CONTRACTION OF SMOOTH MUSCLE OF THE BRONCHIAL TREE AND ITS EFFECTS ON HYSTERESIS OF THE LUNGS

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Experiments on isolated rat lungs under quasi-stationary conditions showed that contraction of the smooth muscle of the bronchial tree leads to an increase in the v/p hysteresis loop of the lungs and to its inclination relative to the p axis. It was thus shown that changes in hysteresis of the lungs in response to smooth-muscle contraction in vivo are due not only to changes in resistance of the bronchial passages to the air flow, but also and primarily to changes in the mechanical properties of the bronchial tree.

Increasing attention is at present being paid in clinical practice to the work of the muscles responsible for ventilation of the lungs, which is calculated from the v/p hysteresis loop of the lungs. In bronchospastic states the work of ventilating the lungs is increased by 10-20 times [2]. The question is whether this takes place entirely through an increase in resistance of the air passages to the air flow or, and indeed primarily, to an increase in the resistance of the bronchial tree to stretching.

In an attempt to solve this problem experiments were carried out under quasi-stationary conditions ruling out any effect of the resistance of the air passages to the air flow on the v/p hysteresis loop of the lungs. The experiments were undertaken in connection with the existing view that contraction of the smooth muscles of the bronchial tree does not affect the v/p hysteresis loop of the lungs under quasi-stationary conditions [9, 10].

EXPERIMENTAL METHOD

Experiments were carried out on isolated lungs of rats of both sexes weighing 200-210 g. Under ether anesthesia, a glass cannula connected to a rubber tube was introduced into the rat's trachea. After decapitation, the tube was closed by a clamp and the lungs isolated; the rubber tube was connected to a three-way tube, one end of which led to a syringe (used to simulate inspiration and expiration), and the other end to a water manometer. The pressure in the lungs was measured every 20 sec after injection or withdrawal of 2 ml air by the syringe. Altogether in each experiment 8 ml air was injected and withdrawn. The v/p hysteresis loop of the lungs was plotted from the results obtained. Hysteresis of the lungs was compared for rats of the control series and rats with contracted smooth muscle of the bronchial tree. Contraction of the smooth muscle was produced by injecting acetylcholine (0.1 g/kg) under ether anesthesia into the jugular vein and giving a further injection of 0.005 g acetylcholine into the right ventricle (after thoracotomy when the heart was contracted).

EXPERIMENTAL RESULTS AND DISCUSSION

In each series of experiments the lungs of ten rats were studied. Comparison of the v/p hysteresis loops of the lungs for rats of the control series and rats with contracted musculature of their bronchial tree showed a sharp inclination of the loop relative to the pressure axis after contraction of the smooth muscle

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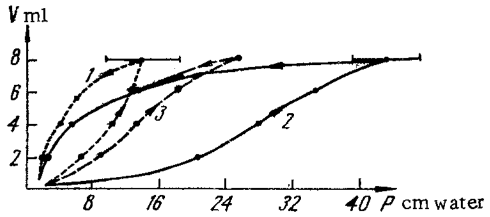

Fig. 1. Effect of contraction of bronchial musculature on v/p hysteresis loop of the lungs. Abscissa, air pressure (P) in lungs (in cm water); ordinate, volume (V) of air in lungs (in ml). Mean results for ten experiments in each series. 1) Experiments of control series; 2) first measurement after contraction of musculature of bronchial tree; 3) second measurement after increase in expansibility of smooth musculature of bronchial tree as a result of preceding stretching.

(Fig. 1). This difference was significant in connection with the difference between the ascending curves at all points measured (P > 95%). For the sake of clarity, the confidence interval (P > 95%) is shown in Fig. 1 for the top points only. The difference between the descending curves was not significant. Hence, the observed increase in area of the hysteresis loop (by almost three times) took place on account of a sharp decrease in expansibility of the lungs (the ascending curve).

It was interesting to examine the effect of preceding inflation of the lungs on their v/p hysteresis loop when measured subsequently.

On second measurement of the hysteresis loop, its area was found to be reduced and the loop itself was displaced relative to the control (Fig. 1). The difference from the control was no longer significant. This is understandable. At the first measurement the expansibility of the smooth musculature of the bronchial tree was sharply reduced by the "viscous aftereffect" in the smooth musculature after contraction of its fibers. On repetition of the measurements it was found that acetylcholine, which is rapidly decomposed under these conditions [1, 5], could no longer cause contraction of the smooth musculature of the bronchial tree, although some increase in its tone still took place.

The last series of experiments showed that on repeated measurement of the v/p hysteresis loop of the lungs it was reduced in area and the static expansibility of the lungs in vitro was increased as a result of stretching of the smooth musculature. This evidently accounts for the results of Neergard's experiments [6], which were performed in vitro.

Redford and Lefcoe [10] observed no effect of acetylcholine on hysteresis of the lungs in vitro. The reason for this could be either the repeated stretching or other factors which prevented them from obtaining an effect in a series of experiments to study the action of acetylcholine on the length/tension curve of the bronchi, although this effect is well known and is clearly defined [8]. Evidently Redford and Lefcoe were unable to obtain an adequate contraction of the bronchial musculature.

Contraction of the bronchial musculature leads to an increase in the area of the v/p hysteresis loop and its displacement relative to the P axis both for the bronchi [8] and for the lungs (the present experiments). Both for the bronchi [7] and for the lungs, repetition of the measurement in experiments conducted in vitro leads to an increase in expansibility of the bronchi (or lungs) and, correspondingly, to a decrease in area of the v/p hysteresis loop and to its displacement relative to the V axis.

Forces of surface tension of the alveoli (including surface-active agents) do not play an exclusive role in the mechanical properties of the lungs. According to some observations [4], filling the lungs with physiological saline changes the hysteresis by only 10%. On the other hand, the small respiratory passages in lungs filled with gas close at the same pressure as in the lungs filled with physiological saline [11]. A fair quantity of surface-active lipids can always be extracted from the lungs – the "organ of lipid metabolism" [3]. However, it may be supposed that it is not the forces of surface tension of the alveoli, but the musculature of the peripheral bronchi which plays the leading role in these changes in the mechanical properties of the lungs.

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