The Half-Second Expiratory Capacity Test: 
A Convenient Means of Evaluating the Nature 
and Extent of Pulmonary Ventilatory Insufficiency

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Pulmonary ventilatory insufficiency is a manifestation of many clinical disorders both pulmonary and non-pulmonary by primary nature. Regardless of the origin of ventilatory dysfunction, it may be classified as one of three types: 1) restrictive, that is with a decrease of pulmonary stroke volume; 2) obstructive, that is impaired pulmonary air flow; or 3) combined, that is both obstructive and restrictive ventilatory insufficiency.

An appreciation of the nature and extent of ventilatory insufficiency in any given clinical situation is important not only for the purpose of the elucidation of altered basic physiological mechanisms, but also for the value that such knowledge imparts toward the proper selection and evaluation of treatment. Thus the development of a precise and yet convenient method for evaluating ventilatory defects is indicated. The purpose of this report is to illustrate the use of such a method which was described elsewhere by us.1, 2, 3

To properly describe ventilatory insufficiency a test must evaluate both pulmonary stroke volume and the velocity of air flow. Matheson and associates4 suggested the capacity ratio \[
\frac{\text{MBC-L/min}}{\text{VC-L}}
\]
while Gaensler5 introduced the air velocity index \[
\frac{\text{MBC\% Pred.}}{\text{VC\% Pred.}}
\]
We have not found either of these tests satisfactory as a means of differentiating the types of ventilatory insufficiency.2, 3 The principal shortcoming appears to arise from the variability intrinsic in the MBC. More recently Gaensler6 has suggested measurement of the first one second portion of the vital capacity as an estimate of the MBC and the ratio of the one second expiratory capacity (1.0 sec. EC) to the total vital capacity (TVC) as a means of identifying obstructive ventilatory defects. He found the 1.0 second capacity to average 83 per cent of the vital capacity in 35 normal subjects. Kennedy7 has indicated that the first 0.75 second portion of the TVC represents that segment of the expiratory flow curve utilized in performing the MBC, and further that the 0.75 second volume could be used for the indirect determination of a function which is comparable to the MBC but which Kennedy identified as the \(\frac{1}{2}\) maximum flow rate. Kennedy suggested that the first 0.75 second rapid expiratory volume is delivered essentially at a constant maximum rate of flow. After 0.75 seconds he

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found that flow abruptly decreases resulting in a break in the volume curve. These conclusions were criticized by Bernstein who found the rapid expiratory curve was a smooth curve without a straight portion or a critical point of inflexion. He also presented evidence to indicate that the characteristics of the rapid expiratory flow curve described by Kennedy were artefactual and could be attributed to impaired frequency response characteristics of the recording apparatus used by Kennedy.

In order to investigate methods of conveniently obtaining information concerning the nature and extent of ventilatory insufficiency, vital capacity measurements were made with a Gaensler-Collins Timed Vitalometer modified by us so that it was possible to measure accurately the first 0.5, 0.75 and 1.0 second segment of the rapid expiratory volume. In the light of the work of Bernstein it became necessary to evaluate the characteristics of the rapid expiratory flow curve obtained by this method. Using a high speed low torque potentiometric recorder described previously smooth rapid expiratory flow curves of the type described by Bernstein were obtained. The 0.5 second volumes were virtually identical as obtained by both of the above methods. This method was further subjected to a comparison with the integral volume curve obtained from a pneumotachograph flow tracing, and again smooth curves virtually identical with the recorded curves were obtained. Figure 1 is an example of a rapid expiratory curve obtained by integration of a pneumotachographic tracing. D'Siland and Kazantisa in studies reported subsequent to the completion of this work found that the actual rapid expiratory flow curve was very similar to an exponential curve but deviates from an ideal curve at a point in time very close to 0.5 second (0.47 ± 0.09 second). It was found by us also, in previous studies that the 0.5 second expiratory capacity (0.5 sec. EC) is the most satisfactory estimate of the maximum velocity of expiratory air flow. Analysis of the first portion of a characteristic normal rapid expiratory flow curve (Figure 1) reveals that the first 0.5 second portion of the vital capacity virtually represents the segment of maximum air flow. (A line OA with its origin at zero time and tangent to the rapid expiratory flow curve would represent an average of the maximum flow rate for the period of time utilized for expiration). Thus in a
single test both 0.5 sec. EC, a measure of the rapidity with which an individual can ventilate his lungs, (referred to here as velocity of air flow), and the TVC, a measure of the maximum pulmonary stroke volume are obtained.

Since the MBC in individuals with normal pulmonary air flow is an estimate of the $\frac{1}{2}$ maximum flow rate, it might be expected that an MBC in turn might be estimated by expressing the rapid portion of the expiratory curve as liters per minute. Assuming expiration and inspiration to be approximately equal in time during rapid breathing, and estimated MBC would be obtained as shown by the formulation in Figure 1, where MBC... = 0.5 sec. EC x 60. In previous studies the 0.5 sec. EC x 60, in normal subjects, was shown to correlate better with the actual measured MBC than do MBC... values derived from other timed expiratory capacities. The relationships between diagrammatic representations of various characteristic rapid expiratory flow curves and the 0.5, 0.75 and 1.0 second intervals utilized in these tests are shown in Figure 2 with the maximum breathing tidal volumes from a normal subject and two patients; one with an obstructive ventilatory defect and another with a restrictive ventilatory defect. Particularly apparent is the fact that the patient with obstructive breathing cannot represent his average maximum velocity of air flow with
an MBC effort, since in order to maintain a satisfactory degree of alveolar ventilation, he must utilize a relatively large tidal volume and a slow rate over a portion of his expiratory curve where air flow is slow. This figure further serves to illustrate certain variables that would affect the value of the actual MBC. It is known that the results of the MBC test are dependent to a large extent on neuromuscular coordination, cooperation, muscular strength and durability, but it now becomes apparent that the tidal volume, the breathing rate, and the segment of the expiratory flow curve utilized to perform the test are equally as important determinants. These are all factors which are to a large extent under voluntary control. This point receives additional emphasis from the values shown in Table I. These data show that in individuals with normal respiratory function, abnormal MBC’s may be obtained owing to non-pulmonary factors whereas the 0.5 sec. EC x 60 provides a more reliable estimate. Thus it can be

**FIGURE 2:** The relationships between three types of expiratory flow curves with respect to the 0.5, 0.75, and 1.0 second time interval and the respective maximum breathing tidal volumes.
shown that the MBC is to a large extent a performance test and that maximum ventilatory capacity could be more precisely determined from the rapid segment of the rapid expiratory volume curve (i.e., the 0.5 sec. EC x 60).

In order to obtain a method whereby one can characterize the velocity of air flow for purposes of comparing different individuals, and thus have a test for defining the nature of altered lung function, we related the 0.5 sec. EC to the TVC so as to obtain a ratio, \( \frac{0.5 \text{ sec. EC} \times 100}{\text{TVC}} \). The validity of this relationship was tested previously\(^2\) where it was also shown that this ratio was the most convenient for separating various ventilatory defects. There is no age or sex regression of the \( \frac{0.5 \text{ sec. EC} \times 100}{\text{TVC}} \) ratio whereas there is with the other timed expiratory capacity ratios, as well as the air velocity index and the capacity ratio. Moreover less overlapping of the results between individuals with apparent normal and abnormal states of air flow was noted with the 0.5 sec. ratio as compared to other tests.

We have shown that the normal value for the ratio \( \frac{0.5 \text{ sec. EC} \times 100}{\text{TVC}} \) should be more than 60 per cent and the TVC should normally be more than 80 per cent of the predicted normal.\(^2\) By the use of these functions and their normal limit values as determinants in a quadrant system, illustrated in Figures 3, 4, 5, and detailed elsewhere,\(^3\) a simple method is obtained for the separation of ventilatory defects into three categories: restrictive, obstructive, and combined obstructive-restrictive. In each of Figures 3, 4, and 5 are presented several examples of cases studied by this

**THE QUADRATIC SYSTEM FOR DEFINING THE NATURE OF VENTILATORY INSUFFICIENCY**

![Graph](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21280/)

**FIGURE 3:** The quadrant system utilized for the evaluation of serial studies on patients with various ventilatory disorders. See text for detailed description.
method to demonstrate the nature of the changes in ventilatory function during the course of the disease or under the impact of therapy. Each capital letter represents the result of a test. Where numerical values are shown, they are the 0.6 sec. EC x 60 and the MBC.

In Figure 3, ABCD represents data obtained from a 16 year old white male with poliomyelitis who developed progressive diaphragmatic and intercostal muscular paresis which resulted in a restrictive ventilatory disorder as shown A to C. Even though the TVC decreased, the ratio showed a tendency to increase indicating the loss of volume consisted predominantly of slow moving air. This provides a very sensitive and important test for poliomyelitis patients as is apparent at C-D which illustrates the development of an obstructive component due to pooling of secretions and relaxation of the intrinsic muscles of the larynx. Tracheotomy was definitely indicated at this point.

Case E-F is an interesting and unusual example of poliomyelitis developing in a 29 year old white male asthmatic who had no recognizable respiratory symptoms at E. The obstructive defect could be promptly relieved by bronchodilator nebulization which was continued, but the patient developed some respiratory muscle weakness and a superimposed restrictive ventilatory disorder became apparent.

An example of precisely the opposite effect is case G-H which represents data from a patient with bronchitis and emphysema who when first studied had a restrictive and obstructive or combined type ventilatory disorder. After antibiotics and nebulization treatments with a bronchodilator drug and a surface active wetting agent which resulted in the

![THE QUADRATIC SYSTEM FOR DEFINING THE NATURE OF VENTILATORY INSUFFICIENCY](image)

**FIGURE 4:** The quadrant system utilized for the evaluation of serial studies on patients with various ventilatory disorders. See text for detailed description.
evacuation of much mucopurulent sputum with mucus plugs, the TVC increased but the \( \frac{0.5 \text{ sec. } EC \times 100}{\text{TVC}} \) ratio decreased indicating that the volume added was predominantly slow moving air, probably from emphysematous lung.

In Figure 4, A-B represents data from a young patient with recent congestive failure before (A) and after (B) compensation. At A, even though he had a predominantly restrictive ventilatory defect, the "obstructive" component became apparent by the change after compensation at B, since an increase in the velocity of air flow as well as the maximum pulmonary stroke volume resulted. Patients with early congestive failure without bronchopulmonary disease usually reveal predominantly a restrictive defect, whereas patients with chronic congestive failure or congestive failure and bronchopulmonary disease exhibit a combined disorder.

Patient C-D in Figure 4 is an example of values obtained from a young asthmatic patient before and after a treatment with nebulized bronchodilator. The change has been predominantly an increase in the velocity of air flow as indicated by the rising ratio.

The data shown at E-H in Figure 4 represent the results of an interesting and unusual situation observed in a young woman with severe asthmatic bronchitis and emphysema. Point E which was obtained soon after admission indicates that the ventilatory defect was restrictive in nature even though the patient is known to have anatomically obstructive disease. This apparent paradox is interpreted to mean that a large segment of the slow-moving air has been lost, most likely as a result of multiple bronchial

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**THE QUADRATIC SYSTEM FOR DEFINING THE NATURE OF VENTILATORY INSUFFICIENCY**

![Graph](image)

**FIGURE 5:** The quadrant system utilized for the evaluation of serial studies on patients with various ventilatory disorders. See text for detailed description.
plugs associated with the patient's acute infection. After treatment with bronchodilator, surface active wetting agent, and Pancreatic Dornase R* nebulization, the vital capacity increased as shown at Point F, but the ratio \[
\frac{TVC}{0.5 \text{ sec. } EC \times 100}
\] decreased indicating that the added volume was predominantly slow moving air. At point G there was again slightly greater improvement of the total vital capacity with a further decrease of the 0.5 sec. ratio, perhaps in part due to the addition of more slow moving air to the total displaceable lung volume, and perhaps in part a result of some superimposed incomplete bronchial obstruction. The patient's function studies at the time of discharge were shown at Point H indicating a further increase in the TVC, but now a striking increase in the velocity of air flow suggesting further that the marked decrease at Point G was due to either bronchospasm or other type of incomplete bronchial obstruction.

Figure 5 represents the results obtained from two patients who were studied many times and were found to move back and forth across the quadrant graph as indicated by the bi-directional arrows. In each instance here, a point usually represents the average of several studies. The first patient, A-D, with severe recurrent asthmatic bronchitis has been noted to follow the pathway A to B to C to D during the course of the development of an exacerbation and to virtually reverse this pathway from D to A during recovery. During the development of an exacerbation with the accumulation of obstructing secretions and bronchospasm, he developed a combined; obstructive-restrictive; ventilatory defect (D). Upon recovery, increases of both the TVC as well as the net velocity air flow, as indicated by a rising ratio from D to A, were noted. This patient was ultimately left with an obstructive ventilatory defect (A) either due to a permanent degree of bronchiole obstruction or pulmonary emphysema.

Patient E-G is a young man with mediastinal Hodgkin's disease who, when first seen at Point E, had large obstructing and restricting mediastinal nodes. Following treatment, he improved progressively with the resolution of the mediastinal nodes through Point F to Point G where he was found to have essentially normal pulmonary ventilatory function. With exacerbations of his condition or the development of intercurrent infection, change in his ventilatory function was characterized principally by a decrease in pulmonary stroke volume, but ultimately he returned to a point in the vicinity of E with a combined obstructive and restrictive ventilatory defect.

Thus these serially studied cases illustrate the valuable and yet conveniently obtained information concerning the nature of the ventilatory defects that becomes available by the use of this method of functional analysis.

*Pancretic Dornase R, desoxyribonuclease extracted from beef pancreas, is a very effective mucolytic enzyme which appears to be free of the undesirable features of other enzymes used for this purpose. This drug was kindly supplied by Sharp & Dohme, Division of Merck & Co., Inc., Westpoint, Pa.
ADDENDUM

Additional data that has become available since the submission of this paper makes it necessary in the interests of uniformity to change the quadrant plot to the extent that the lower limit of the vital capacity should be placed at 65 per cent of predicted instead of 80 per cent as shown. We also feel now that the word "total" which precedes the term "vital capacity" in this manuscript is superfluous.

SUMMARY

A simple method employing single maximum expiratory efforts is presented as a means of defining the nature and extent of ventilatory insufficiency. The method involves the measurement of the 0.5 sec. expiratory capacity and the total vital capacity. Then by relating the 0.5 sec. expiratory capacity to the total vital capacity as a simple ratio, and expression of the maximum velocity of air flow during expiration, is obtained. The total vital capacity is a measure of maximum pulmonary stroke volume. Thus in a single test expressions of the velocity of pulmonary air flow as well as pulmonary stroke volume are found. If these functions are plotted against each other in a quadrant graphic system which is based on normal values for these two functions, a convenient and precise clinical method for defining the physiological nature of ventilatory insufficiency is obtained. This test is applicable even to the seriously debilitated patient who cannot perform the maximum breathing capacity test. Serial studies by this method provide a convenient and informative method of studying the nature of the change in ventilatory function during the course of the disease or resulting from therapy.

RESUMEN

Se presenta un método sencillo que emplea esfuerzos máximos únicos para determinar la naturaleza y grado de la insuficiencia ventilatoria. Los métodos comprenden la medida de la capacidad expiratoria en 0.5 segundos y además la capacidad vital total. Entonces estableciendo relación entre ambas medidas como dato único, se obtiene una expresión de la velocidad máxima de la corriente aérea expiratoria. La capacidad vital total es una medida del volumen pulmonar máximo en un solo esfuerzo. Así en una simple prueba se encuentran las expresiones de la velocidad de la corriente de aire expirado y la del volumen pulmonar de un solo esfuerzo. Si estas funciones son colocadas en contraposición en un sistema cuadrante gráfico que se base en los valores normales do estas dos funciones se logran un método clínico preciso para definir la naturaleza fisiológico de la insuficiencia ventilatoria. Esta prueba es aplicable aún a los enfermos muy seriamente debilitados que no pueden hacer la prueba de la capacidad respiratoria máxima. Los estudios en serie de este método proporcionan un método informativo en el curso de la enfermedad o para valuar resultados terapéuticos.

RESUME

L'auteur présente une méthode simple utilisant les seuls efforts d'expiration maximum pour déterminer la nature et le degré de l'insuffisance ventilatoire. Cette méthode comporte la mesure du volume expiratoire maximum en une demi-seconde, et celle de la capacité vitale. En faisant le rapport du volume expiratoire maximum en une demi-seconde et de la
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REFERENCES