Closing Volume as a Simple, Sensitive Test for the Detection of Peripheral Airway Disease

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The diagnosis of early obstructive airway disease has long been a source of frustration to physicians. Conventional tests of pulmonary function such as the measurement of lung volumes, flow rates, airway resistance and diffusing capacity have not proved sensitive enough to detect small airway involvement. The measurement of "closing volume" (CV) first described by Dollfuss in 1967 seems to be particularly well suited to detect early changes in the lung whether these changes are due to intrinsic small airway disease or loss in lung elastic recoil.

Anthonisen and colleagues first described, in 1969, the use of a modification of Fowler's single breath nitrogen test to measure closing volume. We have also used the single breath technique to derive residual volume (RV). In order to do this, total lung capacity (TLC) is estimated by application of the conventional alveolar dilution equation. We obtain mean alveolar nitrogen concentration after dilution with oxygen by planimetric determination of mean expired nitrogen concentration and correction for dead space admixture. RV is then derived by subtraction of the largest recorded vital capacity (VC) from TLC. Thus, from a single breath, the following subdivisions of lung volume were obtained: VC, RV, TLC, CV, and the ratios CV/VC percent and CV/TLC percent were derived.

Using this technique, we have tested 284 asymptomatic nonsmokers (132 men, 152 women). Using data from these subjects, regression equations were established for the normal predicted values of CV/VC percent and CV/TLC percent both expressed as a function of age. These confirmed the findings of others that closing volume increases linearly with age.

Data obtained from 200 cigarette smokers (100 men, 100 women—all voluntary screenees at an emphysema screening center) were then compared with these normal standards. Of the 100 men smokers, 84 were symptomatic; 56 had a CV/TLC percent ratio greater than 2 SEE above the mean value; 44 had a CV/VC percent ratio greater than 2 SEE above the mean value and 12 had an abnormally low FEV₁.₀. These results are shown in Figure 1.

These results suggest very strongly that the measurement of closing volume is a considerably more sensitive test of early lung damage in smokers than is the FEV₁.₀. In fact, using the data reported above, and considering only those smokers with a normal FEV₁.₀, it is seen that 51 percent of men smokers and 44 percent of women smokers with a normal FEV₁.₀ have an abnormally high CV/TLC percent ratio and 41 percent of men smokers and 33 percent of women smokers have an abnormally high CV/VC percent ratio. These results are shown in Figure 2.

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**FIGURE 1.** Comparison of frequency of abnormal results from tests of lung function (symptoms, CV/TLC percent, CV/VC percent and FEV₁.₀) in 100 men and 100 women smokers.

**FIGURE 2.** Incidence of abnormally high CV/TLC percent and CV/VC percent in 175 smokers with normal FEV₁.₀.
Our interpretation of these results is that in cigarette smokers, airway closure tends to occur at higher lung volumes than would be predicted strictly by age. Whether this premature closure is due to intrinsic small airway disease, to loss of elastic recoil as suggested by Anthonisen and co-workers\(^2\) and Mansell and Bryan\(^6\) or to dynamic compression of small airways as proposed by Hyatt and Okeson\(^7\) or whether indeed actual closure of airways occurs, is at present not known. Furthermore, the extent to which these changes are reversible on cessation of smoking is at present speculative.

The clinical importance of the test of closing volume may be that it can detect early lung damage, possibly at a stage when it is still totally reversible. Also, if the closing volume really does reflect changes in the small airways, it holds considerable promise as a yardstick by which to measure the effects of therapy in patients with airways obstruction.

### References
7. Hyatt RE, Okeson GC: Expiratory flow limitation, the cause of so-called “airway closure” or “closing volume.” Physiologist: 14, 166, 1971

### Discussion

**Dr. T. Clark:** When you use the term symptomatic, do you mean production of sputum?

**Dr. Buist:** Symptomatic to us meant admitting to one or more of the symptoms of chronic sputum production, shortness of breath or chronic cough. The patient fills in his own questionnaire.

**Dr. Clark:** Does this test provide any more information than residual volume?

**Dr. Buist:** We are probably underestimating residual volume by our technique in people with severe maldistribution of alveolar ventilation. We think that closing volume is more valuable than residual volume. It certainly is simpler to perform.

**Dr. Permuth:** I want to comment on Dr. Clark’s question. Residual volume may be confusing in normals. An increased residual volume can occur in some “normals” without closure of airways. Therefore, closure should be more sensitive than increased RV.

**Dr. Macklem:** Theoretically, closing volume should be more sensitive.

**Dr. Lourenco:** Did you find any correlation between years of smoking and closing volume?

**Dr. Buist:** We have not correlated pack years with closing volume yet, although we do have those data.

**Dr. Godfrey:** Did you test any younger groups? I understand in children the closing volume is high.

**Dr. Buist:** We tested anyone 18 years and over. Young children do have large closing volumes. The closing volume of an eight-year-old, for example, is on the mean the same as that of a person aged 40.

**Dr. Filley:** How important do you think it is to maintain absolutely steady flow rates during expiration?

**Dr. Buist:** In our experience, it is fundamental. It doesn’t matter whether the patient uses a flow rate of 0.2 or 0.7L/sec, but once flow is started, it must remain constant. I think it is both a slow and a steady flow which is important.

**Unidentified Physician:** Have you made any measurements in closing volumes in asthmatics?

**Dr. Buist:** Closing volumes in the asthmatics we have tested are high and they decrease after inhaling a nebulized bronchodilator.

**Dr. Macklem:** Esophageal balloon measurements are needed to simultaneously measure elastic recoil at closing volume in order to correlate these.

**Dr. Clark:** Regarding closing volume in asthmatics, there are many difficulties in interpretation of these measurements. We got a variety of patterns in asthmatics and have essentially stopped using it on these subjects.