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A COMPARISON BETWEEN PULMONARY
ELIMINATION CAPACITY OF ACETYLENE AND
RADIOACTIVE ARGON AND XENON INJECTED
INTRAVENOUSLY DISSOLVED IN SALINE

*A new method of studying the functioning of the lungs
with particular reference to diffusion*

By

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INTRODUCTION

It is of extreme importance that the gas exchange in the lungs is brought about in an efficient manner. In patients with allergic diseases of the lungs the gas exchange, as we know, can be profoundly disturbed. During most attacks of asthma for instance, the ventilation of the lungs as well as the uptake of oxygen are lower than under basal conditions (*Colldahl* 1943, 1947). The altered gaseous tension during asthmatic attacks can provoke changes in tissue metabolism (*Colldahl* 1943, 1947 and 1960). All methods that give us information about the functioning of the lungs may therefore be of interest.

In 1953, a gas in an aqueous solution, injected intravenously was used for the first time in studying the functioning of the lungs and circulation (*Colldahl*). The gas used was acetylene and the test was called P.A.E.C. It could later be shown that all the acetylene so injected was eliminated rapidly through the lungs. In a healthy person about 40 per cent was eliminated in the first minute after injection, under conditions of normal lung ventilation. If the concentration of acetylene in the expired air was registered continuously by means of a special

infra-red spectro-photometric method a direct determination of the interval between the commencement of the injection and the initial appearance of acetylene in the expired air could also be made. The acetylene elimination capacity was especially low in the presence of extensive pulmonary fibrosis but the gas elimination was also retarded during an asthmatic attack.

Acetylene is, like carbon dioxide, very soluble in water. For respiratory studies it is, however, also of interest to study the elimination rate of gases with low solubility in water, especially if one wishes to investigate the rate of diffusion of the gases from the lung capillaries to the alveolae. Noble gases are particularly good as radioactive tracers for this purpose as they are completely eliminated from the body in a short time. Under suitable conditions the diffusion of a gas through the lung membranes is, according to well-known physical laws, directly proportional to the solubility of the gas in water and inversely proportional to the square root of its molecular weight. If this can be applied to the present case the diffusion rate for argon should be about 40 times less than that for acetylene. The corresponding figure for xenon is about 20. The diffusion rates for argon and xenon are about the same as for oxygen.

If acetylene and argon (containing the radioactive isotope A^{41}) are injected intravenously together and the concentrations of the gases are continuously registered in the expired air, one would expect to find a retardation of the elimination of argon compared with that of acetylene, particularly if difficulties of diffusion exist. The conveyance in the blood and the mixing of the gases in the alveolar-bronchial system ought to be equal for both gases. Preliminary reports on this subject are published 1959 (*Colldahl, Alväger & Uhler*).

As far as we know the simultaneous study of the uptake or elimination through the lungs of different gases in order to study lung function has not been investigated before. In an interesting work, however, Partitional Respirometry was proposed in 1955 by *Hatch & Cook* for 'measuring the gas exchange capacity of the cardio-respiratory system by means of which the over-all pulmonary function is broken down into its

elements, ventilation, diffusion and blood flow, and the relative contribution of each to the gas exchange capacity', could, according to the authors be determined. This method makes use of three gases, ether, acetylene and carbon monoxide. These are inhaled by the subject in physiologically acceptable concentrations, though these concentrations are not given. The retention in the body of the different gases is measured in periods of 9 to 20 minutes. It was originally planned by *Hatch & Cook* to make up a single test mixture containing all the test gases and to determine their respective concentrations simultaneously in the expired air in order to obtain the separate retention under exactly the same conditions of cardio-respiratory performance. Such combined tests could however not be performed because of technical difficulties.

A combined test for studying the simultaneous elimination of different gases through the lungs is described here.

METHOD/PROCEDURE

Noble gases in small quartz bulbs were irradiated in a reactor and the activated gases dissolved in saline. The injections were made into the cubital vein and 30 ml containing both radioactive gas and acetylene were injected in 2 seconds with an automatic syringe driven by compressed air. The radioactivity in the syringe was measured just before the injection. When argon is used it is necessary to make a correction to allow for its decay. The concentrations of both gases, acetylene and argon, were measured simultaneously in the same cuvette of the infra-red spectro-photometer, while the radioactivity was measured by a sodium iodide scintillator detector placed close to the cuvette. The γ -spectrometer is equipped with a pulse-height analyser which makes it possible to reduce the background activity considerably. In the case of Xe the pulse-height analyser is necessary in order to distinguish between the different radioactive Xe isotopes produced by reactor irradiation. The concentrations of the gases are registered on

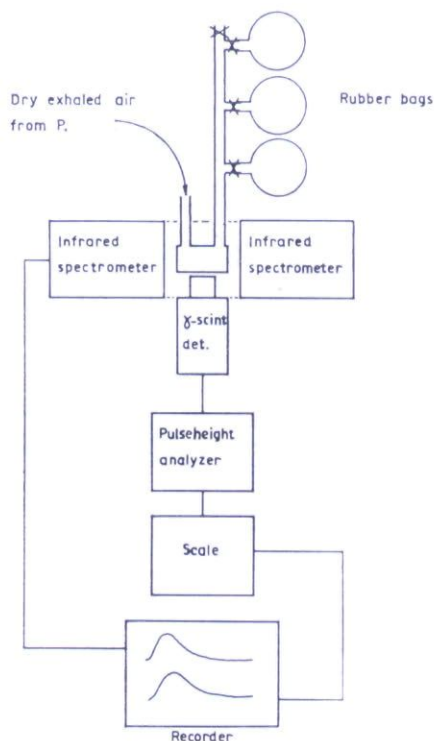


Fig. 1.

The technical arrangements for measuring simultaneously acetylene and radioactive gases in the exhaled air.

a kymograph of the mingograph type. After passing the cuvette the expired air is collected in rubber bags.

The technical arrangements are seen from Fig. 1.

The amounts of the gases eliminated, expressed as percentages of the amounts injected, were determined by collecting expired air for different periods of time and analysing it.

For details concerning acetylene determination see *Colldahl* 1953 and 1960.

RESULTS

The amounts of eliminated gases in a series of patients are shown in Figs. 2 and 3.

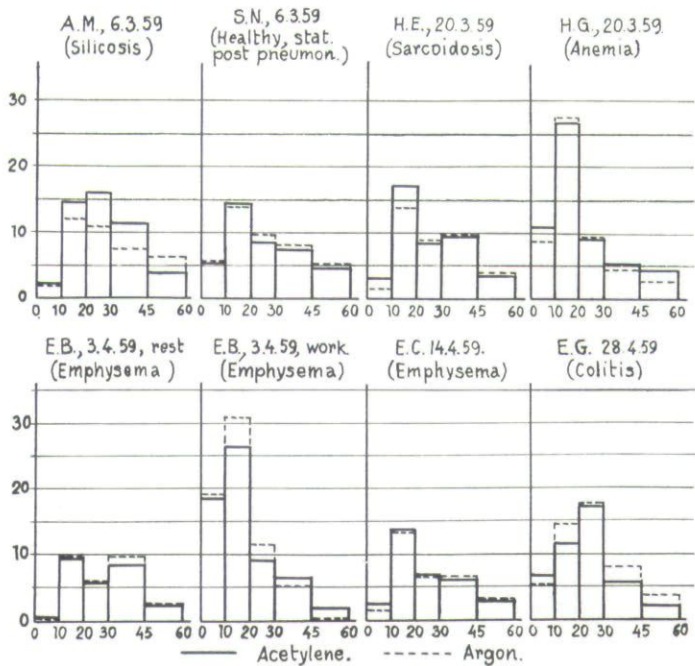


Fig. 2.

Ordinate: Gas eliminated (as a percentage of the amount injected).
 Abscissa: Time in seconds.

From these figures we can see that patients without lung diseases in rest eliminate argon at least as rapidly as acetylene (SN, HG, EG).

In patients with silicosis and sarcoidosis of the lungs there is in rest a tendency to eliminate argon more slowly than acetylene. (AM, HE, OA). In patients with emphysema the eliminated amounts of the gases in rest are lower than normal particularly during the first 10 seconds. This is also the case in some patients with silicosis and sarcoidosis. (OA, 28.4.59 and HE. 29.5.59).

In patients with emphysema in rest the eliminated amounts of both gases are about the same, even if the total amount eliminated is low.

In some patients who in rest have a somewhat slower elimi-

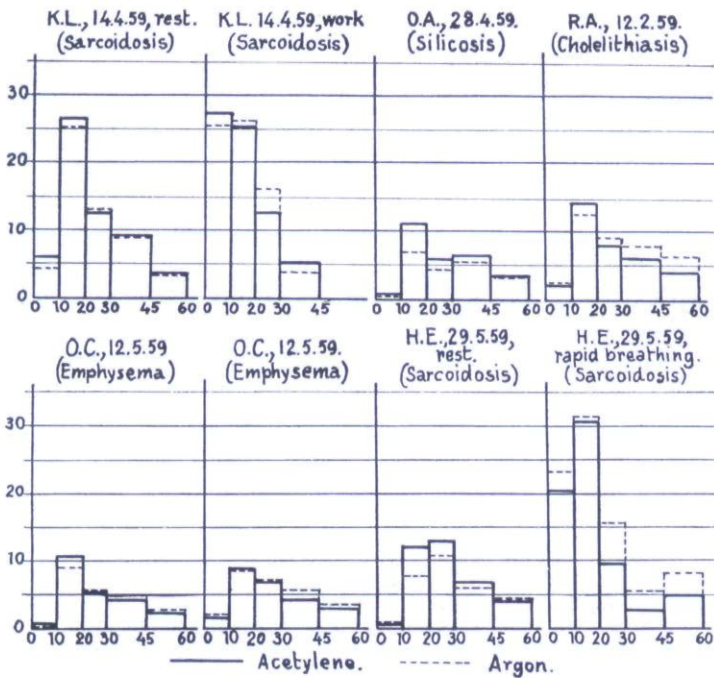


Fig. 3.

Ordinate: Gas eliminated (as a percentage of the amount injected).

Abscissa: Time in seconds.

nation of argon than acetylene this difference can disappear when the patient works or breathes rapidly.

Even if the difference between the amounts of acetylene and argon eliminated is small it can be seen very distinctly on the tracing where the concentrations of the gases are registered continuously. This can be seen from fig. 4, B. In this tracing from a patient with sarcoidosis the peak intensity for acetylene is reached after about 11 seconds but that for argon is not reached until after 16 seconds. In fig. 4, A we see a patient with normal lungs. In this case the greatest intensity for both acetylene and argon is reached after about 10 seconds.

The elimination of xenon and acetylene can be changed in asthmatic patients during an attack of asthma. This is seen from fig. 5. In moderate asthma the elimination curve for

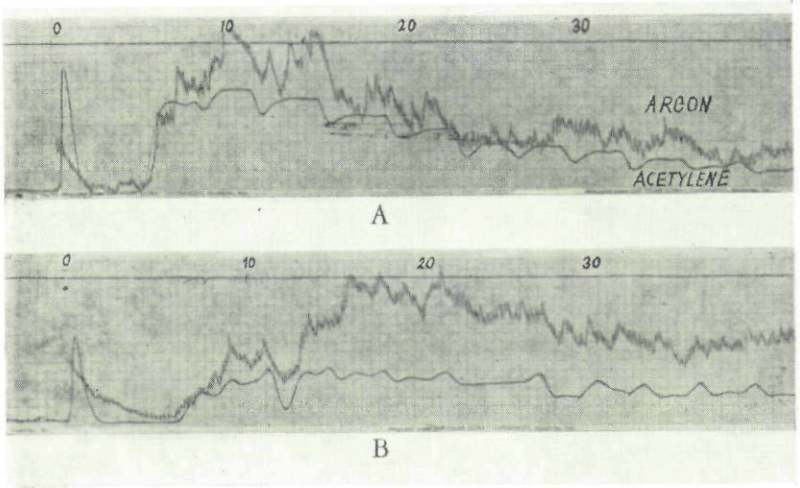


Fig. 4.

(A) Person with normal lungs. (B) Person with lung sarcoidosis.

Ordinate: Acetylene concentration (on a logarithmic scale) and the counting rate for argon (on a linear scale). The top intensity for acetylene corresponds to an acetylene concentration of 0.15 per cent, the top intensity for argon to a counting rate of 1500 c.p.m. (The initial curve deflections at time 0 depend on electric signals from the apparatus and are independent of gas concentrations).

Abscissa: Time in seconds.

The person with normal lungs was HG and the person with sarcoidosis was HE (the same patients as in Fig. 2). The tracings are from the tests taken on the 20.3.59.

xenon was retarded compared with that for acetylene. When the patient had got better and had only slight asthma the shape of the curves for the two gases followed each other more closely.

In decompensated heart disease the elimination curves for both xenon and acetylene are retarded. This is seen from fig. 6. (Pat. KA.). This patient had a venous pressure of 22 cm H_2O .

The upper diagram in fig. 6 is from a patient with ulcer and shows a more regular shape.

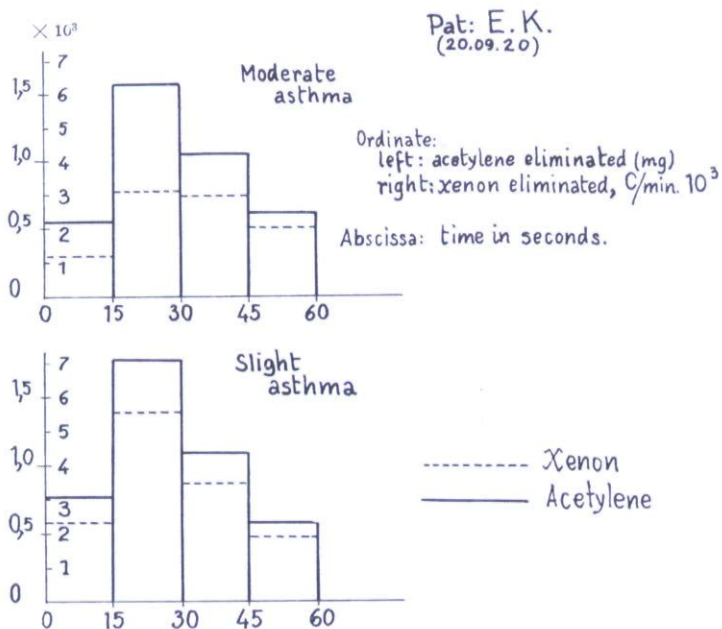


Fig. 5.

The first test was made on 23.1.59 and the second on 27.1.59. The two scales for left and right ordinates are independent of each other. The right ordinate gives the number of counts in thousands per min. (e.g. 3 = 3000 counts).

DISCUSSION

In this test the elimination rates of acetylene and argon or xenon are compared. The gases that have physiological importance are CO_2 and O_2 . The diffusing capacities of CO_2 and acetylene are similar and so are the diffusing capacities of argon or xenon and O_2 . The test gases have the advantage of not being metabolised in the body.

Three separate processes must be differentiated in connection with the elimination of intravenously administered gases:

- The transport in the blood from the place of injection to the lung capillaries.
- The passage through the lung membranes and
- The washing out by ventilation processes from the alveolae through the bronchi and out.

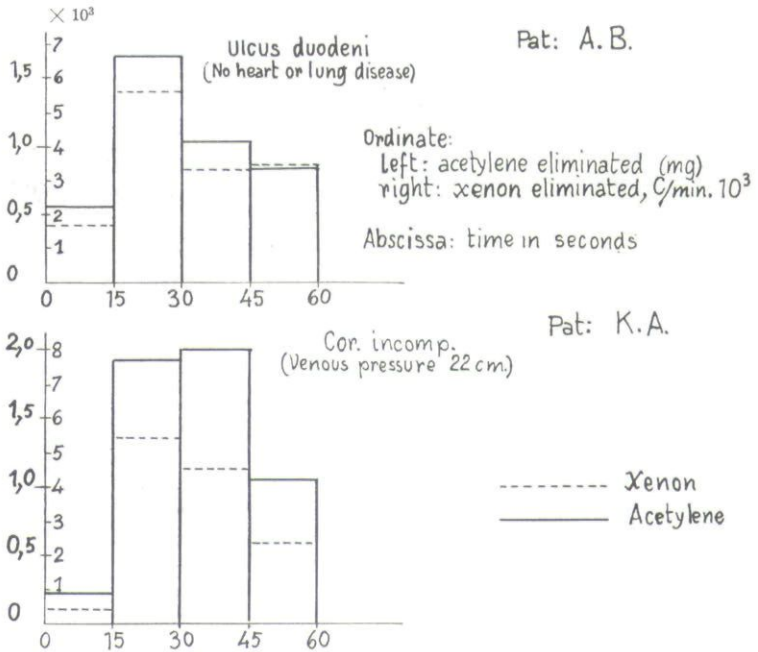


Fig. 6.

The two scales for left and right ordinates are independent of each other. The right ordinate gives the number of counts in thousands per min. (e.g. 3 = 3000 counts).

In liquids gases with different molecular weights diffuse at different speeds.

In gases gas molecules diffuse very much more rapidly than in liquids.

In general the rate of diffusion depends on the molecular weight and is inversely proportional to the square of the molecular weight.

Quite apart from the molecular weight, the solubility of a gas in the membranes is also of importance since there will be different concentration gradients for gases with different rates of solubility in the membranes.

If two gases are injected intravenously at the same time and it is observed that there is a difference in the rate of elimination of the gases, this will depend on the process described in

(b) above, since one can assume that they will be carried at the same rate through the blood and also through the ventilation process.

The passage of the gases through the bronchial system ought not to be regarded as the cause of any discrepancies in the rate of elimination of the gases, as the addition of the test gas in such a negligible quantity (less than 0.3 per cent) ought not to affect either the viscosity or the density of the exhaled air to any measurable degree, nor can any separation of the gases be expected.

By this method of injecting two different gases intravenously and following the elimination of the gases from the system, we should therefore have obtained a method which makes it possible for us to demonstrate if there is any difficulty for the gases to pass through the lung membranes. If there should be any such difficulty this will have been caused by a change in the membranes of a permanent or a temporary nature.

We have been able to demonstrate a discrepancy between the test gases that may be a sign of the existence of impaired diffusion through the membrane in cases of sarcoidosis, silicosis and asthma. The changes can be reversible as for instance, in asthma where the lung membranes during periods of asthmatic trouble are oedematus and are covered with a film of mucus.

It has been found that if the gas with the slowest diffusion rate is eliminated more slowly than the other gas when the patient is at rest, the difference between the rates of elimination will diminish and even disappear when the patient breathes or pants rapidly. This may possibly be caused by the fact that the diffusion surface of the membranes is larger when the lungs are distended as they are by work or deep and rapid breathing.

SUMMARY

The elimination with the exhaled air of acetylene and radioactive argon or xenon has been studied following their injection

together intravenously in saline solution. The following conclusions can be drawn:

In patients with normal lungs the elimination of the different gases follows each other closely.

In patients with lung sarcoidosis and silicosis acetylene is eliminated faster than argon or xenon. This can also be the case in asthmatic patients during an attack or in status ashtmaticus.

In patients with severe emphysema the eliminated amounts of the gases are small but the different gases are eliminated in the same amounts in per cent of the injected amount. In this case there are reasons to believe that the gas passage through the lung membranes is not impaired and that the slow gas elimination depends on circulatory and ventilatory disturbances.

In patients with decompensated heart disease the elimination rates for the different gases are retarded.

When argon and xenon are eliminated more slowly than acetylene this in all probability depends on impaired diffusion and the degree of difference may be used as a measure of the impairment.

ACKNOWLEDGEMENTS

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