HEMODYNAMIC CHANGES AFTER EXCLUSION OF VARIOUS PORTIONS OF LUNG TISSUE

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Depending on the method of carrying out artificial blood circulation with self-oxygenation [1-3, 5, 6, 10], during a certain period of time one or another part of the lung serves as the "oxygenator." In a number of cases when this occurs the load on the right side of the heart increases significantly. Exclusion of an excessively large volume of lung tissue and its vascular bed leads, on the one hand, to right ventricular failure and,on the other hand, to a decrease in the cardiac debt [8, 9, 11, 14] and thereby the rate volume of perfusion.

The goal of the present work was to elucidate the limit of possible decrease in the vascular bed and pulmonary respiratory surface, as well as the nature of hemodynamic changes arising therefrom.

METHODS

The experiments were performed on 40 dogs of weight six to 25 kg. Under intubation anesthesia with relaxants (Lysthenon [= succinylcholine. Publ.]) a bilateral thoracotomy was made in the fifth intercostal space with the intersection of the sternum. The root of the corresponding lung (or part) was isolated and a tourniquet applied beneath it. After stabilization of all indices the initial data was recorded and slowly, over two to three minutes, the tourniquet was tightened and so maintained for 60 min, after which it was removed and observations were continued over the succeeding 60-120 minutes. For determination of the percentage of excluded tissue we used the schema of Rahn [13].

In series I (12 experiments) we excluded the left lung (41.6% of all pulmonary tissue), in series II (10 experiments)—the right lung (58.4%), in series III (11 experiments)—the right lung and the two upper portions of the left lung (74.8%) and in series IV—(7 experiments) the right lung and the lower portion of the left lung (84.6%). Arterial pressure was measured by a mercury manometer, right ventricular and pulmonary artery pressure by an electromanometer, venous pressure (superior vena cava) by a water manometer (height expressed in millimeters of a mercury column), coronary blood flow—by direct catheterization of the coronary sinus [7, 12], oxygen saturation of arterial and venous blood—by a cuvette oxyhemometer, EKG in three standard leads recorded on a polycardiograph (Galileo make). Measurements were made pre-operatively and at various operative stages. During the experiment no medicines were given. Fluid was always given after removal of the tourniquet only to replace blood loss. The results were treated statistically by various method.

RESULTS AND DISCUSSION

Series I. At the moment the left lung was excluded a significant decrease in mean arterial pressure was observed (to 22.2 ± 7.7 mm Hg, s.t.; $p < 0.05$), with a rapid return to the initial level at which it subsequently remained during the entire period of compression of the pulmonary root. After removal of the tourniquet the value of mean arterial pressure clearly fell. The mean pressure in the pulmonary artery 15 min after compression of the root was moderately elevated (to 2.4 ± 0.8 mm Hg s.t.; $P < 0.05$) and it subsequently became normal and fell slightly after the tourniquet was removed. Systolic pressure in the right ventrical rose maximally at five minutes after compression of the lung root (to 4.7 ± 1.6 mm Hg, s.t.; $P < 0.05$), and at 30 min returned to a normal level. After removal of the tourniquet the systolic pressure in the right ventricle fell (to 3.1 ± 0.09 mm Hg s.t.; $P < 0.05$). Venous

pressure throughout the experiment did not change significantly. Immediately after compression of the lung root the coronary blood flow increased and remained markedly elevated during the entire experiment with the highest peak at 30 min. The oxygen saturation of arterial and venous blood after exclusion of the left lung did not change. On the EKG in most instances no deviation from normal appeared. Sometimes changes were observed which were characteristic for right heart strain (increased P_{II} and P_{III}); sometimes disturbances typical of myocardial hypoxia (decreased ST_{II} and ST_{III} interval, tall T wave). These changes, as a rule, were extremely insignificant and disappeared by 30-45 min after root compression.

Series II. When the right lung a was occluded a more marked and persistent pressure increase was observed in the right ventricle and pulmonary artery (respectively, 4.6 ± 3 mm Hg.; $P < 0.05$ and 4 ± 1.3 mm Hg, $P < 0.05$) as compared to series I. The coronary blood flow in the first five minutes after compression of the lung root was lowered and then, as in the preceding series, it rose to the initial values. The dynamics of the remaining indices were similar to those obtained in series I.

Series III. As in series I and II, exclusion of 74.8% of the lung tissue did not produce significant decreases of mean arterial pressure. After compression of the lung roots the mean pressure in the pulmonary artery and the right ventricular systolic pressure rose sharply (to 14 ± 6.3 mm Hg; $P < 0.05$), and remained significantly increased throughout the period of compression. After removal of the tourniquet the right ventricular and pulmonary arterial pressure remained high and fell only slightly after 45 min. The venous pressure during the 45 min after root compression was validly increased (1.7 ± 0.4 mm Hg; $P < 0.05$) and subsequently fell (by 0.8 ± 0.3 mm Hg; $P < 0.05$).

Coronary blood flow increased more sharply than in series I or II. The EKG revealed changes characteristic for persistent myocardial hypoxia and right ventricular overload. These changes, as a rule, continued throughout the experiment. The arterial blood oxygen saturation during the period of pulmonary root compression was not essentially altered.

In half of the experiments at 30-45 min after removal of the tourniquet a sharp decrease in arterial blood oxygen saturation was noted (mean of 77% in comparison to 92% in the initial test). The venous blood oxygen saturation decreased during the entire period of compression and continued to fall after removal of the tourniquet. The arterio-venous difference at the end of the experiment exceeded the initial level by $2^1/2$ times (42% as compared with 17% in the initial test).

Series IV. Exclusion of 84.6% of the lung tissue was accompanied by a sharp decrease in the mean arterial pressure (by 22.7 ± 8.8 mm Hg, $P < 0.05$), which continued during the entire period of pulmonary root compression. The mean pulmonary artery pressure after pulmonary root compression rose (by 12 ± 3 mm Hg, $P < 0.05$), but less significantly than in experiments of series III. This increase in pulmonary artery pressure continued during the first 30 min of pulmonary root compression and then fell. After removal of the tourniquet the pulmonary artery pressure was lower than the normal level (by 5.8 ± 1.4 mm. Hg, $P < 0.05$). Similar changes were also noted in the right ventricular systolic pressure. In distinction from experiments of series III the venous pressure showed a tendency fo tall. In the pulmonary root compression period the coronary blood flow was decreased by two times. Changes in arterial and venous blood oxygen saturation were similar to changes in these parameters in series III. On the EKG, in addition to the changes described, expressed even more markedly, disturbances in intraventricular conduction were noted (splitting and widening of the QRS_{II} and QRS_{III} complexes). The lack of signs of right ventricular overload was also characteristic.

Thus, the results of our investigations show that exclusion of one of the lungs from respiration and from the circulation (40-60% of lung tissue) does not produce significant or persistent changes in hemodynamics or in the oxygen supply of the organism.

In contradistinction to this, the elimination of a larger volume of lung tissue from respiration and blood circulation is accompanied by clear signs of right heart overload and by an increase in the arterio-venous oxygen gradient. Taking into account the persistance of a normal arterial blood oxygen saturation and the sharp increase in arterio-venous gradient, it is to be hypothesized that exclusion of more than one lung leads to a clearcut fall in minute volume.

At the present time it is difficult to explain the observation made in these investigations and in earlier reports by other authors [4], that the arterial blood oxygen saturation falls after removal of the tourniquet from the pulmonary root.

Proceeding from our experimental results, we feel it most advisable when the lungs are used as "auto-oxygenator" to exclude not more than one lung, i.e. not more than 60% of the lung tissue, from the circulation.

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