symptoms are more likely to occur if the operation is hurried; the more quietly everything is done and the fewer the number of persons present the better will it be tolerated; at present the method is looked upon as somewhat of a therapeutic curiosity and tends to attract too much attention.

Results.

It is as yet difficult to estimate the value of blood transfusion apart from its use in haemorrhagic shock, where its value is incontrovertible, since it is only too frequently resorted to as a last desperate hope. If it is to be of real assistance it must be used much more frequently and early, for its final value will not depend on the cases of gastric ulcer snatched from death, nor the occasional miraculous recovery of the pernicious anaemia patient, but rather on a sound understanding of its rationale and method of action, and such can only be discovered by frequent observations in large numbers of varying conditions. In those conditions where unknown metabolic processes are at work—for example, haemophilia, purpura haemorrhagica, haemorrhagic necrosis, etc.—much might be learned both of the value of blood transfusion, and even of the underlying factors of these pathological conditions, by carefully carried out observations; and, again, its rôle in such chronic infections as tuberculosis might be found to be not entirely useless.

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THE COMPOSITION OF THE GASES IN ARTIFICIAL PNEUMOTHORAX.

BY

LEONARD HILL, M.B., F.R.S.,

AND

J. ARGYLL CAMPBELL, M.D., D.Sc. EDIN.

(From the National Institute for Medical Research, Hampstead.)

ON several occasions during the past year we have had the opportunity to obtain samples of gas from the thoracic cavity in patients with artificial pneumothorax. As our interest was thereby stimulated we carried out several experiments in which we produced artificial pneumothorax in animals—cats, rabbits, and a goat. We studied the composition of the air in the thoracic cavity, using Haldane's apparatus for the analysis of oxygen and carbonic acid. Our observations, although fairly numerous, form but a small contribution to the total, since the previous researches on this subject are extensive. We have made a study of the previous literature and consider that a critical review will be useful, seeing that the conclusions reached by different observers were so varied. As we are at present carrying out a research on the changes in composition of air injected into other body cavities and tissue spaces, and obtaining thereby rather striking results, we feel we are perhaps fortunately placed for a review of the afore-mentioned subject, and attempt herein to bring the different results, previously obtained, into line.

A very early research was that of Davy,¹ who in 1823 studied the gases in a case of pneumothorax. He obtained some of the gas from the thoracic cavity after the death of the patient. It was found that air had passed freely from the lung into the pleural cavity through a valvular ulcerated opening in the upper part of the superior lobe; the valvular opening prevented the air escaping again. Davy found 8 per cent. of carbon dioxide and 92 per cent. of nitrogen in the gas. He carried out numerous experiments on animals, injecting various gases and mixtures of gases—air and carbon dioxide, hydrogen and carbon dioxide, hydrogen and nitrous oxide gas. In the light of modern research, the older observers appear to have been much handicapped as regards the accuracy of their results owing to crude analytical methods. It seems hardly fair, then, to criticize their pioneer work.

Many important researches have been published in modern times. In 1914 Webb, Gilbert, James, and Havens² made extensive series of observations, mainly with the object of determining from a clinical point of view the best gas to inject to produce artificial pneumothorax, and concluded that, as Haldane had predicted, little, if any, clinical advantage was

gained by the employment of nitrogen rather than atmospheric air for the production of artificial pneumothorax. Although they did not pay any great attention to or discuss fully the reasons for the changes in the composition of the injected gases, they gave very complete details of the analyses after the injection of oxygen, nitrogen, and air. Their figures for carbon dioxide in the imprisoned gas after many hours varied between 2.64 and 13.59 per cent., and the figures for oxygen varied between 0.41 and 8.66 per cent., except when pure oxygen was the gas injected into the thorax, the figures for oxygen percentage after forty-eight hours being then as high as 24.04 per cent. The remaining percentage, and therefore much the highest percentage, was made up by nitrogen. To quote these authors:

"The oxygen cases are especially noteworthy from the discovery of the large addition of nitrogen which must have diffused into the pleural space. Since blood contains only a small percentage of nitrogen (about 2.4 per cent.), diffusion must take place between alveolar air and pleural space to establish equilibrium. It would, therefore, seem certain that, whatever gas is used for the production of pneumothorax, it does not long remain pure; for Nature rapidly changes it until an analysis yields the equivalent of alveolar air. At our elevation (6,000 feet) alveolar air averages carbon dioxide 6 per cent., oxygen 14 per cent., and nitrogen 80 per cent.

"In general the longer the time between injections the higher the percentage of carbon dioxide and the lower the percentage of oxygen, the former tending to reach 10 per cent., and the latter 1 per cent. to zero."

The second paragraph just quoted contradicts the first paragraph as far as the oxygen is concerned. The first paragraph says the oxygen should be the same as in the alveolar air—that is, 14 per cent.—whereas the second paragraph states that the oxygen tends to reach from 1 per cent. to zero. It is quite obvious that their explanations are not sufficient to cover the variations given in their tables. They carried out an experiment under strictly physiological conditions with two monkeys. The right lungs of two monkeys of equal size and weight were collapsed under ether, one with 125 c.cm. of air and the other with the same amount of nitrogen. Forty-eight hours after positive pressure had been induced in this way the amount of gas still present in the monkey injected with air was 83 c.cm., and on analysis it gave carbon dioxide 8.06, oxygen 4.24, and nitrogen 87.70; whereas the amount of gas still present in the monkey injected with nitrogen was 92 c.cm., and on analysis it gave carbon dioxide 8.52, oxygen 5.61, and nitrogen 85.87. The figures show slight variation, but no conclusion may be drawn from them unless it was known that the lung in each monkey was collapsed to the same extent, or in other words that the circulation was similarly altered in both. These observers appear to have left the gases in the blood out of consideration, but, as has already been stated, the composition of the gases was not their main theme.

The blood gases have been very fully considered by Rist and Strohl³ in their conclusions. They made a very careful physical study of the volume changes of the gases and of the changes in absolute quantities of the gases in the thoracic cavity following the injection of air, nitrogen, oxygen, and carbon dioxide. They represented these changes by means of graphs showing the variations in quantities and also in partial pressure at definite intervals after the injection of each gas. They concluded that several days after the operation for artificial pneumothorax—not complicated by purulent exudate—analysis of the gases contained in the pleural cavity proves that the composition of the gases is the same in all cases. The phenomena which occur after the injection of gas into the pleural cavity, according to these observers, are explained completely by the exchange of gases which takes place in the living body, and which consist of a diffusion through the pleural membrane with rapidity proportional to the coefficient for each gas, and depending on the partial pressure of each gas on each side of the membrane. Equilibrium, they state, is established between the gases of the pleural cavity and the venous blood, and they hold that their graphs show why different results have been obtained at different phases before the establishment of this equilibrium. It is well known that carbon dioxide diffuses twenty-five times more rapidly through tissues than does oxygen, and obviously allowance must be made for this and similar physical laws. Rist and Strohl found that after the injection of nitrogen and oxygen the total quantity of gas was increased for a short period, probably owing to the rapid diffusion of carbon dioxide out of the blood; thus is the phenomenon of over-compression explained. Some of our own experiments illustrate very clearly how rapidly the percentage of carbon dioxide rises in

air injected into the thoracic cavity. It was demonstrated in one of Dr. Clive Riviere's patients. He kindly allowed us to withdraw two samples immediately after he had produced artificial pneumothorax with air containing 0.03 per cent. of carbon dioxide. On July 14th, 1922, at 2.59 p.m. 100 c.cm. of air were injected slowly into the thoracic cavity of a boy; at 3.4 p.m. a sample was withdrawn which now contained 0.8 per cent. of carbon dioxide. From 3.5 p.m. to 3.11 another 300 c.cm. of air were injected; at 3.12 p.m. a sample was withdrawn which contained 1.93 per cent. of carbon dioxide (see Table IIB). Grass⁴ obtained similar results.

TABLE I.
March 27th, 1922. Cat: Urethane.

Time.	Conditions.	Percentage Composition of Air in Thoracic Cavity.	
		CO ₂ .	O ₂ .
12.50	20 c.cm. of air injected*	—	—
12.53	Sample withdrawn	4.50	19.70
12.54	10 c.cm. of air injected	—	—
2.1	Sample withdrawn	6.10	15.00

* The composition of the air injected in all cases was approximately 20.93 per cent. oxygen, 0.03 per cent. carbon dioxide, and 79.04 per cent. nitrogen.

We injected 20 c.cm. of pure air containing 0.03 per cent. of carbon dioxide and 20.93 per cent. of oxygen into the thoracic cavity of an urethanized cat (see Table I) and found that after three minutes the percentage of carbon dioxide had risen to 4.50, whilst the percentage of oxygen had fallen only about 1 per cent. In the case of a goat the carbon dioxide rose from 0.03 to 3.56 per cent. in less than eight minutes after the injection of 300 c.cm. of air under local anaesthesia (see Table IIA). We are indebted to our colleague Dr. L. Colebrook for carrying out this operation. The oxygen in this experiment fell only about 1 per cent. in the same time.

TABLE IIA.
Goat: Local anaesthetic (L.C.).

Time.	Conditions.	Percentage Composition of Air in Thoracic Cavity.	
		CO ₂ .	O ₂ .
12.19 to 12.22	300 c.cm. of air injected	—	—
12.27	Sample withdrawn	3.56	19.70
12.31	Sample withdrawn	4.45	18.47
12.35	Sample withdrawn	4.74	18.04

TABLE IIB.
July 14th, 1922. Dr. Riviere's patient—Boy. Local anaesthetic.

Time.	Conditions.	Percentage Composition of Air in Thoracic Cavity.	
		CO ₂ .	O ₂ .
2.59 p.m.	100 c.cm. air injected into thoracic cavity	—	—
3.4	Sample withdrawn	0.80	—
3.5 to 3.11	300 c.cm. air injected into thoracic cavity	—	—
3.12	Sample withdrawn	1.93	—

Rist and Strohl were justified in excluding cases of pneumothorax attended by purulent exudate. It has long been known that the carbon dioxide percentage rises very high, as much as 11.5 per cent., in pathological fluids. Grass⁴ found that in pneumothorax accompanied by exudate the carbon dioxide percentage was as high as 13.62, whereas in dry pneumothorax it averaged about 6. Pathological processes probably explain some of the high figures for carbon dioxide recorded in gases in pneumothorax. It must also be remembered that in physiological conditions the urine and the bile sometimes contain from 7 to 9 per cent. of carbon dioxide (Strassburg⁵); therefore it is reasonable to conclude that in the tissues where these secretions had formed the percentages must be about the same. Very recently Dunn and Thompson⁶ pointed out that 9 per cent. of carbon dioxide must be recognized as a normal figure for the gases in the

stomach. It might be expected, therefore, that the venous blood would sometimes normally contain a fairly high percentage; thus high percentages might be present in cases of pneumothorax, if Rist and Strohl are correct in their conclusion that the composition of the gases in the thoracic cavity depends on the gases in the venous blood. Recently, however, Rist and Strohl's work has been criticized by Dantrebande and Spehl,⁷ who conclude that it is more correct to state that the carbon dioxide percentage in the thoracic cavity depends on the carbon dioxide present in the blood bathing the compressed lung, the blood of which is richer in the carbon dioxide than is the blood in the normal lung, because the compression slows the circulation. They also point out that Rist and Strohl used inaccurate figures for the volumes of gases in normal blood.

Another factor which must be taken into account is whether the pneumothorax is open—that is, whether there is a communication with the outside air or with the air in the lung by means of which air can pass freely into the thoracic cavity. Grass and Meiners⁸ point out that this can easily be determined by analysing a sample of gas from the pneumothorax and then drawing out more gas; if there is an opening, fresh air will enter the thoracic cavity as the gas is being removed and the fresh air will thus lower the carbon dioxide percentage in the pneumothorax gas. Undoubtedly such a leakage may explain the very low figures for carbon dioxide given by some observers as being present in cases of pneumothorax.

At this stage we may sum up the position as regards carbon dioxide in the gases of pneumothorax as follows: The carbon dioxide percentage in the thoracic cavity comes into equilibrium fairly rapidly with the carbon dioxide in the blood bathing the compressed lung, unless pathological processes in the tissues of the lung or pleura cause a local increase—or perhaps occasionally decrease—of carbon dioxide, and unless there is a leakage of air into the cavity which will lower the percentage of carbon dioxide.

We consider that the equilibrium is established very rapidly between the injected air and the blood as regards the carbon dioxide. Of course the greater the quantity of air injected the longer the interval before the equilibrium will be established, but even at the latest a couple of hours should be the limit. Henderson and Haggard⁹ have shown that after injecting 2 litres of air into the abdominal cavity of a dog equilibrium as regards carbon dioxide content was established in an hour and three-quarters. Our own results with gases in the stomach, intestine, bladder, in the thoracic and abdominal cavities, and under the skin (see Table III, A and B) gave very similar results, so that there is no reason to

TABLE IIIA.
Cat: No anaesthetic.

Time.	Conditions.	Percentage CO ₂ under the Skin.
11.0 a.m.	400 c.cm. of air injected under skin	—
1.0 p.m.	Sample withdrawn	5.21
2.25	Sample withdrawn	5.00
3.40	Sample withdrawn	5.20
4.10	Sample withdrawn	5.11

TABLE IIIB.
Rabbit: Urethane.

Time.	Conditions.	Percentage CO ₂ in bladder.
12.30 p.m.	25 c.cm. injected into the bladder	—
1.15	Sample withdrawn	5.34
1.40	Sample withdrawn	5.80
2.10	Sample withdrawn	5.80

doubt that equilibrium is established very rapidly in the thoracic cavity—that is, of course, unless the tissues have become much thickened by pathological processes; but an extensive general thickening would be somewhat rare. It has been found that fat renders the diffusion of carbon dioxide slower, owing to low solubility of this gas in fat.

As regards the oxygen percentage in the gas of pneumothorax it is obvious that any leakage in the cavity will raise the percentage, owing to the entrance of air. In view of recent physiological research it seems that, if the gases are left undisturbed in the thoracic cavity, the oxygen percentage falls very slowly and finally becomes very much lower than that of the blood bathing the lung. It probably corresponds finally with the oxygen percentage in the surrounding tissue. In physiological experiments on monkeys Webb and his co-workers² obtained fairly low figures for oxygen percentage three days after the last injection of air and nitrogen, the percentages being 4.85 and 3.57 respectively; these figures probably represent the oxygen percentage of the surrounding tissues. They seem much too low for oxygen percentage in the blood of such monkeys. Henderson and Haggard⁹ obtained low figures (about 6 per cent.) for oxygen in gas in the abdominal cavity; nevertheless the percentages they found were much higher than those—1 per cent. and less—given by Edkins¹⁰ for oxygen in the stomach cavity.

Our own figures for oxygen percentage in gas in the abdominal cavity of normal animals resemble those of Henderson and Haggard.

Thus on November 3rd, 1922, at 12.30 p.m., 250 c.cm. of air were injected into the abdominal cavity of a rabbit (see Table IV); at

TABLE IV.
Rabbit: Urethane.

Date.	Time.	Conditions.	Percentage Composition of Air in Abdominal Cavity.	
			CO ₂ .	O ₂ .
1922. Nov. 3	12.30 p.m.	270 c.cm. air injected	—	—
	3.10	Sample withdrawn	4.67	15.66
Nov. 6	12.10 p.m.	Sample withdrawn	7.01	5.00
Nov. 7	1.50 a.m.	Sample withdrawn	6.42	5.31

3.10 p.m. on the same day the oxygen percentage was 15.66. On November 6th, at 12.10 p.m., the same gas being in the abdominal cavity, the percentage was 5.00, and on November 7th, at 11.50 a.m., the oxygen percentage was 5.31. We also obtained low oxygen percentages in air that had been under the skin of normal animals for some days. Thus air containing 10.93 per cent. oxygen was injected under the skin on February 2nd, 1923, at 5 p.m.; on February 5th, at 1 p.m., the percentage of oxygen was found to have fallen to 3.50 (see Table V).

TABLE V.
Rabbit: No anaesthetic.

Date.	Time.	Conditions.	Percentage Composition of Air under the Skin.	
			CO ₂ .	O ₂ .
1923. Feb. 2	5 p.m.	Air injected under skin	—	—
Feb. 5	1 p.m.	Sample withdrawn	8.23	3.50
Feb. 7	4.40 p.m.	Air injected under skin	—	—
Feb. 9	2.30 p.m.	—	8.13	3.55

It is possible that the oxygen tension varies somewhat in different tissues and also at different times in the same tissue. Very low figures, resembling those (1 per cent.) of Edkins for the stomach cavity, have been obtained in the gases in pneumothorax, so that in these cases the oxygen percentage in the surrounding tissue may have been the same. Pathological changes in the lungs and pleura, such as thickenings, would probably lower the oxygen percentage in these tissues,

TABLE VI.
Dr. Pask's patient.

Time.	Conditions.	Percentage Composition of Air in Thoracic Cavity.	
		CO ₂ .	O ₂ .
Hours. 0	450 c.cm. oxygen injected into left pleural cavity	—	—
48	Sample withdrawn	4.90	15.34

as would also the presence of pathological exudates. Grass⁴ found the percentage of oxygen to be about 1 in cases with exudate, whereas it averaged 4 in cases of dry pneumothorax.

Previous results, particularly those of Webb and his co-workers² and of Rist and Strohl,⁸ and our own results, prove

that any oxygen injected was very slowly absorbed by the tissues compared with the rate with which carbon dioxide diffused out from the tissues. Dr. Pask of High Carley, Ulverston, kindly allowed us to examine a sample of gas from the thoracic cavity of one of his patients. Two days after the injection of 450 c.cm. of pure oxygen the percentage of oxygen present in the cavity was still about 15 (see Table VI). Similar figures were obtained from patients by Webb and his co-workers.²

Summary.

1. The carbon dioxide percentage in the gases of pneumothorax appears to approximate very rapidly to that of the blood bathing the compressed lung. The volume of gas introduced in carrying out artificial pneumothorax may thus be increased at first, but not more than about 6 per cent.

2. The oxygen percentage in the gases of the pneumothorax cavity approximates very slowly to that in the tissues bounding the cavity. As nitrogen diffuses out equally, it makes little difference whether oxygen or air be used for inducing artificial pneumothorax.

3. Pathological fluids and tissues usually cause abnormally high percentages of carbon dioxide. Pathological changes probably lower the oxygen content.

4. Any leakage in the thoracic cavity lowers the carbon dioxide percentage, but increases the oxygen percentage in the imprisoned gas.

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STERILIZATION OF THE UNFIT.*

BY

R. A. GIBBONS, M.D., F.R.C.S. EDIN.,

GYNAECOLOGIST TO THE GROSVENOR HOSPITAL FOR WOMEN.

IF in this country the revolutionary suggestion be advanced of sterilizing the mentally defective children and preventing the marriage of those with mental weakness, or those having such a strong family history of insanity as to make it certain that idiots or mentally unfit offspring would result, it is quite evident that strong arguments in its favour must be adduced before legislation could be hoped for.

The Increase of Insanity.

On January 1st, 1922, the number of notified insane persons under care in England and Wales was 123,714, an increase of 3,370 on the number on January 1st, 1921. This increase followed one of 3,580 in 1920, and may be compared with the average annual increase of 2,251 for the ten years ending December 31st, 1914—the decade immediately preceding the war.¹ The mentally defective persons under care on January 1st, 1922, numbered 13,810 (males 6,326, females 7,484). Compared with the same date in the year previous this was a net increase of 1,784 patients.¹

In Scotland on January 1st, 1922, exclusive of insane persons maintained at home by their natural guardians, there were 18,027 insane persons of whom there was official cognizance, including the inmates of training schools for imbecile children, who have not been certified under the Mental Deficiency Act, and of the Criminal Lunatic Department of Perth Prison.² The increase over the previous year was 221.

In Ireland on December 31st, 1919, there were 22,578 insane in various district, auxiliary, private asylums and mental hospitals; so that in Great Britain and Ireland there were at the dates mentioned no fewer than 178,129 affected.³ This does not include all those cases affected mentally who are in sufficiently good circumstances to obviate the necessity of entering a public institution.

As the foregoing shows that there is an annual increase in these numbers, it is clear that there is urgent need to do all in our power to ameliorate this state of affairs.

It has been estimated⁴ by an eminent authority that there are at present in the United States of America⁴ 42 institutions for the feeble-minded, 350 hospitals for the insane,

* Read before the Westminster and Holborn Division of the British Medical Association on April 12th, 1923. The discussion is reported at page 760.