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Research Article

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Steady State Measurement of Regional Ventilation to Perfusion Ratios in Normal Man *

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It has been known for some time that inequalities of the ratio of alveolar ventilation to perfusion ($\dot{V}_A/\dot{Q}$) exist in the normal human lung and that these inequalities frequently are magnified and distorted by disease. The quantitative assessment of these ratios has proved a difficult task, however, and until recently could be achieved only by a descriptive division of the lung into hypothetical "compartments," which might or might not have anatomic or geographic counterparts.

The advent of radioactive gases and the development of external counting methods (1, 2) made it possible to measure regional gas concentration and to tentatively map the regional $\dot{V}_A/\dot{Q}$ distribution in the normal lung (3, 4). Unfortunately, however, these experiments involved techniques that limited their applicability. It was necessary to measure regional ventilation and regional perfusion separately, and so their ratio could not be directly determined. All measurements were made during a breath-holding period, usually at relatively high lung volumes, and after an inspiration during which volume and flow rate were not rigidly controlled. It is known that regional ventilation and perfusion vary with lung volume in normal subjects in these circumstances (5, 6), and it is apparent that such single breath measurements would be even less reliable in patients with airway disease, in whom the distribution of inspired gas is dependent upon inspiratory flow rate (7).

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It seemed important, therefore, to develop a method for direct measurement of regional $\dot{V}_A/\dot{Q}$ during continuous infusion of a radioactive gas under normal steady state conditions. The results obtained in four normal subjects are presented, and the limitations of such a technique are discussed.

Methods

Theory. Under steady state conditions, regional $\dot{V}_A/\dot{Q}$ determines the concentration of any gas in a lung region, and if regional concentration is measured, $\dot{V}_A/\dot{Q}$ may be calculated. Because of varying lung geometry, regional concentrations of an isotope cannot be deduced from count rate alone; two separate steady state techniques have therefore been combined.

When a solution of ^{133}Xe is infused intravenously at a constant rate, it will evolve into the lung gas and, providing that neither ventilation nor perfusion changes, will attain a steady state. A description of this steady state for any lung region is as follows:

$$\dot{Q}\,(C\bar{v} - F_{AP}\alpha) = \dot{V}_A F_{AP}, \qquad [1]$$

where $\dot{Q}$ is regional blood flow; $\dot{V}_A$ is regional alveolar ventilation; $C\bar{v}$ is ^{133}Xe concentration in pulmonary arterial blood during infusion; α is the Bunsen coefficient of ^{133}Xe at 37° C [0.181 ml per ml blood at 760 mm Hg (8)]; and F_{AP} is fractional ^{133}Xe concentration in regional alveolar gas.

It is apparent that if $C\bar{v}$ (which is the same for all lung regions) is known and if F_{AP} can be measured, Equation 1 may be solved for regional $\dot{V}_A/\dot{Q}$. When ^{133}Xe is used, F_{AP} cannot be directly measured, but the regional count rate during infusion (U_p) can be recorded. A subsequent rebreathing procedure will permit calculation of F_{AP} from U_p.

When a normal subject rebreathes ^{133}Xe from a closed circuit with a volume of about 10 L, the regional and spirometer count rates will reach values that are apparently constant. Since this occurs long before peripheral tissues are saturated with the gas, a steady state of ^{133}Xe exchange across the lungs may be assumed to exist. This is described by the following relationship:

$$\dot{V}_I F_I = \dot{V}_A F_{Ai} + \dot{Q} F_{Ai}\alpha, \qquad [2]$$

where F_I is inspired ^{133}Xe concentration; F_{Ai} is regional alveolar ^{133}Xe concentration during rebreathing; and $\dot{V}_I$ is

regional inspired ventilation. It can be shown that, at $\dot{V}_A/\dot{Q} > 0.2$, $\dot{V}_I$ may be assumed to be equal to $\dot{V}_A$, with an error of $<10\%$. Regional count rates during rebreathing (U_i) are directly measured, and F_{Ai} is computed from this.

If both infusion and rebreathing procedures are carried out under the same conditions, i.e., when regional lung volumes are constant, F_{AP} may be related to F_{Ai} as follows:

$$F_{AP}/F_{Ai} = U_p/U_i. \quad [3]$$

In Equations 1 to 3 there are three unknowns, $\dot{V}_A/\dot{Q}$, F_{AP}, and F_{Ai}; if regional $\dot{V}_A/\dot{Q}$ is the same during infusion and rebreathing, they may be solved as follows:

$$\dot{V}_A/\dot{Q} = \frac{C\bar{v} \times U_i}{U_p \times F_I}. \quad [4]$$

It is apparent that both $C\bar{v}$ and F_I may be in the dimensions millicuries per liter without altering the validity of Equation 4.

Effect of dead space. The above calculations do not take into account the fact that alveolar gas is inspired from the dead space during both ^{133}Xe infusion and rebreathing. Since dead space gas is in part a mixture of gases from more than one lung region, the effect of its reinspiration is to lessen differences in concentration among different lung regions. Treatment of the problem demands definition of dead space volume and gas composition and the distribution of dead space gas when inspired.

At the end of expiration, gas in the mainstem bronchi, trachea, and upper airways contains contributions from all regions; toward the periphery, the airways contain gas from fewer regions and, at the outermost limit, contain gas of the same composition as the region they subserve. Because we can measure only the gas compositions at the two extremes of the above continuum, we are forced to treat the dead space as a two compartment model, one compartment being the dead space common to all lung regions and the other being the dead space unique to the region it subserves. Since reinspiration of gas from the regional dead space does not change alveolar gas composition, this volume of ventilation is not involved in gas exchange. We have chosen to assume that the regional dead space equals half the anatomical dead space, which probably is an overestimation (9). There is no reason to suppose that dead space gas is inspired sequentially; therefore, the ratio of dead space to tidal volume may be considered uniform throughout the lung.

The above assumptions may be summarized in formal fashion as follows: *1*) The total gas-exchanging ventilation of a region ($\dot{V}e$) is the sum of the regional alveolar ventilation ($\dot{V}_A$) and the regional share of the ventilation of the common dead space ($\dot{V}'_D$). Similarly, the total gas-exchanging ventilation of the lungs ($\dot{V}e_T$) is the sum of the over-all alveolar ventilation ($\dot{V}_{AT}$) and the ventilation of the common dead space ($\dot{V}'_{DT}$).

2) The common dead space is half of the anatomical dead space, and its ^{133}Xe concentration is equal to over-all end tidal concentrations during infusion (F_{ApT}) and rebreathing (F_{AiT}).

3) The regional distribution of gas inspired from the common dead space is the same as the distribution of the remainder of the inspired volume, i.e., $\dot{V}'_D/\dot{V}e = \dot{V}'_{DT}/\dot{V}'e_T$. Therefore, Equation 1 becomes:

$$\dot{Q}(Cv - F_{Ap\alpha}) + \dot{V}'_D F_{ApT} = \dot{V}e F_{Ap},$$

and Equation 2 is modified to:

$$F_I(\dot{V}e - \dot{V}'_D) + F_{AiT}\dot{V}'_D = \dot{V}e F_{Ai} + \dot{Q}F_{Ai\alpha}.$$

If $(\dot{V}'_{DT}/\dot{V}e_T)\,\dot{V}e$ is substituted for $\dot{V}_D$ in both equations, they are solved as follows:

$$\dot{V}e/\dot{Q} = \frac{C\bar{v}U_i}{U_pF_I(1-\dot{V}'_{DT}/\dot{V}e_T)+\dot{V}'_{DT}/\dot{V}e_T(U_pF_{AiT}-U_iF_{ApT})}. \quad [5]$$

A similar series of equations may be solved for $\dot{V}_A/\dot{Q}$ when $\dot{V}_A$ represents ventilation exclusive of the dead space ventilation:

$$\dot{V}_A/\dot{Q} = \frac{C\bar{v}U_i}{U_pF_I + \frac{\dot{V}'_{DT}}{\dot{V}_{AT}}(U_pF_{AiT} - U_iF_{ApT})}. \quad [6]$$

Procedure and calculations. Four normal young men were studied while seated erect with their backs against a plastic grid. With coordinates on the grid and a chest radiograph, 10 or 12 scintillation counters with 17-cm tubular collimators were positioned over various regions of both lungs. The subjects breathed through a tap that could be connected to a small plastic breathing valve or to a valveless spirometer with a mixing pump. A scintillation counter with a thin crystal 2 inches in diameter (mouth counter) was positioned over the valve. A digital ratemeter was used to integrate count rates over intervals of 0.5 second, and this permitted a continuous recording of end tidal ^{133}Xe concentrations. The spirometer circuit also contained a scintillation counter. The chest and spirometer count rates were monitored and recorded as described by Ball, Stewart, Newsham, and Bates (1). The mouth counter was calibrated by filling the breathing valve with known concentrations of ^{133}Xe.

The subject relaxed and breathed naturally through the mouthpiece valve for 10 to 15 minutes. When the minute volume appeared to be stabilized, a solution of ^{133}Xe in saline contained in a syringe driven by a Harvard pump was infused for 5 minutes at a rate of approximately 2 mc per minute into a previously prepared left antecubital vein. The subject was unaware of when ^{133}Xe infusion began. Expired air was collected during the last 2 minutes of the infusion. After the last collection, the infusion pump was turned off and the subject, breathing room air naturally, cleared the ^{133}Xe from his lungs.

When washout was judged complete (both by observation of the mouth count rate and of the data recorded for calculation of chest wall background as described below), the subject was turned into the spirometer circuit, which contained trace amounts of ^{133}Xe. He breathed from this closed circuit until both the spirometer and the regional count rates were stable, oxygen being added at a rate sufficient to keep the spirometer volume constant. After

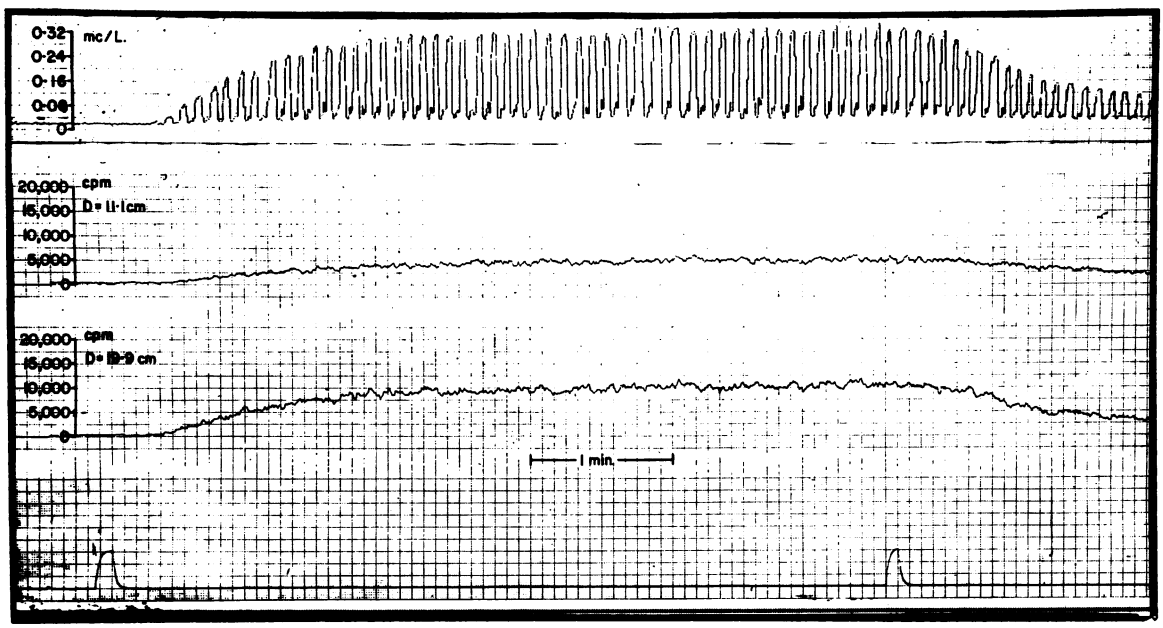

FIG. 1. EXPERIMENTAL RECORD DURING ^{133}Xe INFUSION IN SUBJECT AP. The signal on the bottom channel indicates when the infusion pump was turned on and off. The middle two records are from counters over the right lung (D = distance from the lung top) and are calibrated in counts per minute. The top tracing is from a counter over the breathing valve and is calibrated in millicuries per liter. This tracing has been slightly retouched for purposes of reproduction.

steady regional count rates had been attained, the subject was turned out of the closed circuit and again allowed to breathe room air.

In order to calculate intrapulmonary count rates from gross regional count rates, it was necessary first to subtract the count rate due to ^{133}Xe present in the chest wall. This was estimated by the method of Milic-Emili and coworkers (6), which assumes that tissue ^{133}Xe increases in linear fashion with time during ^{133}Xe administration and decreases in linear fashion during washout. Preliminary experiments had confirmed the validity of these assumptions for these experimental conditions.

The minute ventilation was measured over the last 2 minutes of ^{133}Xe infusion, and samples of expired gas were analyzed for O_2 and CO_2 by the Scholander method (10), and for ^{133}Xe with a stationary scintillation counter (5). The respiratory quotient (R) and the total respiratory ^{133}Xe output ($\dot{V}$xe) were calculated from these data; then the total alveolar ventilation and dead space could be measured using $\dot{V}$xe and $F_{A_{pT}}$. The instrumental dead space equaled 35 ml. V'_{DT} was computed from these data.

Neither the mixed venous concentration ($C\bar{v}$) nor cardiac output was measured during infusion, and both were estimated from other data. Using the measured R, we assumed values for mixed venous oxygen pressure ($P_{\bar{v}O_2}$) and $P_{\bar{v}CO_2}$ and used the O_2-CO_2 diagram (11) to calculate total $\dot{V}_A/\dot{Q}$. This, together with the over-all alveolar ventilation corrected to BTPS (body temperature, pressure, saturated with water), was used to compute over-all cardiac output and—since, barring major recirculation, the infusion rate must approximate the product of $C\bar{v}$ and cardiac output—the $C\bar{v}$.

The design of our mouthpiece precluded our measuring $F_{A_{iT}}$; this was calculated by substituting total $\dot{V}_A/\dot{Q}$, as obtained above, in Equation 2.

Results

Figure 1 shows a typical recording made during ^{133}Xe infusion. Regional count rates rise quickly in the first 2 to 3 minutes and increase very slowly thereafter. This slow rise usually can be accounted for by the increase in chest wall background. Mouth counter records show

TABLE I

*Respiratory ^{133}Xe output compared with infusion rate**

Subject	Injection rate	Vxe†			
		4th minute	5th minute	Mean	% injection rate
	mc/min		*mc/min*		
MJ	2.06	1.78	1.83	1.81	88
TA	1.83	1.61	1.50	1.56	86
MR	2.22			2.09	93
AP	2.08			1.94	93

* Serial measurements were made in subjects MJ and TA during the fourth and the fifth minutes of infusion. In MR and AP, measurement was made during the fourth through fifth minutes.

† Vxe = total respiratory ^{133}Xe output.

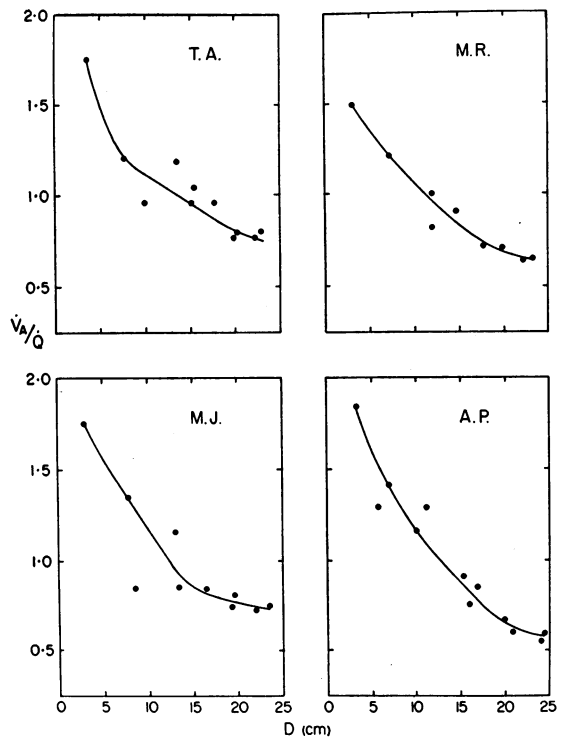

FIG. 2. REGIONAL $\dot{V}_A/\dot{Q}$ IN FOUR SUBJECTS. Ordinate: $\dot{V}_A/\dot{Q}$ calculated from Equation 4 (see text); abscissa: distance down the lung (D); 0 cm = lung top. $\dot{V}_A/\dot{Q}$ = ratio of alveolar ventilation to perfusion.

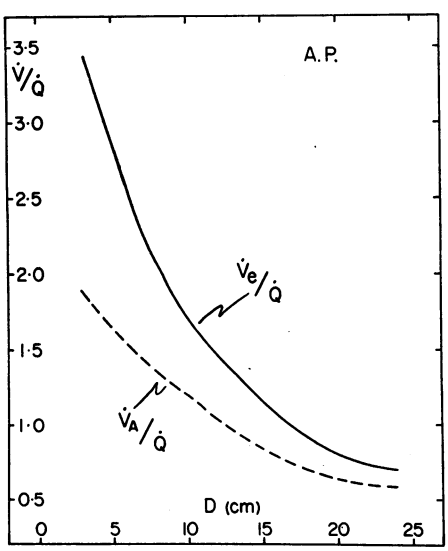

FIG. 3. $\dot{V}_E/\dot{Q}$ IN SUBJECT AP. Ordinate: regional $\dot{V}/\dot{Q}$; abscissa: distance (D) from lung top. $\dot{V}e/\dot{Q}$ (Equation 5) is the unbroken line; $\dot{V}_A/\dot{Q}$ (Equation 4) is the broken line. $\dot{V}e/\dot{Q}$ = ratio of the total gas-exchanging ventilation of a region to perfusion.

that a constant concentration is attained about 2 minutes after the infusion is begun and continues for the subsequent 3 minutes, providing assurance of the achievement of a steady state. Expired volume and ^{133}Xe concentration in expired gas were measured, and the resulting $\dot{V}xe$ values are shown in Table I. The ^{133}Xe output was >85% of the input in all subjects, and $\dot{V}xe$ did not change appreciably over the last 2 minutes of the experiment in the two subjects in whom serial measurements were made. These data indicate that an over-all steady state may be induced in normal subjects under the conditions of these experiments with ^{133}Xe infusion.

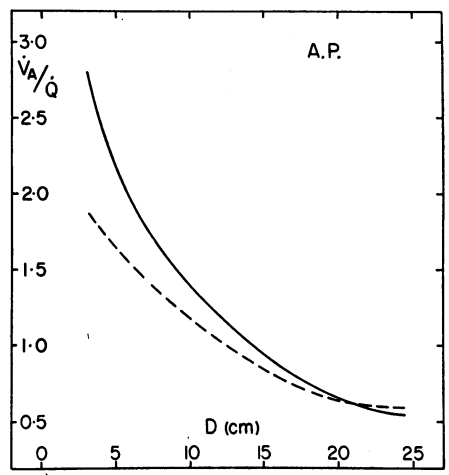

FIG. 4. EFFECT OF DEAD SPACE ON REGIONAL $\dot{V}_A/\dot{Q}$ IN SUBJECT AP. Ordinate: regional $\dot{V}_A/\dot{Q}$; abscissa: distance from lung top. The unbroken line is $\dot{V}_A/\dot{Q}$ from Equation 6; the broken line is $\dot{V}_A/\dot{Q}$ from Equation 4.

Figure 2 depicts regional $\dot{V}_A/\dot{Q}$ values, derived from Equation 4, in four subjects. $\dot{V}_A/\dot{Q}$ was highest at the apex (about 3.0 cm below the top of the lung) and fell at a decreasing rate toward the base. The $\dot{V}_A/\dot{Q}$ ranged from 1.49 to 1.83 at the apex and from 0.56 to 0.80 at the lung base. An example of changes in $\dot{V}e/\dot{Q}$ down the lungs as calculated by Equation 5 is presented in Figure 3, where it is contrasted with regional $\dot{V}_A/\dot{Q}$ as calculated by Equation 4. Because over-all $\dot{V}e$ is higher than $\dot{V}_A$ by an amount equal to ventilation of the common dead space, the entire curve is higher. In relation to perfusion, a greater amount of dead space is distributed to the apex than to the base; therefore, the $\dot{V}e/\dot{Q}$ plot deviates from the $\dot{V}_A/\dot{Q}$ plot near

the top of the lungs. Figure 4 contrasts $\dot{V}_A/\dot{Q}$ as calculated by Equation 4 (which assumes no dead space rebreathing) with $\dot{V}_A/\dot{Q}$ as calculated by Equation 6 (which allows for this effect). The dead space results in overestimation of low $\dot{V}_A/\dot{Q}$ and greater underestimation of high $\dot{V}_A/\dot{Q}$.

Discussion

Limitations of method. Since achievement of a steady state is essential to interpretation of these data, this must be the first concern in assessing the validity of technique.

During infusion, regional ^{133}Xe concentration (F_{A_p}) approaches its steady state value as an exponential. This approach is dependent upon regional alveolar ventilation ($\dot{V}_A$), perfusion ($\dot{Q}$), and alveolar volume (V_A), and may defined by ratios involving all three variables. The simplest of these definitions states that the slope of the exponential approach of F_{A_p} to steady state values is the sum of $\dot{V}_A/V_A$ and $\dot{Q}\alpha/V_A$. The larger this sum, the quicker a steady state is attained. With previously published data (4, 5), it can be calculated that F_{A_p} will reach at least 90% of its steady state value well within the 5-minute infusion time of our experiments. However, if both $\dot{V}_A/V_A$ and $\dot{Q}/V_A$ were very low in the same region, F_{A_p} would not rise to steady state levels within acceptable time (and radiation dosage) limits. Regions with such characteristics could not be accurately assessed by our method.

The approach of regional alveolar ^{133}Xe concentration during rebreathing (F_{A_i}) to constant values is related in similar fashion to $\dot{V}_A/V_A$ and $\dot{Q}/V_A$, but theoretical analysis of the relationship of F_{A_i} and time is rendered complex because, with the closed circuit we use, inspired ^{133}Xe concentrations decrease with time. In theory, the inspired concentration must decline progressively until it equals F_{A_i} throughout the lung when the subject as a whole is in equilibrium with the spirometer. In practice, however, the decrease in inspired concentration can be divided into two components with different time constants. A relatively rapid and readily detectable decrease is due mainly to the dilution of spirometer ^{133}Xe by lung gas. When regional count rates become constant, this process may be considered complete. Blood and peripheral tissue uptake of ^{133}Xe will continue to remove the gas from the spirometer after regional count rates appear constant; however, because of the insolubility of ^{133}Xe and the size of the spirometer circuit (about 10 L), the continued uptake will not be reflected in a significant decrease in spirometer concentration during a 3- to 5-minute period. Thus, the conditions of Equation 2 are satisfied. The initial inspired concentration is higher than the constant inspired ^{133}Xe concentration (F_I of Equation 2), which tends to increase the speed of approach of F_{A_i} to the values described in Equation 2, so that it is virtually certain that at least 90% of these values will be attained in 5 minutes of rebreathing by normal subjects.

Recirculation of ^{133}Xe introduced by infusion or by rebreathing has not been considered in this analysis and could conceivably exert an important influence on the establishment of steady state conditions. Studies of ^{133}Xe exchange in the periphery are under way in this laboratory, and from results obtained so far it may be calculated that recirculating ^{133}Xe amounts to 5 to 10% of input concentration ($C\bar{v}$ or F_I) after 5 minutes of rebreathing or infusion. Solution of Equations 1 and 2 after the addition of recirculation terms has the effect of subtracting one such term from the other, and the total error due to recirculation will be $<5\%$.

It is improbable that regional count rates during infusion (U_p) and rebreathing (U_i) can be determined with an error $<10\%$ (see below). Also, it is probable, as discussed above, that an error of no greater magnitude is introduced by the assumption of steady state conditions at the end of the infusion and rebreathing periods. Therefore, it is justifiable to analyze the data as described. Further support for this approach is given by the measurements presented in Table I.

To compute U_p and U_i it is necessary first to subtract chest wall background counts. This was done by extrapolation back from regional count rates recorded at a time when it was considered that washout from the lungs of the ^{133}Xe was complete. Selection of this point in time obviously is an arbitrary procedure, which might give rise to sizable errors in estimation of tissue background. In areas where intrapulmonary count rates are high, such errors are not impor-

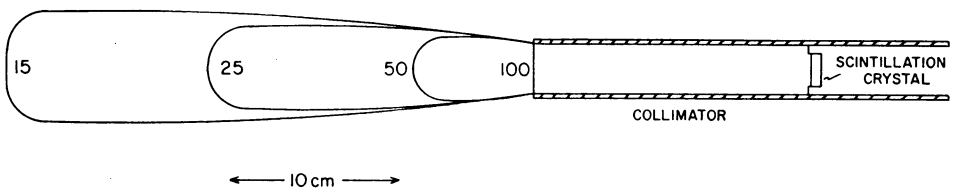

FIG. 5. ISOCOUNT CURVES FOR COLLIMATION USED IN PRESENT STUDY (17 CM). Numbers on the isocount curves refer to a counting rate of 100% at the end of the collimator.

tant, but where the regional lung volume is small and $\dot{V}_A/\dot{Q}$ is high, error in the estimation of tissue background can seriously influence U_p and U_i. An excellent example of an area with small volume and high $\dot{V}_A/\dot{Q}$ is the lung apex of erect normal man, which is a zone where measurement is further complicated by the relatively large amount of overlying soft tissue. It is apparent in Figure 2 that regions near the apex produce less reproducible results (probably as a consequence of this factor) than do those at the base.

During infusion, U_p is taken to represent the ^{133}Xe in the lung gas only. This assumes that the blood, which also contains ^{133}Xe, makes a negligible contribution to U_p. This assumption is false when applied to $\dot{V}_A/\dot{Q}$ of apical regions on the same (left) side as the arm into which the infusion is made. Such $\dot{V}_A/\dot{Q}$ values are lower than those from counters in a comparable position on the other (right) side, indicating a significant contribution to U_p by count rates from intravascular ^{133}Xe. Accordingly, our calculations were made with only single measurements of $\dot{V}_A/\dot{Q}$ at distances <6 cm down the lung, and the values from these regions presented in Figure 2 represent data gathered from the right lung only. We suspected that a similar problem might arise in other areas with a relatively large vascular volume and, therefore, deliberately placed counters behind the heart and one or both pulmonary arteries in all subjects. Data from these counters yielded $\dot{V}_A/\dot{Q}$ values similar to those from comparable counters not over major vascular areas, leading us to conclude that count rates from ^{133}Xe in blood were negligible in such areas, which had much higher intrapulmonary count rates than those obtained at the apexes.

An obvious and important limitation of the technique is that it does not reveal $\dot{V}_A/\dot{Q}$ differences within a counter field. As shown in Figure 5, the present counter fields have the shape of a truncated cone, the diameter being 3.75 cm adjacent to the counter (i.e., in the posterior chest) and about 6 cm in the anterior chest. These are not very small volumes of lung tissue, and each counter can be expected to record only a mean of the behavior of the lung beneath it, and because of overlap of counter fields differences from region to region might be underestimated.

Infusion of ^{133}Xe delivers a higher dose of radiation than do multiple single injections. In our experiments the subjects received a mean dose of 332 millirads to the lung and 19 millirads to the rest of the body. Although this dosage is not excessive by the usual isotopic standards, it is considerably higher than that given in other experiments involving ^{133}Xe and probably prohibits repetitive infusion experiments in normal subjects for solely experimental purposes.

Implications. The general shape of the curves in Figure 2 is similar to those previously reported (4, 5). Elimination of the dead space effect by use of Equation 6 produces data comparable to those calculated by West (4), and agreement is good between the two sets of results except that our measurements of apical $\dot{V}_A/\dot{Q}$ are somewhat lower than his calculated values, but this difference vanishes if it is assumed that the whole, rather than half, of the anatomical dead space is common to all lung regions. Quantitative comparisons between the present results and previous studies of regional $\dot{V}_A/\dot{Q}$ in our laboratory (5) are more difficult, but two clear-cut discrepancies emerge. First, the apical $\dot{V}_A/\dot{Q}$ evaluated by ^{133}Xe infusion is considerably lower than that previously reported, probably due to the assumption in earlier analyses of nonpulsatility of pulmonary blood flow. Second, the present data do not show the minimal $\dot{V}_A/\dot{Q}$ above the lung base that was noted previously (5); the reason for this discrepancy is not apparent.

The assessment of regional $\dot{V}e/\dot{Q}$ has greater physiological significance than do the measurements discussed above, since $\dot{V}e$ is a better approximation of the total gas-exchanging ventilation. Figure 6 shows the regional alveolar gas tensions of subjects AP and MR, calculated from measured $\dot{V}e/\dot{Q}$ distribution and the O_2-CO_2 diagram and modified according to the principles of Ross and Farhi (12). There is less variation in gas composition from apex to base than that calculated by West (4). This discrepancy is due in part to the lower apical $\dot{V}A/\dot{Q}$ found in these experiments and partly to the reinspiration of dead space gas. Neither our measurements nor those of West of resting apical $\dot{V}A/\dot{Q}$ are beyond reproach. The former may be inaccurate because of chest wall radiation, and the latter were secured at high lung volumes and transpulmonary pressures. The effect of reinspired dead space gas, however, can serve only to decrease regional gas tension differences (12). It follows, then, that over-all alveolar-arterial gas tension differences due to varying regional $\dot{V}A/\dot{Q}$ must be smaller than those that do not allow for the dead space effect. Calculation of over-all alveolar-arterial differences from our data would be of interest. Regional ventilation per unit volume or perfusion per unit volume can be measured with minimal physiological disturbance, but there is no proved way to measure regional lung volume, and in the absence of such measurements calculation of over-all alveolar and arterial gas tensions is indirect and inexact.

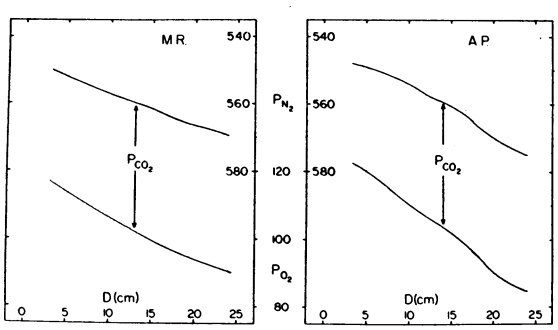

FIG. 6. REGIONAL PARTIAL PRESSURE (P) OF RESPIRATORY GASES IN SUBJECTS AP AND MR. Ordinate: P_{O_2} is on the lower part of the Figure; P_{N_2} is on the upper. Abscissa: distance (D) from lung top. Distance between P_{O_2} and P_{N_2} lines represents P_{CO_2}, which is equal to $700 - (P_{O_2} + P_{N_2})$.

Summary

A method is described whereby the ratio of alveolar ventilation to perfusion ($\dot{V}A/\dot{Q}$) in individual lung zones may be measured during normal steady state conditions. Regional count rates were recorded during a 5-minute period of constant intravenous infusion of ^{133}Xe dissolved in saline and during a similar period of ^{133}Xe rebreathing into a closed circuit. Theoretical considerations and experimental measurements have indicated that, for practical purposes, a steady state is achieved within these time limits in normal subjects. Similar patterns of regional $\dot{V}A/\dot{Q}$ were recorded during quiet tidal breathing in four normal subjects seated upright. It was possible to correct these data to allow for the influence of reinspired dead space gas and to compute regional $\dot{V}e/\dot{Q}$, where $\dot{V}e$ represented total gas-exchanging ventilation. Regional respiratory gas concentrations were calculated from such $\dot{V}e/\dot{Q}$ measurements and appeared to show less regional variation than previously reported. Limitations of the technique are discussed.

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