NEW INSIGHTS INTO PHYSIOLOGY AND PATHOPHYSIOLOGY BY RESISTANCE-VOLUME RECORDINGS

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This work deals with the assessment of airway resistance in the course of a single breath. The study showed the presence of an early increase in the resistance at the beginning of expiration, which intensifies during expiration and ends up with a sharp decline during expiring the last remaining volume of ca 350 ml. The dynamic changes in airway resistance over a breath depend on the disharmonic interplay between diaphragm function and bronchial wall tonus. Thus, airway resistance is not constant during breathing, as could be misleadingly judged from the total resistance averaged over a breath. The study underscores the importance of recording the resistance-volume curves alongside the standard flow-volume curves to be able to discern the peculiarities of airway resistance changes during a single breath. Knowing changes in the instantaneous airway resistance characteristic for a given lung pathology could appreciably improve the diagnostic and therapeutic powers.

Key words: airway resistance, breathing, flow volume curve, resistance-volume curve, spirometry

Spirometry is still the most frequent method of lung function investigations. Although the method is simple, there are enormous problems concerning the adequate interpretation of results. The interindividual predicted values show for individual results unacceptably large SD (1). Besides, the dependence on the investigator's experience and on the cooperation of the investigated subject is the source of erroneous results (2, 3). Therefore, we really should think of better methods that would enable us to set early and correct diagnosis, the best kind of treatment and would be cost effective.

The method of body plethysmograph provides us with two types of important results: the airway resistance and the intrathoracic gas volume. These to indices are independent of subject's cooperation and give direct
information on the crucial changes in the lungs/airways in different pathological conditions. The airway resistance (Raw) is calculated from a straight line over the alveolar pressure and flow (4). The straight line makes the impression that the Raw is a stable value over the whole breath, but this is not the case in healthy persons. Substantial changes in Raw during the time course of a single breath become even more conspicuous in pulmonary patients.

Fig. 1. Resistance (Raw)-volume curves (right panel), the corresponding Raw-alveolar pressure curves (bottom left), and flow-volume curves (upper left) of different breaths in a healthy person.

Fig. 2. Mean values of Raw-volume curves for 6 healthy subjects depicting Raw at the beginning of expiration (Raw Ebeg), the maximum value during expiration (Raw Emax), Raw at the beginning of inspiration (Raw Ibeg), and the minimum Raw during inspiration (Raw Imin). Total resistance (Rt) is shown as the mean value stretching over the different parts of a breath.
Perhaps even more important information can be obtained from a calculation of Raw over the volume of a single breath. To this end, we developed a computer program for calculating and tracing Raw-volume curves. The investigations were performed with a masterlab of Jaeger (Würzburg) by using software developed by T. Schäfer (Bochum) and E. Smith (Würzburg). Examples of the use of the program in terms of interrelating Raw, flow, and volume are shown in Fig. 1. All human investigations whose results are presented below were approved by an institutional Ethics Committee.

It can be seen that the flow-volume curves are similar, although the volumes breathed in are different. The Raw-volume curves are similar at the beginning of expiration for different breaths, but early in expiration Raw starts increasing unevenly to reach its peak and then at the remaining volume of ca 350 ml to be expired a sharp decrease in Raw takes place. Clearly, Raw is not constant over a breath.

Changes in Raw over a breath are schematically presented in Fig. 2. Despite the uniform value of total resistance (Rt), Raw values are different over the volumes of an individual breath. Early in expiration Raw increases to a maximum and then it starts declining in the last part of expiration, close to the beginning of inspiration. Further in inspiration, Raw decreases by a small amount. At the beginning of expiration, Raw already lies slightly higher than its level at the beginning of inspiration and then further increases in early expiration, as outline above. Thus, there is a clear dynamics of Raw changes over the volume. The Raw-volume change depends not only on the volume, but on the alveolar pressure and the tonus of bronchial walls at different volumes. The Raw at the beginning of expiration may be defined as the basic tonus of bronchial walls. A significant correlation exists between the beginning expiratory and the maximum expiratory Raw (Fig. 3). The higher the beginning Raw the stronger the Raw increase during

![Fig. 3. Correlation between Raw at the beginning of expiration (Raw Ebeg) and the maximum Raw of expiration (Raw Emax) in 14 healthy subjects.](image)
the progressing expiration. Raw always increases with the time course of expiration. This happens also when Rt is slightly or even more strongly increased during the latter part of expiration. Therefore, the Raw-volume curve shows a higher level of RawEmax than that for Rt.

At deep expiration, Raw shows the strongest increase just borderline with the moment of closure of airways (Fig 4). Because of that, it is recommended that the expiration during a vital capacity maneuver be performed as complete as possible. Concerning the mechanisms of Raw changes during a breath, it seems we detect during expiration at first the effect of diaphragm relaxation with a relatively sharp increase in Raw. Later on during expiration, Raw is determined by the relationship between the bronchial wall and the alveolar space pressures. With a decrease of the volume the pressure of the bronchial wall overcomes that in the alveolar space and Raw shows a further increase. The dynamics of changes of the Raw-volume curve are dependent on the continually changing state of the diaphragm muscle and bronchial wall tonus. Changes of the Raw-volume curve could provide us with a clue as to the underlying pathological conditions.

In conclusion, even in healthy persons the airway resistance shows dynamic variations during normal breathing. The tonus (relaxation) of the diaphragm and that of the bronchial wall change out of harmony. The increase of airway resistance during expiration at first depends on the diaphragm relaxation and later a further increase takes place when the pressure of the bronchial wall overcomes that in the alveolar space. At pathological conditions the different parts of the resistance generating system can be influenced in a different manner.
REFERENCES


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