated most strongly with BRImax (top), but also had strong correlations with FEV₁ percent predicted (middle) and FVC percent predicted (bottom). ○ = VL subjects; ● = NVL subjects.

Exercise limitation. The most obvious of these is lung
disease, with a clear-cut ventilatory limitation to
exercise most obvious in patients with severe airflow
obstruction.4,13,14 However, multiple studies have
demonstrated that skeletal muscle dysfunction may
contribute to exercise impairment.2–4 Malnutrition, a
consequence of pancreatic insufficiency-induced
malabsorption and increased caloric requirements due to the increased work of breathing, may cause decreased muscle mass. CF, like any chronic disease, may predispose the patient to a sedentary lifestyle and result in deconditioning. Other potential contributors to skeletal muscle dysfunction in CF patients include medications (e.g., corticosteroids), electrolyte abnormalities, and an increased predisposition to oxidant-induced muscle injury. Patients with CF also may have impaired cardiac output, but this is usually not exercise-limiting.

Possibly because of the very fact that exercise requires the integrated functioning of multiple organs in the multisystem disease that is CF, exercise capacity has been shown to be one of the strongest markers of prognosis and mortality. Exercise-training programs have been shown to improve exercise tolerance and maximal exercise capacity in CF patients and may slow the decline of lung function over time. Other demonstrable benefits of aerobic exercise in CF patients include decreased dyspnea, improved mucociliary clearance, and improved ability to carry out activities of daily living.

For all of the above reasons, exercise testing is commonly performed in patients with CF. Exercise testing may provide information about prognosis and functional status, may screen for exertion-related oxyhemoglobin desaturation, and may be used to write an initial exercise prescription for those patients entering an exercise program. The current guidelines for interpretation of exercise tests, however, necessitate that the patient achieve or approach maximal exercise capacity. Many patients cannot or will not exercise to a maximum for a variety of subjective reasons. This study provides a means to identify those patients who have a ventilatory limitation to exercise from those who have a nonventilatory limitation to exercise, with a sensitivity of 95% and a specificity of 84%. As would be expected of a physiologic variable used to identify a ventilatory limitation, BRIAT correlates very well with other commonly used measures of respiratory function. The strongest correlation is with the variable it is used as a surrogate for, the BRImax. However, when used as a surrogate for BRImax, multivariate analysis reveals BRIAT to be a better predictor of ventilatory limitation than any of the commonly used noneexercise parameters tested.

This study identified a BRIAT cutoff of 0.29 as the optimal discriminating point between VL and NVL patients. That this differs from the 0.42 cutoff identified by Medoff et al is not surprising when the study populations are taken into account. Medoff et al compared patients with severe COPD (i.e., mean FEV₁, 24% of predicted) to cardiac patients and healthy subjects with no known lung disease, and pulmonary function at or near the normal range. In contrast, this study examined a single patient population with a range of pulmonary function and, to a lesser degree, nutritional status as measured by BMI. Even the NVL group had impaired pulmonary function (albeit mild), and while the pulmonary function of the VL group was significantly lower than that of the NVL group, the FEV₁ of the VL group was higher than that of the COPD population in the study by Medoff et al. Our study made no attempt to enroll only those subjects with extremes of pulmonary function. In fact, one might expect that if the COPD population in the study by Medoff et al had less severe lung disease, the optimal cutoff value obtained may have been different.

There are a number of potential limitations to this study, most relating to the manner in which the exercise study was performed, particularly the defining thresholds used. In contrast to the study of Medoff et al, who determined the lactate threshold invasively via measurement of arterial blood lactate levels, the present study used the noninvasive V-slope method. In lung disease patients, values obtained by the V-slope method correlate very well with measures obtained invasively, including patients with CF. Recent studies have shown that noninvasive assessment of the AT in CF patients is accurate and reproducible across a wide range of pulmonary function. When the safety and lower cost of noninvasive measurements are taken into account, noninvasive determinations of the AT may be preferable for most laboratories.

A second and more controversial point is the choice of criteria used for defining a ventilatory limitation to exercise. There does not appear to be an accepted “gold standard” criterion among exercise physiologists, but one widely used criterion is that used in this study, a BRImax of ≥ 0.70.
methods of determining an exercise ventilatory limitation have been studied, but are more complex to perform and have not been standardized.

The MVV is an important measurement in the determination of both BRImax and BRIAT. Direct measurement of the MVV, usually performed via maximal ventilation over a 12-s period multiplied by 5, is dependent on the subject’s effort and possibly on the breathing pattern adopted. Because of the difficulty that some patients have in performing this maneuver, various prediction equations based on the FEV1 have been developed. In this study, we directly measured MVV in the pulmonary function laboratory and used this value as the MVV, unless it was less than the product of FEV1 \times 35. The assumption is that a directly measured MVV below this value likely represents a suboptimal effort on performance of the MVV maneuver. Some believe that the product of FEV1 \times 40 more accurately estimates the true MVV, but FEV1 \times 35 is widely used, and we think that it represents an acceptable estimation of MVV.

Defining a maximal or near-maximal exercise effort for those patients not clearly demonstrating a ventilatory limitation also can be problematic, without a single clear-cut defining variable. The criteria we used (i.e., normal exercise capacity, approaching the maximal predicted HR, or attainment of a respiratory exchange ratio of \geq 1.09) are measurable noninvasive parameters that are in common use.

It was expected that patients in the VL and NVL groups would have significantly different pulmonary functions, and, given the known relationship of pulmonary function to nutritional status in CF patients, the lower weight and BMI of the VL group also was anticipated. Somewhat unexpected was the lack of a statistically significant difference in V̇O2max between the two groups. The mean V̇O2max for the VL group was 286 mL/min lower than that for the NVL group, a trend that may well have produced a statistically significant difference in VO2max in a larger study. A leading postulated mechanism as to why CF patients have a reduced exercise capacity is reduced muscle mass. Thus, it is not surprising that the VO2max (expressed as the percent predicted and milliliters per kilogram per minute) further minimizes the difference between the two groups, as both of these expressions normalize for weight.

In summary, measurement of the breathing reserve at the AT accurately distinguishes CF patients who have a ventilatory limitation to exercise from those who do not have a ventilatory limitation with a high degree of sensitivity and specificity. The BRIAT correlates very well with other measures of pulmonary function but identifies those patients who do have a ventilatory limitation better than a variety of other commonly used nonexercise parameters. Measurement of the BRIAT may be useful in assessing the presence of a ventilatory limitation in adult CF patients whose exercise studies are limited by a submaximal effort. The utility of noninvasive measurements, as performed in this study, should make application of the BRIAT safer and more widely available.

ACKNOWLEDGMENT: The authors thank Liz McFarlane for her expert assistance in preparation of this manuscript.

REFERENCES

Enjoy the Convenience of CHEST on CD-ROM

Now search 2002 issues of CHEST and its supplements right on your computer. No more leafing through pages to find that article or topic you’re interested in. Just enter a key word, author, or other search field, and click your way to a wealth of valuable information.

This CD-ROM offers full-text and PDF files of all issues and supplements. View or print articles that look exactly like they did in the print journal.

Order your CHEST 2002 CD-ROM today! 800-343-2227 or 847-498-1400

ACCP member $60 • nonmember $75 • plus shipping