Nomograms for Use in Determining Pulmonary Compliance and Non-Elastic Resistance*  

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The angle \(0 (0 \leq \theta \leq 180)\) measured counterclockwise from the positive directed portion of the X-axis to a line, is called the inclination of the line. The tangent of the angle, \(\tan \theta\), generally is designated by the letter \(m\), and is called the slope of the line. It is evident from Fig. 1 that the slope of \(P_1 (x_1, y_1)\) and \(P_2 (x_2, y_2)\) is given by

\[
\text{Slope of } P_1, P_2 = \tan \theta = \frac{y_2 - y_1}{x_2 - x_1}
\]

In other words, given any two points in the plane, the ratio of \(y_2 - y_1 / x_2 - x_1\) gives the slope of the line \((m)\) or the tangent \(\theta\) formed by the line with the x-axis. 

In the study of the mechanics of breathing, pulmonary compliance is defined as the change in lung volume \((\Delta V)\) produced by unit change in transpulmonary pressure \((\Delta P)\) and is expressed as the ratio of \(\Delta V / \Delta P\). Measurements are made at the very beginning and at the very end of inspiration, actually the points of zero air flow. The calculation of pulmonary compliance usually uses volume expressed in liters and transpulmonary pressure expressed in cm. H\(_2\)O. Non-elastic resistance is defined as pressure differential \((\Delta P)\) required for a unit change of respiratory flow \((V)\) and is expressed as the ratio of \(\Delta V / \Delta P\). Mean non-elastic resistance is calculated as the ratio of transpulmonary pressure difference in cm. H\(_2\)O over respiratory flow difference in liters per second measured between mid-inspiration and mid-expiration. For each case only two points on the curve are considered. For pulmonary compliance volume change \((\Delta V)\) is plotted on Y-axis and pressure change \((\Delta P)\) on X-axis. For non-elastic resistance pressure change \((\Delta P)\) is usually plotted on Y-axis and flow change \((\Delta V)\) on X-axis. 

Values for pulmonary compliance obtained from the ratio, \(\Delta V / \Delta P\), were plotted as a nomogram (Fig. 2). The nomogram is a plot of tidal volume against transpulmonary pressure. For example, if the measured tidal volume is 0.5 liters and the observed transpulmonary pressure is 2.5 cm. H\(_2\)O the pulmonary compliance is 0.200 L/cm. H\(_2\)O as determined on the nomogram (Fig. 2). The nomogram is a set of linear isopleths having individual slopes. Each isopleth has its numerical value of slope, and represents the compliance value. The nomogram for the non-elastic resistance was similarly constructed. Various values of the ratio of transpulmonary pressure difference at various respiratory

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flow differences were plotted as isopleths (Fig. 3). The values of transpulmonary pressure are plotted on the ordinate and values of respiratory flow are plotted on the abscissa. For example, if transpulmonary pressure is 2.0 cm. H$_2$O and respiratory flow is 1 liter per second, non-elastic resistance will be 2.0 cm. H$_2$O/L/sec. If, on the nomogram, two perpendicular lines to the axes are drawn through each of the points, these will intersect a point which represents numerical value of non-elastic resistance. Each of the isopleths is the hypotenuse of a triangle, the X-axis is the adjacent side of the triangle. Since the isopleths form an angle — with the X-axis, the angle of the axis of a pressure-volume loop can be applied directly to the nomogram to obtain the pulmonary compliance. The same is true in the case of non-elastic resistance, if the transpulmonary pressure and respiratory flow or the flow-resistance line are known.

Ordinarily the methods used for measuring pulmonary compliance and non-elastic resistance are: (1) recording simultaneously tidal volume, respiratory flow and transpulmonary pressure; (2) recording a pressure-volume loop and flow-resistance line. Recordings of tidal volume, respiratory flow and transpulmonary pressure require analysis for their numerical magnitudes. The data are then applied on the nomogram. If an X-Y recorder is used, calibration scales of the X-Y axes, when kept constant, can be used as perpendicular axes of the nomograms. The isopleths when placed on the transparent overlays can be directly applied to the recording for pulmonary compliance and non-elastic resistance measurements.

![Nomogram for calculating and measuring pulmonary compliance.](image-url)
The nomograms described in this paper are time-saving for calculating pulmonary compliance and non-elastic resistance. Nomograms of this type have a wider application in that they can be used for any problems where the relation between pressure and volume or flow are involved. Appropriate change of scales is the only requirement of these uses.

**Summary**

1. Nomograms for determining pulmonary compliance and non-elastic resistance of respiratory system have been presented.
2. The nomograms were constructed by using paired parameters and using the slopes of their linear relations or the angles of inclination of their lines of the graphs.
3. The nomograms described make the calculations in the studies of pulmonary compliance and non-elastic resistance simple.

**Resumen**

1) El autor presenta nomogramas determinantes del grado de movilidad funcional del pulmón y de resistencia inelástica del sistema respiratorio.
2) Estos nomogramas han sido trazados empleando parámetros pareados y siguiendo el gradiente de sus relaciones lineales, o el ángulo de inclinación de sus líneas en las gráficas.
3) Los nomogramas descritos simplifican los cálculos en el estudio de la movilidad funcional y resistencia inelástica respiratoria.

**Résumé**

1) Des nomogrammes pour déterminer la compliance et la résistance non élastique des poumons ont été proposés par les auteurs.
2) Les nomogrammes ont été établis en utilisant des paramètres couplés et la courbe de leur relation linéaire ou les angles d'inclinaison de leurs lignes sur les graphiques.
3) Les nomogrammes ainsi décrits simplifient les calculs lors de l'étude de la compliance et de la résistance non élastique des poumons.

ZUSAMMENFASSUNG

1. Es werden Nomogramme zur Bestimmung der pulmonalen Komplianz und des nichtelastischen Widerstandes des Respirationsystems vorgelegt.

2. Die Nomogramme wurden ermittelt durch Verwendung gepaarter Parameter und der Kurven ihrer linearen Beziehungen zu den Winkeln der Inklination ihrer Fallinien in den graphischen Darstellungen.

CARCIDEAL FUNCTION

The Valsalva maneuver ratio (the ratio of the maximal tachycardia to the maximal bradycardia induced by a standard Valsalva maneuver) was determined in 200 normal subjects and 220 patients with heart disease and related disorders. Ninety-six percent of the normal subjects had Valsalva maneuver ratios of 1.50 or higher, and this value was defined as the lower limit of normal. The ratio tended to decrease with increasing severity of dyspnea in patients with aortic and mitral valve disease, ischemic heart disease and cardiomyopathies.

The ratio was inversely related to the left ventricular end-diastolic pressure (p 0.01) in patients with aortic valve disease and mitral insufficiency. There was a tendency for patients with radiologic evidence of pulmonary congestion to have abnormally low Valsalva maneuver ratios, and for patients without pulmonary congestion to have normal values. Abnormal ratios were recorded in patients with right ventricular failure secondary to thromboembolic pulmonary hypertension and chronic pulmonary disease.


ESOPHAGEAL MOTILITY

Esophageal motility was studied radiologically in three groups of patients with certain connective-tissue disorders, including 29 with scleroderma, 27 with proved systemic lupus erythematosus, and 27 with long-standing rheumatoid arthritis.

Complete lack of normal esophageal peristalsis was found in 20 of the 29 cases of progressive systemic sclerosis (scleroderma); in 4 patients systemic lupus erythematosus esophageal peristalsis was slightly decreased. Esophageal motility was normal in all 27 cases of rheumatoid arthritis.

Only 45 per cent of the scleroderma patients with esophageal aperistalsis had ever experienced dysphagia, and in no case of systemic lupus erythematosus with lesser degrees of esophageal abnormality was there dysphagia.

The apparent close relationship of esophageal aperistalsis and Raynaud's phenomenon, especially in those patients exhibiting resorption of the ungual turrits, is emphasized. The possibility that the two abnormalities have a common pathophysiologic basis is briefly discussed.

Esophageal aperistalsis or stony is considered an important manifestation of progressive systemic sclerosis and may even be useful in the diagnosis of the occasional case in which cutaneous manifestations of scleroderma do not develop. The possibility is suggested that in those patients with systemic lupus erythematosus manifesting less striking changes in esophageal motility, the more characteristic findings of progressive systemic sclerosis may later develop.