H. Eliasson and Yancy Y. Phillips

Interpretation of Eucapnic Voluntary Hyperventilation in the Diagnosis of Asthma


Chest 1995;108;1240-1245
DOI 10.1378/chest.108.5.1240

The online version of this article, along with updated information and services can be found online on the World Wide Web at:
http://chestjournal.org/cgi/content/abstract/108/5/1240

CHEST is the official journal of the American College of Chest Physicians. It has been published monthly since 1935. Copyright 2007 by the American College of Chest Physicians, 3300 Dundee Road, Northbrook IL 60062. All rights reserved. No part of this article or PDF may be reproduced or distributed without the prior written permission of the copyright holder (http://www.chestjournal.org/misc/reprints.shtml). ISSN: 0012-3692.
Interpretation of Eucapnic Voluntary Hyperventilation in the Diagnosis of Asthma*

Cpt Kenneth M. Hurwitz, MC, USA; Maj Gregory J. Argyros, MC, USA; Maj James M. Roach, MC, USA, FCCP; Lt Col Arni H. Eliasson, MC, USA, FCCP; and Col Yancy Y. Phillips, MC, USA, FCCP

Eucapnic voluntary hyperventilation (EVH) of dry gas is a physiologic bronchoprovocation challenge useful in the diagnosis of asthma. To determine the best parameter and threshold for diagnosis and the proper timing of postchallenge measurements, we reviewed 120 challenges, comparing the decrement from baseline in FVC, FEV₁, mean forced expiratory flow during the middle half of the FVC (FEF₂₅₋₇₅%), and peak expiratory flow rate (PEFR) each at 0, 5, 10, and 20 min postchallenge. After adjustment to a standard minute ventilation of 30 times the baseline FEV₁ for 6 min, the mean response by 90 mild asthmatics differed from 30 normal subjects in all four parameters (p<0.0001). In asthmatics, maximum decline from baseline (mean±SEM) was as follows: FVC, 12.1±1.2%; FEV₁, 19.7±1.7%; FEF₂₅₋₇₅%, 33.5±2.5%; and PEFR, 29.0±1.9%. Normal subjects had a maximum fall as follows: FVC, 2.9±0.7%; FEV₁, 3.8±0.7%; FEF₂₅₋₇₅%, 11.8±2.0%; and PEFR, 11.5±1.0%. Based on comparison of receiver operator characteristic curves, FEV₁ was more accurate than FEF₂₅₋₇₅% and equivalent to FVC and PEFR. A threshold of 10% change or greater in FEV₁ had a specificity of 90%, with a sensitivity of 63.3%. A threshold of 15% or greater had a specificity of 100%, with a sensitivity of 53.3%. The FEV₁ fell by 10% or more in 55 of 90 asthmatics at 5 or 10 min after hyperventilation. Measurements at 0 or 20 min added two additional positive responses. We conclude that in the proper clinical setting, subjects whose FEV₁ declines by 10% or more at 5 or 10 min after EVH should be diagnosed as having asthma.

(CHEST 1995; 108:1240-45)

Bronchoprovocation is a useful clinical tool to confirm airway hyperreactivity in suspected asthmatics. Because no one method is universally reliable, a variety of techniques for demonstrating airway hyperreactivity have been employed, including inhalation challenge with pharmacologic agents, antigen, and nonisotonic saline solution; exercise; and cold or dry gas hyperventilation. While methacholine or histamine inhalation challenges are the most widely used, their administration is time-consuming, supply of some of the agents has been erratic, and they may lack specificity for asthma vs other conditions.1 General experience with the earlier methods of hyperventilation testing has been limited by the expense of the equipment needed to cool the inspired gas and maintain isocapnia. First described in 1985, eucapnic voluntary hyperventilation (EVH)² is a simplified method of dry gas hyperventilation we have found to be economical and clinically useful. The technique is not widely used, though, and interpretive strategies may vary.

The purpose of this study was to determine the proper criteria for judging a normal vs asthmatic response in subjects undergoing EVH. In particular, we sought to identify the appropriate demarcation in the postchallenge spirometry to distinguish between a group of subjects with mildly symptomatic asthma and normal controls. To accomplish this, we reviewed the response to EVH in 90 asthmatics and 30 normal subjects. We focused on the response in FVC, FEV₁, mean forced expiratory flow during the middle half of the FVC (FEF₂₅₋₇₅%), and peak expiratory flow rate (PEFR) to establish the most accurate parameter and threshold of response to help us distinguish between these groups. In addition, we evaluated the time course

Key words: asthma; bronchoprovocation; exercise-induced asthma; hyperventilation

*From the Pulmonary and Critical Care Medicine Service, Department of Medicine, Walter Reed Army Medical Center, Washington, DC, and the Uniformed Services University of the Health Sciences, Bethesda, Md.

This study was supported by the Department of Clinical Investigation, Walter Reed Army Medical Center.

The opinions and assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army, Uniformed Services University of the Health Sciences, or the Department of Defense. Manuscript received November 28, 1994; revision accepted June 9, 1995.

Reprint requests: Dr. Hurwitz, Pulmonary and Critical Care Medicine, Walter Reed Army Medical Center, Washington, DC 20307

---

EVH=eucapnic voluntary hyperventilation; FEF₂₅₋₇₅%=mean forced expiratory flow during the middle half of the FVC; PEFR=peak expiratory flow rate; ROC=receiver operating characteristic; Vₑ=minute ventilation
of the response following hyperventilation challenge to find the optimum time for measurements and perhaps further simplify the testing procedure.

**METHODS**

**Subjects**

Challenges for review were recovered from the files of subjects who participated in one of six research protocols requiring EVH challenge at our institution between 1987 and 1994. All asthmatic subjects were volunteers recruited from the outpatient clinics of Walter Reed Army Medical Center. Asthmatics were eligible for participation if they met the American Thoracic Society clinical criteria, including prior demonstration of reversible airway obstruction or an abnormal bronchoprovocation challenge. Most patients had been referred to our clinic for exertional dyspnea. Subjects solicited for study typically had mild symptoms and often normal results of baseline spirometry. Two of the studies excluded asthmatics who required daily medications. Although four of the studies enrolled only asthmatic subjects who responded to a screening EVH challenge, all asthmatics screened for those studies were included in this review, regardless of their response to EVH. Exclusionary criteria in all the studies were use of oral corticosteroids, upper respiratory tract infection, or acute exacerbation within 1 month prior to testing, as well as pregnancy or cardiorespiratory disease other than asthma. Prior to testing, all subjects were asked to refrain from inhaled bronchodilators for 12 h, and from inhaled corticosteroids, theophylline, and caffeine for 24 h. Furthermore, to ensure safety and to identify a group comparable to those who undergo bronchoprovocation challenge in a clinical setting, only subjects with a baseline FEV1 above 60% predicted were enrolled.

The normal controls were all volunteers without asthmatic symptoms or any of the exclusionary criteria listed above. All subjects participated voluntarily and gave written informed consent. The research was approved by the Walter Reed Army Medical Center Clinical Investigation and Human Use Committees. Funding for the study was provided by the Department of Clinical Investigation.

**Study Design**

All available records from EVH trials done under research protocols at our institution were reviewed. Data were extracted from each individual study to include baseline spirometry, challenge duration and intensity, and postchallenge spirometry at all available time intervals. Each subject was included only once, even if data from several EVH challenges from that subject were available. When subjects had participated in more than one study, the challenge using a minute ventilation (Ve) closest to 30 times the baseline FEV1 was selected.

**EVH Challenge Technique**

EVH was performed as a single challenge, as described by Phillips and colleagues. A schematic of the apparatus is shown in Figure 1. After baseline spirometry (Cybermedic Excel; Louisville, Colo), subjects hyperventilated a compressed gas mixture of 5% CO2, balance air in a single challenge. Target Ve was set at 24 to 30 times baseline FEV1 per minute for 6 min, depending on the study protocol. Flow rate was measured by a rotameter (Fischer & Porter Co; Warminster, Pa) in the inhalational circuit, which directed the gas through a 3.5-L meteorologic balloon, then to the mouthpiece. Subjects were coached to maintain their ventilatory rate so as to keep the balloon half full. Test gas was dry and at room temperature (22°C). During the posthyperventilation measurements, the subjects breathed room air. Spirometry was performed 0, 5, 10, and 20 min after the end of dry gas administration. At each time interval, at least two consistent expiratory spirometers were performed and the highest values for FVC and FEV1 were recorded. The values for FEF25-75% and PEFR were selected from the best test (the test with the largest sum of FVC and FEV1), in accordance with American Thoracic Society standards. Of those postchallenge values, the one showing the greatest decline from baseline in each parameter was taken as indicative of the maximal bronchoconstrictive response. The change was expressed as the percent decline from baseline to postchallenge level.

To account for slight variations among the protocols in minute ventilation (24, 25, or 30 times the FEV1), maximum responses of each parameter were adjusted assuming a linear relationship for each individual between the intensity of challenge and the maximum response, as demonstrated by Argyros et al. The results of each challenge were normalized to a "standard" Ve of 30 times baseline FEV1. For example, the adjusted change in FEV1 was then calculated as follows: dFEV1 (adjusted) = dFEV1 (measured) x 30/VE/baseline FEV1.

**Analysis**

Data are expressed as the mean±SEM. The primary response variable to EVH testing was the percentage decline of each parameter compared with baseline. Groups were compared using the two sample t test, and association between respiratory parameters was examined using Pearson's correlation coefficient. All reported p values are two sided, with p less than 0.05 considered statistically significant. Where reported, 95% confidence intervals are used. Commercially available software was used for statistical analysis (Statistix 4.0; Analytical Software; St. Paul, Minn).

Receiver operating characteristic (ROC) curves are presented comparing spirometric parameters. The ROC curves depict the true-positive rate (sensitivity) vs the false-positive rate (1 minus the specificity) at various levels of change in the spirometric measurements. The area under the curve was estimated using the Wilcoxon statistic. Comparisons between ROC curves were made using the method of Hanley and McNeil and included the correction for correlation.

**RESULTS**

Baseline subject demographics are given in Table 1. The 90 asthmatics ranged in age from 19 to 80 years, and were 64% male. Of those with data available, 18

---

**Figure 1.** Schematic of EVH apparatus. Dry gas is metered through a rotameter, then fills the target balloon. The subject is coached to maintain a Ve sufficient to keep the balloon half emptied.
of 54 (33%) had a history of tobacco use. Information was available on medication use in 55 of 90 asthmatics. Of those with data available, daily or frequent medications included inhaled β-agonists in 44 of 55 (80%), inhaled corticosteroids in 29 of 55 (53%), oral theophylline in 3 of 55 (5.5%), and inhaled cromolyn in 2 of 55 (3.6%). Other asthmatics used only episodic or seasonal medications. The 30 normal subjects ranged in age from 25 to 46 years, and were 70% male. Thirteen of 26 (50%) normal subjects reported current or previous tobacco use. As expected, baseline spirometry prior to challenge differed between the two groups. Normal subjects had a baseline FVC ranging from 88 to 120% of predicted, and an FEV1 ranging from 74 to 121% of predicted. Asthmatics had a baseline FVC of 65 to 140% predicted, and an FEV1 of 61 to 139% of predicted.

A comparison of challenge intensity is given in Table 2. Target VE for asthmatics ranged from 36 to 167 L/min, which was 24 to 30 times the baseline FEV1 or 15 to 42 times the predicted FEV1. Of the asthmatics, 36 (40%) were tested at 24 times FEV1, 31 (34%) at 25 times FEV1, and 23 (26%) at 30 times FEV1. The total volume of inhaled gas ranged from 213 to 1,001 L. In normal subjects, target VE ranged from 77 to 168 L/min, which was 25 to 30 times the baseline FEV1 or 22 to 36 times the predicted FEV1. Of normal subjects, 7 (23%) tested at 25 times FEV1 and 23 (77%) at 30 times FEV1. The total volume of inhaled gas in normal subjects ranged from 462 to 1,006 L. VE, VE per predicted FEV1, and total volume of inhalation were all lower in asthmatics than normal subjects (p<0.0001). Postchallenge data were available for 112 subjects at 0 min, 118 subjects at 5 and 10 min, and 113 subjects at 20 min.

Table 2—Comparison of Challenge Intensities

<table>
<thead>
<tr>
<th>Challenge VE, L/min</th>
<th>Normal</th>
<th>Asthmatic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>110±4.1</td>
<td>85.5±2.81</td>
</tr>
<tr>
<td>VE/baseline FEV1, min⁻¹</td>
<td>28.8±0.4</td>
<td>25.9±0.31</td>
</tr>
<tr>
<td>VE/predicted FEV1, min⁻¹</td>
<td>28.3±0.7</td>
<td>23.6±0.51</td>
</tr>
<tr>
<td>Total volume inhaled, L</td>
<td>658±25</td>
<td>513±171</td>
</tr>
</tbody>
</table>

*Values expressed are mean±SEM.  
1p<0.0001.

As expected, the mean maximum fall (adjusted for challenge intensity) was larger in asthmatics than in normal subjects for all four parameters measured (p<0.0001), as shown in Table 3. The magnitude of reactivity was greatest for asthmatics in FEF25–75%, followed by PEFR, FEV1, and then FVC. A weak association existed between the fall in FEV1 after EVH and the FEV1 percent predicted at baseline (r=−0.28, p=0.008); that is, those asthmatics with a lower percent predicted prechallenge FEV1 had a tendency to be more responsive to EVH.

ROC curves were used to compare the accuracy of the four parameters (Fig 2). The accuracy of the test, expressed as the area under the curve (±SE), was as follows: 0.84±0.04 for FEV1; 0.84±0.04 for PEFR; 0.82±0.04 for FVC; and 0.77±0.04 for FEF25–75%. FEV1 was more accurate than FEF25–75% (p=0.018), but equivalent to PEFR and FVC (p>0.4).

ROC curves were also used to determine the threshold for diagnosis using the maximum response in each parameter. For a specificity of 90% or greater, the following integral values of thresholds (and their associated sensitivity/specificity in parentheses) were identified: 5% fall in FVC (66.7%/90%), 10% fall in FEV1 (63.3%/90%), 20% fall in PEFR (66.7%/93.3%), and 25% fall in FEF25–75% (56.7%/90%). A specificity of 100% was achieved in our group with a threshold of 14% change in FEV1, yielding a sensitivity of 53.3%. The curve for FEV1 with a range of thresholds is shown in Figure 3.

The time course to maximum response in asthmatics is depicted in Figure 4. Peak response occurred at a median time of 5 min for FVC, FEV1, and FEF25–75%, and at 10 min for PEFR. As measured by FEV1, 10 asthmatics had their maximum response at 0 min, 48 at 5 min, 21 at 10 min, and 11 at 20 min. Cumulatively, 79 of 90 (87.8%) asthmatics reached their maximum FEV1 response by 10 min. Using 10% or greater as a threshold for a diagnostic FEV1 response, 33 asthmatics had their first positive response at 0 min, 20 at 5 min, 2 at 10 min, and 2 at 20 min (Fig 5). The two subjects who did not have a positive response until 20 min had a greater than 9% response in FEV1 by 10 min. All of the asthmatics with positive responses at 0 min also had positive responses at 5 or 10 min.

Table 1—Subject Characteristics

<table>
<thead>
<tr>
<th>Age, yr</th>
<th>Normal</th>
<th>Asthmatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>34.2±1.2</td>
<td>36.1±1.3</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tobacco, (pack-yr)</th>
<th>Normal</th>
<th>Asthmatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.6±2.0</td>
<td>4.3±1.2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FVC, L</th>
<th>Normal</th>
<th>Asthmatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.83±0.16</td>
<td>4.39±0.131</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>% predicted</th>
<th>Normal</th>
<th>Asthmatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>103±1.7</td>
<td>95.2±1.51</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Challenge VE, L/min</th>
<th>Normal</th>
<th>Asthmatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>110±4.1</td>
<td>85.5±2.81</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VE/baseline FEV1, min⁻¹</th>
<th>Normal</th>
<th>Asthmatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>28.8±0.4</td>
<td>25.9±0.31</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VE/predicted FEV1, min⁻¹</th>
<th>Normal</th>
<th>Asthmatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>28.3±0.7</td>
<td>23.6±0.51</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total volume inhaled, L</th>
<th>Normal</th>
<th>Asthmatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>658±25</td>
<td>513±171</td>
<td></td>
</tr>
</tbody>
</table>

*Values expressed are mean±SEM.  
1p<0.0001.
Discussions

The diagnosis of asthma in a patient with suggestive symptoms is, foremost, a clinical one. When the diagnosis is less certain, tests of airway hyperreactivity can be useful in identifying patients with abnormal bronchomotor responsiveness. The limitations of the tests must be recognized, though, in that none of the commonly used techniques of bronchoprovocation are universally accurate. Inhaled pharmacologic provocation with methacholine or histamine, though sensitive and widely applied, is recognized to result in nonspecific bronchial hyperreactivity. Exercise is a more physiologic challenge, but it is notoriously insensitive. Hyperventilation with dry or cold dry air has more sensitivity than exercise, and perhaps more specificity than the pharmacologic challenges. Physiologically, hyperventilation tests are appealing in evaluating exercise-induced asthma.

Our study sought to refine the interpretation of EVH in the diagnosis of asthma. Several limitations warrant discussion. First, the normal subjects and asthmatics in our study group differed in a number of ways. Baseline flows and volumes were lower in asthmatics than in normal subjects. In part, this is explained by mild resting obstruction in the asthmatics. However, a larger proportion of female subjects and a slightly higher mean age among the asthmatics also contributed to lower mean predicted values. Because of this, the normal subjects on average underwent a more intense challenge than the asthmatics.

Second, the intensity of the challenge varied slightly in different protocols as we gained more experience with the test. In this analysis, we attempted to adjust for variations in the intensity of hyperventilation by standardizing to a target Ve of 30 times the baseline FEV1. Ongoing work at our institution has shown that there is a linear relationship within individual asthmatics between bronchospastic response and respiratory heat and/or water exchange expressed as the challenge duration times Ve/FEV1 over a narrow range of Ve. We feel comfortable normalizing for a Ve within the range of 24 to 30 times FEV1. We do not have similar evidence for normal subjects who may not respond any differently to challenges of varying intensity, but we empirically adjusted their responses in a

Figure 2. ROC curves showing maximum response to EVH in asthmatics. The area under each curve is shown in parentheses. The accuracy of FEV1 is greater than FEF* and equivalent to FVC and PEFR.

Figure 3. ROC curve showing decline in FEV1 after EVH. The percent decline of FEV1 from baseline is shown in parentheses. At a threshold of 10% fall in FEV1, specificity is 90% and sensitivity is 83.3%.

Figure 4. Mean maximum response over time after challenge with EVH for four spirometric parameters in asthmatics.
similar fashion. The correction factor was small, however, altering our interpretation of thresholds by approximately 1% compared with unadjusted data. The problematic adjustment of the results based on challenge technique highlights the need for a standard challenge.

Third, dosing the challenge by measured FEV₁ naturally resulted in a wide range of challenge intensities. We set the Vₑ of all EVH challenges as a multiple of the measured baseline FEV₁ in order to give proportional dosing depending on the ventilatory capacities of each individual. It seems reasonable to adjust the intensity of this physiologic bronchoconstrictive stimulus based on physical parameters. Hyperventilation challenges the heat and water exchange capacities of the airways. That exchange occurs across the exposed surface of the respiratory mucosa, which is reasonably proportionate to FEV₁ (or FVC). A fixed challenge for persons of varying age and size would not be equivalent in terms of water lost per unit of respiratory mucosal surface. The concept of dose per unit area could also be expected to apply to pharmacologic inhalation challenge. However, the range of dosing is so great with pharmacologic agents (1,000-fold from start to maximum dose of methacholine) that the two- or threefold difference in human dimensions is inconsequential. A further advantage of individualizing the challenge is the added safety in those with less respiratory reserve.

Our first goal in this study was to identify the spirometric parameter most distinctly altered by EVH. Analysis by ROC curves showed FEV₁ to be slightly more accurate overall than FEF₂₅₋₇₅% in distinguishing normal subjects from asthmatics. However, PEFRs, which are more related to effort than the other parameters, were just as discriminating as FEV₁ in this well-motivated group. Clearly, the four parameters studied are closely interdependent, and any one of them could reasonably be used to judge response. The trend favored FEV₁ and confirmed the usual clinical practice.

As to the appropriate threshold value for FEV₁ response, a requirement for a 20% fall, as commonly used for the pharmacologic challenges, is inappropriate when applied to EVH. While this degree of response is highly specific, it will miss many clear cases of asthma. The importance of avoiding false-positive results will vary according to the implications of making such a diagnosis. Certainly one can afford a small loss in specificity if the result is a trial of bronchodilators. If the result of a positive test result is denial of insurance or employment, however, perhaps a higher threshold would be more appropriate. For general use, we recommend a threshold of 10% or greater fall in FEV₁. In our study, this gave a sensitivity of 63% with a specificity of 90%. Convenient alternative thresholds would be a fall of 5% in FVC, 20% in PEFR, or 25% in FEF₂₅₋₇₅%. In circumstances where avoiding a false diagnosis is paramount, a threshold of 15% fall in FEV₁ is remarkably specific for asthma.

After analysis of the time course of response to EVH, we believe that it is possible to reduce the number of postchallenge measurements to even further simplify the testing procedure. Our subjects showed a consistent peak in bronchoconstriction between 5 and 10 min postchallenge. Blackie and colleagues have previously shown that the time course of response to hyperventilation is related to the intensity and duration of the dose. With a standardized 6-min challenge, however, we should be able to eliminate the 20-min posthyperventilation measurement while sacrificing little sensitivity. Additionally, unless the volume history of the first postchallenge spirometry result affects subsequent measurements, we would sacrifice very little by omitting the immediate postchallenge measurement. In fact, if deep inspiration after induced bronchoconstriction causes lessening of the induced response, as suggested by Lim and colleagues, then there may be a greater sensitivity at 5 or 10 min if the first measurement is omitted. Advantages to taking fewer measurements include smaller effects of fatigue, particularly in less-motivated subjects, as well as a lesser requirement for technician time.

As performed in our trial, EVH is easy to administer. While a full methacholine challenge in our laboratory requires 45 min or more of technician time, an EVH challenge can be completed routinely within 30
min. As described above, we use a single 6-min challenge rather than an escalating dose, as is done with methacholine, and in some centers with dry gas. Despite possible concerns about overdosing very sensitive subjects, we have had no adverse results in those with mild asthma who would typically be subjected to EVH as a diagnostic test. Additionally, division of the challenge into smaller increments of hyperventilation has been shown to induce a lesser degree of reactive bronchoconstriction, likely due to the development of overlapping refractory periods. Our experience with EVH confirms its usefulness as a bronchoprovocation test that can be used when the diagnosis of asthma is uncertain. The accuracy of the test compares well to the more commonly used inhalation challenges when the threshold fall in FEV1 is set at 10%. Practicing physicians will certainly adjust this based on the implications of the result, but must recognize that a threshold of 15 or 20% change is too stringent for many clinical scenarios. Standardization of the challenge technique is vital to widen applicability. We believe a single intense episode of hyperventilation followed by spirometry at 5 and 10 min postchallenge is adequate to accurately differentiate between asthmatics and nonasthmatics. With careful attention to technique, EVH can be an economic alternative to pharmacologic inhalation in clinical practice.

ACKNOWLEDGMENT: The authors gratefully acknowledge Robin Howard for her assistance in statistical analysis.

REFERENCES
12 Hanley JA, McNeil BJ. The meaning and use of the area under a receiver operating characteristic (ROC) curve. Radiology 1982; 143:29-36
13 Hanley JA, McNeil BJ. A method of comparing the areas under receiver operating characteristic curves derived from the same cases. Radiology 1983; 148:839-43
**Interpretation of Eucapnic Voluntary Hyperventilation in the Diagnosis of Asthma**


*Chest* 1995;108;1240-1245

DOI 10.1378/chest.108.5.1240

This information is current as of August 18, 2008

<table>
<thead>
<tr>
<th>Updated Information &amp; Services</th>
<th>Updated information and services, including high-resolution figures, can be found at: <a href="http://chestjournal.org">http://chestjournal.org</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>Citations</td>
<td>This article has been cited by 8 HighWire-hosted articles: <a href="http://chestjournal.org">http://chestjournal.org</a></td>
</tr>
<tr>
<td>Permissions &amp; Licensing</td>
<td>Information about reproducing this article in parts (figures, tables) or in its entirety can be found online at: <a href="http://chestjournal.org/misc/reprints.shtml">http://chestjournal.org/misc/reprints.shtml</a></td>
</tr>
<tr>
<td>Reprints</td>
<td>Information about ordering reprints can be found online: <a href="http://chestjournal.org/misc/reprints.shtml">http://chestjournal.org/misc/reprints.shtml</a></td>
</tr>
<tr>
<td>Email alerting service</td>
<td>Receive free email alerts when new articles cite this article sign up in the box at the top right corner of the online article.</td>
</tr>
<tr>
<td>Images in PowerPoint format</td>
<td>Figures that appear in CHEST articles can be downloaded for teaching purposes in PowerPoint slide format. See any online article figure for directions.</td>
</tr>
</tbody>
</table>