The History of Anesthesiology

Reprint Series: Part Five

Hickman

Jackson

Sword

Waters

CARBON DIOXIDE ABSORPTION

Sykes in one of his admirable essays on the *First Hundred Years of Anaesthesia* ranks Henry Hill Hickman first on the basis of merit, among the pioneers. Unfortunately for Hickman carbon dioxide was not the appropriate gas. Anaesthetists turned their attention once more to carbon dioxide around the turn of the century when physiologists revealed the essential role of that gas in homeostasis. Although it was first believed that hypercarbia was preventive of circulatory collapse, Dennis E. Jackson and Ralph M. Waters believed that normocarbia was more salutary during anesthesia. Jackson demonstrated the efficacy of carbon dioxide absorption during closed system anaesthesia in the dog while, later on, Waters introduced the technique in man. Brian C. Sword advocated the circle rebreathing system as being more convenient than Waters' to and fro apparatus. Anaesthetists today have lost sight of the advantages of rebreathing: economy, conservation of body heat and water, and avoidance of atmospheric pollution.

A

LETTER

ON

SUSPENDED ANIMATION,

CONTAINING

EXPERIMENTS

Shewing that it may be safely employed during

OPERATIONS ON ANIMALS,

With the View of ascertaining

ITS PROBABLE UTILITY IN SURGICAL OPERATIONS ON THE

Human Subject,

Addressed to

T. A. KNIGHT, ESQ. OF DOWNTON CASTLE,
Herefordshire,

ONE OF THE PRESIDENTS OF THE ROYAL SOCIETY,

[illegible]

BY DR. H. HICKMAN,
OF SHIFFNAL;

Member of the Royal Medical Societies of Edinburgh, and of the Royal College of Surgeons, London.

IRONBRIDGE: Printed at the Office of W. Smith.

1824.

Hickman's Pamphlet

In the same year (1824) Hickman published his famous pamphlet, which is given here in full:— Hickman's Pamphlet

A Letter on Suspended Animation, containing Experiments showing that it may be safely employed during Operations on Animals, with the view of ascertaining its probable utility in surgical operations on the Human Subject, addressed to T. A. Knight, Esq., of Downton Castle, Herefordshire, one of the Presidents of the Royal Society.

TO THE PUBLIC

At the particular request of gentlemen of the first rate talent, and who rank high in the scientific world, it is, that the author of the following letter is induced to lay it before the public generally, but more particularly his medical brethren; in the hope that some one or other, may be more fortunate in reducing the object of it beyond a possibility of doubt. It may be said, and with truth, that publications are too frequently the vehicles of self-adulation, and as such, suffer greatly from the lash of severe criticism; but the author begs to assure his readers, that his views are totally different, merely considering it a duty incumbent on him (as a medical practitioner, and servant to the public), to make known any thing which has not been tried, and which ultimately may add something towards the relief of human suffering, arising from acute disease. The only method of obtaining this end is, in the author's opinion, candid discussion, and liberality of sentiment, which, too commonly is a deficient ingredient in the welfare of so important a profession, productive of serious consequences, not only to the parties themselves, but to the patient whose life is entrusted to their care. The duty and object, however, of the Physician and Surgeon, is generally considered to be the relief of a fellow-creature, by applying certain remedies to the cure of internal affections, or cutting some portion of the body, whereby parts are severed from each other altogether, or relieving cavities of the aggravating cause of disease. There is not an individual, he believes, who does not shudder at the idea of an operation, however skilful the Surgeon, or urgent the case, knowing the great pain that must necessarily be endured ; and it is frequently lamented by the operator himself, that something has not been done to tranquilise fear, and diminish the agony of the patient. With this view of the subject then, it is, that he submits his observations and experiments to the public in the brief form of a letter to a private gentleman of the highest talent as a man of science, who with others, thought them worthy to be laid before the Royal Society ; and if one grain of knowledge can be added to the general fund, to obtain a means for the relief of pain, the labours of the author will be amply rewarded.

A LETTER, ETC.

Sir,

The facility of suspending animation by carbonic acid gas, and other means, without permanent injury to the subject, having been long known, it appears to me rather singular that no experiments have hitherto been made with the object of ascertaining whether operations could be successfully performed upon animals whilst in a torpid state ; and whether wounds inflicted upon them in such a state would be found to heal with greater or less facility than similar wounds inflicted on the same animals whilst in possession of all their powers of feeling and suffering. Several circumstances led me to suspect that wounds made on animals whilst in a torpid state, would be found, in many cases, to heal most readily ; and the results of some experiments which I have made lead me to think that these conjectures are well founded, and to hope that you will think the results sufficiently interesting to induce you to do me the honour to lay them before the Royal Society. The experiments were necessarily made upon living animals, but they were confined to animals previously condemned to death; and as their lives were preserved, and their suffering very slight, (certainly not so great as they would have sustained if their lives had been taken away by any of the ordinary methods of killing such animals) I venture to hope that they, in the aggregate, rather received benefit than injury. Subjects of different species were employed, chiefly puppies of a few weeks or months old, and the experiments were often repeated, but as the results were all uniform, and as my chief object is to attract the attention of other medical men to the subject, I wish to do little more than state the general results.

Experiment 1st. Dogs of about a month old were placed under a glass cover, surrounded by water, so as to prevent the ingress of atmospheric air, where their respiration in a short time ceased, and a part of one ear of each was then taken off; there was no hemorrhage, and the wounds were healed at the end of the third day, without any inflammation having taken place, or the Animals having apparently suffered any pain or inconvenience from the operation.

Experiment 2nd. After the same animals had fully recovered their powers of feeling, a similar part of the other ear of each was taken off; a good deal of blood now flowed from the wounds, and some degree of inflammation followed, and the wounds did not heal till the fifth day.

Experiment 3rd. An experiment was made similar to No. 1, in every respect, except that the suspension of animation was much more suddenly brought on by the agency of sulphuric acid and carbonate of Lime. The results in this case were not so satisfactory; some blood escaped from the wounds, and a slight degree of inflammation followed, and the wounds did not heal so rapidly as the first experiment.

Experiment 4th. Mice, having been confined in a glass tube of a foot long, were rendered insensible by carbonic acid gas slowly introduced in small quantities, and one foot from each was taken off; no hemorrhage took place upon the return of sensation, and the wounds appeared quite healed on the third day, without the animals having apparently suffered pain, when they were given their liberty.

Experiment 5th. An adult dog was rendered insensible by means similar to the preceding, and the muscles and blood vessels of one of its legs were divided. There was no hemorrhage from the smaller vessels; a ligature which secured the main artery came away on the fourth day, and the animal recovered without having at any period shown any material symptom of uneasiness. In this experiment animation was suspended during seventeen minutes, allowing respiration occasionally to intervene by means of inflating instruments.

Experiment 6th. A dog was rendered insensible by the means employed in experiment first, and an incision was made through the muscles of the loin, through which a ligature was passed, and made tight; no appearance whatever of suffering occurred upon the return of animation, nor till the following day, when inflammation came on with subsequent suppuration. The ligature came away on the seventh day, and on the twelfth the wound was healed.

As the recital of such experiments as those preceding must be as little agreeable to you, as the repetition of them has been to myself, I shall not give a detail of any others, but shall only state the opinions which the aggregate results have led me to entertain. I feel perfectly satisfied that any surgical operation might be performed with quite as much safety upon a subject in an insensible state as in a sensible state, and that a patient might be kept with perfect safety long enough in an insensible state, for the performance of the most tedious operation. My own experience has also satisfied me that in very many cases the best effects would be produced by the patient's mind being relieved from the anticipation of suffering, and his body from the actual suffering of a severe operation; and I believe that there are few, if any Surgeons, who could not operate more skilfully when they were conscious they were not inflicting pain.

There are also many cases in which it would be important to prevent any considerable hemorrhage, and in which the surgeon would feel the advantages of a diminished flow of blood during an operation. I have reason to believe that no injurious consequence would follow if the necessity of the case should call for more than one suspension of animation; for a young growing dog was several times rendered insensible by carbonic acid gas, with intervals of about twenty-four or forty-eight hours, without sustaining, apparently, the slightest injury. Its appetite continued perfectly good, and I ascertained, by weighing it, that it gained weight rapidly. I am not, at present, aware of any source of danger to a patient, from an operation performed during a state of insensibility, which would not operate to the same extent upon a patient in full possession of his powers of suffering, particularly if he were rendered insensible by being simply subjected to respire confined air. I used inflating instruments in one experiment only, and therefore am not prepared to say to what extent such may be used with advantage; but I think it probable that those and the Galvanic fluid would operate in restoring animation in some cases. I was prepared to employ the Galvanic fluid if any case had occurred to render the operation of any stimulant necessary, but all the subjects recovered by being simply exposed to the open air; and I feel so confident that animation in the human subject could be safely suspended by proper means, carefully employed, that, (although I could not conscientiously recommend a patient to risk his life in the experiment) I certainly should not hesitate a moment to become the subject of it, if I were under the necessity of suffering any long or severe operation.

I remain, Sir,

Your obedient Servant,

H. H. HICKMAN.

Shiffnal, Aug. 14th, 1824.

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ORIGINAL ARTICLES

A NEW METHOD FOR THE PRODUCTION OF GENERAL ANALGESIA AND ANÆSTHESIA WITH A DESCRIPTION OF THE APPARATUS USED[1]

By D. E. Jackson, M.D., Ph.D., St. Louis, Mo.

In the following paragraphs there will be described a method for the production and maintenance of prolonged general analgesia or anæthesia by means of nitrous oxide, ethyl chloride, ether, chloroform, ethyl bromide, "somnoform," etc., with oxygen. The method involves a continuous process of rebreathing of the gaseous or volatilized anæsthetics from which the exhaled carbon dioxide, etc., have been removed and to which oxygen is constantly added in proportions suitable to maintain the patient in a satisfactory condition. The method involves the use of special apparatus which is so arranged as to give the anæsthetist complete control of every phase of the anæsthesia at all times. In the apparatus here described great care has been taken to provide safety devices. So far I have had an opportunity to try this method only on animals, but there seems to be good reason to expect that in man results entirely comparable to those produced in animals may be readily obtainable. It is chiefly with this object in view that I have carried out a long series of experiments by this method.

A number of the basic principles upon which I have constructed the apparatus herein described have long been known to science. As early as the year 1780 Antoine-Laurent Lavoisier had isolated carbon dioxide from expired air and had shown that in respiration oxygen is consumed, thereby starting work which within the next century was to lead to a long series of brilliant investigations along the lines of general metabolism and of analysis of respired gases. Names which should perhaps here be mentioned in connection with this subject are, Magnus (1837), Bischoff (1837), Regnault and Rieset (1849), Voit (1861), Pettenkofer (1863), Andrews (1868), Pflüger (1868), Bert (1878), Zuntz (1880), C. Martin (1888), Geppert and Zuntz (1888), Luciani and Piut-

[1]From the Department of Pharmacology, Washington University Medical School, St. Louis, Mo.

ti (1888), Atwater and Rosa (1899), Hewitt (1900), Haldane and Pembrey (1900), Atwater and Benedict (1905), Cushny (1909), Benedict (1909, 1912), Rolly and Rosiewicz (1911), Yandell Henderson (1910), Gatch (1911), and Meltzer and Auer (1909-11). Regnault and Rieset were probably the first to pass a current of oxygen into a small chamber in which an animal was confined for the purpose of analyzing the changes produced in the air by the respiration of the animal. They used a strong alkaline hydroxide solution to absorb the carbon dioxide output of the animal. Oxygen was added from a constant pressure reservoir. These principles have been used by practically all workers on respiratory metabolism since 1849. In the present experiments I have utilized them not for the purpose of obtaining data regarding the metabolism of the animal but with the object of maintaining conditions suitable for the normal respiration of the animal while at the same time there are added to the respiratory medium such quantities of gaseous or volatile anæsthetics as may be necessary to produce and maintain any desired and attainable degree of analgesia or anæsthesia, depending on the pharmacological properties of the substance administered. It will be noted at once that only very small quantities of the anæsthetic, such as nitrous oxide, ethyl chloride, ether, ethyl bromide, etc., are needed to produce a prolonged effect on the animal. And the depth of the anæsthesia becomes simply a matter of the degree of saturation of the animal with the anæsthetic. Since the anæsthetist has complete control of the amount of anæsthetic introduced into the animal it is obvious that when the desired degree of nervous depression has been reached no more anæsthetic need be given. The method by which these results are attained can best be explained by reference to Fig. 1 which is a diagrammatic plan of the apparatus used.

Description of Apparatus

A small electric motor (1) operates an air pump (2) which may be either of the rotary form (as shown here) or, perhaps, better of the piston form. By means of a closed system of pipes and vessels air may be kept continually circulating through the apparatus without either loss or gain of air except at the instance of the operator. Air leaving the pump at pipe (3) passes by the valve (4) unless this valve be open in which case part or all of the air will escape into the room. If the valve (4) be closed then the air proceeds through the valve (5) past the air-cock (6) and through pipe (7) into the special wash jar (9). This jar is three and one-half inches in diameter and twelve inches high and has an air-tight cover. The glass tube entering the jar is connected with the outer metal pipe by rubber hose. The glass tube makes an S-shaped bend a little distance below the cover and then passes through a bell-shaped piece of glass (8) which is firmly attached to the glass tube. Below the glass bell the tube again passes down inside a glass cylinder about two inches in diameter and six inches long. This cylinder reaches nearly to the bottom of the jar and is firmly attached to the glass tube by four glass spokes, two above and two below, each pair of spokes being placed in the same straight line, but on opposite sides of the glass tube. The glass tube lacks about one inch of reaching as low down as the outer glass cylinder. The jar is filled to the height of three or four inches from the bottom with a strong aqueous solution of sodium hydrate and calcium hydrate. The purpose of this solution is to absorb the

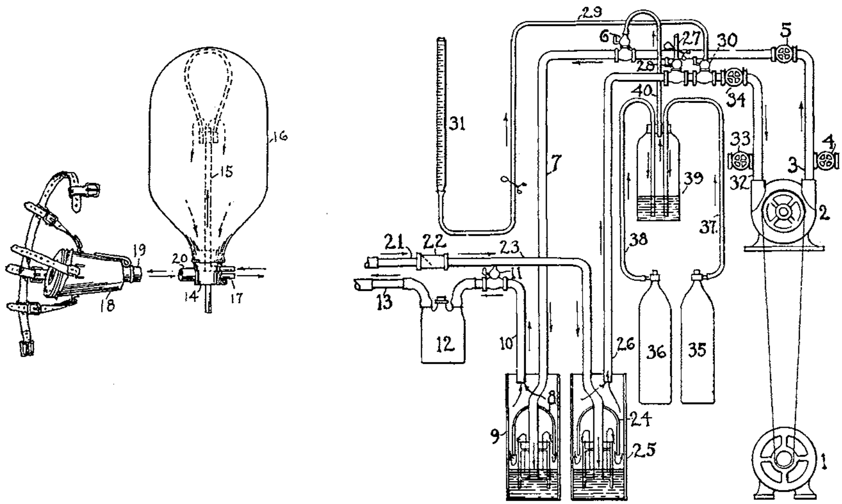

Fig. 1.—Schema showing the general plan of the apparatus together with head-piece, breathing bag and muzzle, as arranged for use with animals. The arrows indicate the direction of the air current. Number 35 represents the oxygen tank and 36 the nitrous oxide tank. In reality the apparatus carries two tanks each of oxygen and nitrous oxide. For full description see text.

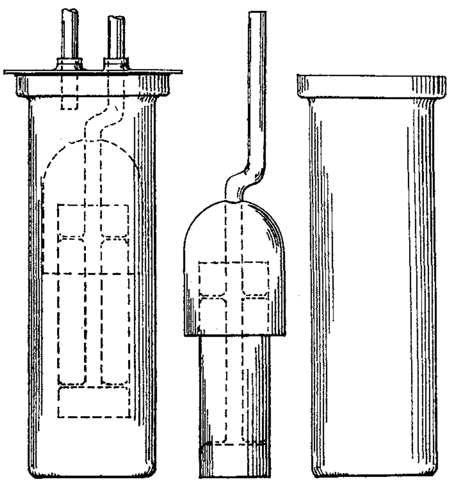

Fig. 2.—This drawing illustrates on an enlarged scale the wash jars shown at 9 and 25 in Fig. 1. For use the jars are filled with fluid to the height of 3 or 4 inches. For full description see text.

carbon dioxide produced by the animal. Air entering through the glass tube passes out of the lower end of the tube into the solution. Since there is a strong current of air circulating there is a great deal of splashing of the fluid. But this splashing is almost wholly confined within the glass cylinder. This upward splashing is entirely caught by the glass bell and directed back down into the jar. The air passes up into the bell, thence downward underneath the lower edge of the bell, thence upward into the upper part of the jar and out through the tube (10) which leads past an air-cock (11) into a glass chamber (three-necked Woulff bottle) which serves as a safety device permitting the operator to see if any fluid, etc., is passing from the machine to the animal. In this reservoir (12) may also be placed water to moisten the air breathed (I have not found this to be necessary), sodium bicarbonate solution to further purify the air (I have not found this to be necessary), or, carbon dioxide or other drugs or gases may be introduced into it especially for experimental purposes, or, oil of bitter orange peel may be placed in it to perfume the air breathed by the patient. From this reservoir the air passes through the pipe (13) to which is connected an ordinary red antimony rubber hose about three or four feet long and having an inside diameter of three-eighths of an inch. This hose carries the air (and anæsthetic) to the face- (or head-) piece. Two special forms of face- (or head-) pieces have been made, one for dogs, the other for man. I shall confine the description mainly to the former since I wish to deal only with animal experiments in this paper.

In the animal head-piece a tapering brass cylinder about two inches in diameter at the top is closed at the bottom (14). Fastened to the bottom is a brass rod which extends downward about two and one-half inches. This rod may be inserted into a hole in the operating board and thus serve to hold the head-piece upright. Into the right-hand side of the cylinder are soldered two brass tubes three-eighths of an inch in diameter. To the outer ends of these are attached the rubber hoses passing to and from the machine. The brass tube carrying air into the cylinder turns upward at a right angle near the center of the cylinder and thus carries the air up near the top of the surrounding rubber bag. To the upper end of this tube it attached (by each end) a long coil of steel wire which forms a closed loop above the tube and serves as a flexible support for the rubber bag (16) which is slipped down over the spring. (The sides of the spring are bent in close together for removing or replacing the bag.) The lower end of the rubber bag fits snugly around the upper end of the brass cylinder. In the left side of the brass cylinder is an opening into which is soldered a brass tube (20) about one and one-eighth of an inch in diameter and about three-fourths of an inch long. The animal breathes back and forth through this tube. A large perforated cork may be placed in this tube and the side tube of a tracheal cannula slipped through the hole in the cork if one cares to open the trachea. If one does not desire to kill the animal then the metallic muzzle (18) as shown in the diagram may be placed over the animal's nose and mouth. This muzzle is a brass cylinder tapering toward the front where it ends in a large opening into which a flange (19) is soldered. This flange slips over the tube (20) on the head-piece, the joint being made air-tight by a broad rubber band. The rear end of the muzzle is slanted at an angle as shown in the diagram, and around the edges on the outside are soldered two rings of heavy wire. A sheet of heavy rubber dam is tied over the rear end, a number 18 wire being used to tie the rubber down in between the two heavy wires soldered to the rim of the muzzle. In the center of the rubber dam a round opening about one and one-eighth inches in diameter is made. This slips tightly over the animal's nose and mouth. The muzzle is held on by four straps which pass to a collar to which each is attached by buckles. I have found this muzzle fairly satisfactory. The objections are that the animal cannot open its mouth well to breathe and saliva is liable to occasionally accumulate within the muzzle. The first objection is liable to be noticed with nitrous oxide, and the latter with irritating anæsthetics.

Within the head-piece and rubber bag a thorough ventilation of the air is assured by having the incoming air pass in near the top of the bag while

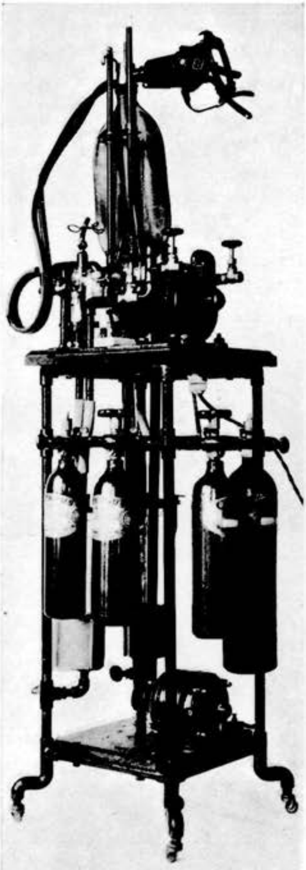

FIG. 3.

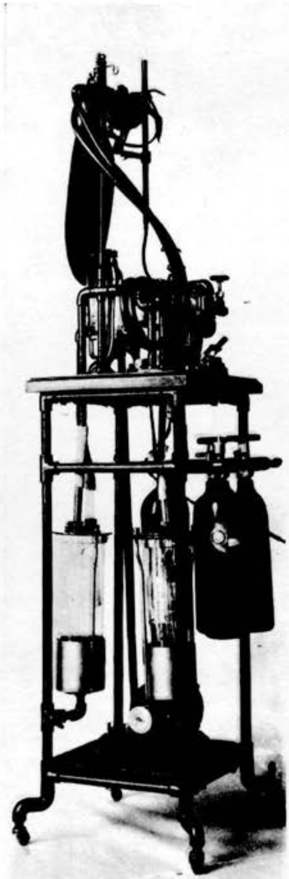

FIG. 4.

Fig. 3.—General view of the apparatus showing the left and rear sides. The muzzle, head-piece and breathing bag as arranged for dogs are shown hanging from a hook at the top of the apparatus. The rubber tubes connecting the head-piece to the apparatus are three or four feet long, thus enabling the anæsthetist to place the apparatus at a considerable distance from the animal when an anæsthetic is being given.

Fig. 4.—General view of the apparatus showing the front and left sides. The position of the wash jars is well shown.

the outlet is at the bottom. This occurs only while the pump is running. If the pump be stopped any desired amount of rebreathing may be secured. Oxygen may be allowed to reach the bag constantly or intermittently as preferred so the oxygen supply to the animal is entirely independent of the rebreathing or of the carbon dioxide content of the bag. (These same principles apply in the face-piece which I have constructed for the human subject.) From the head-piece air passes out through the rubber hose at (17) and back to the machine with which it is connected by the metal pipe (21). These two pieces of rubber hose are clamped side by side by small flat metal clamps. They are thus

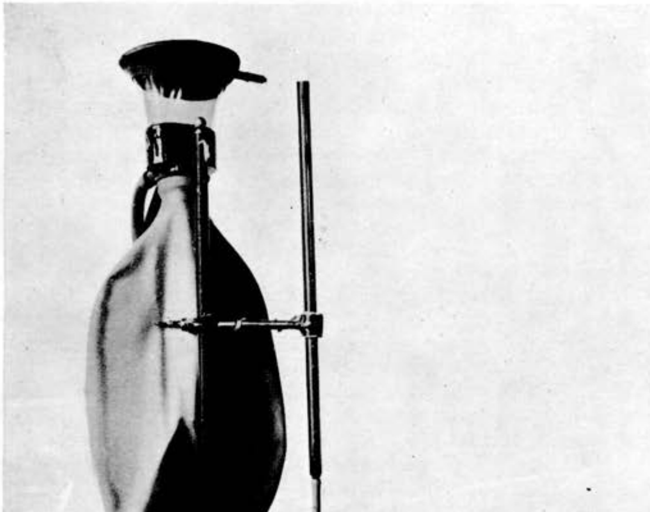

Fig. 5.—View showing the upper portion of the apparatus. The breathing bag and face-piece as arranged for man are shown hanging from a hook at the top of the apparatus.

kept almost entirely out of the way. This head-piece may also be used for intra-tracheal insufflation. The tube leading to the head-piece in this case has a Y-tube inserted in its course near the brass cylinder of the head-piece. From the two forks of the Y-tube short rubber tubes carrying screw clamps pass to the cylinder. One of these tubes connects onto the inlet tube as usual. The other rubber tube is connected with the inside of the cylinder by means of a small metal or glass tube passing through a cork inserted in an opening in the brass cylinder (not shown in the diagram). From this small tube inside the cylinder a catheter may be passed out through the flange (20) and either enter the trachea directly or pass in at the side tube of a tracheal cannula. The correct amount of pressure for the intra-tracheal tube can be obtained by adjusting the screw clamps on the short rubber tubes coming from the Y-tube. (I believe this same principle may very well be used in man, possibly even for nitrous oxide anæsthesia).

Air passing from the animal back to the machine enters the pipe (21) and soon reaches a check valve (22) which is intended as a safety device to pre-

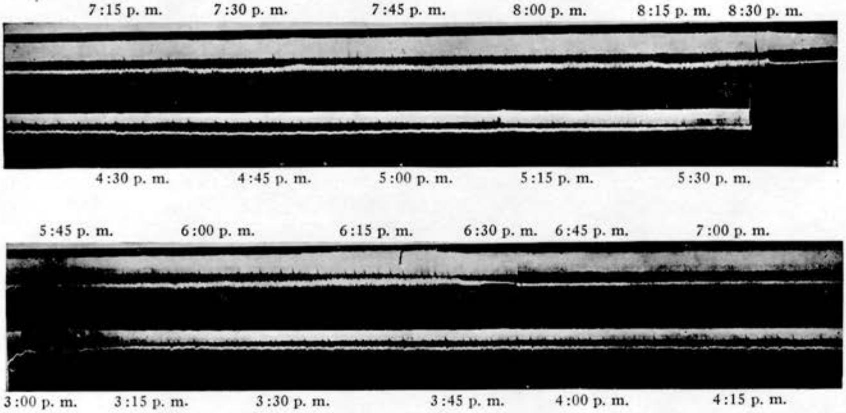

Fig. 6.—This is a photographic reproduction (in two sections) of the blood pressure and respiratory tracings from a dog under *nitrous oxide* anæsthesia. The original tracing formed a single record eighteen feet long as recorded on a slowly moving drum. The total length of duration of the anæsthesia was a little more than *five and one-half hours* and the animal was in excellent condition at the close of the experiment. The time is marked on these records in fifteen-minute intervals. A few breaks in the course of the tracings are due to clots in the arterial cannula, readjustment of the apparatus, etc. The signal magnet (at the base line) shows five-second intervals.

vent any reversal of the air current. From this valve the air passes through the pipe (23) to a second wash jar (25) exactly like the first but containing concentrated sulphuric acid which removes excess moisture from the air. This acid also serves the further purpose of being a good sterilizer of the air leaving the animal's lungs. And the faint possibility of any organic poison being exhaled by the animal is also provided against by the acid. In addition, by placing the acid here, the air which passes on to the pump is made relatively dry and this serves to prevent the pump from rusting.

From the wash jar (25) the air passes through the pipe (26) back toward the pump. But at a short distance from the pump two air-cocks are connected with the tube. Through the first of these cocks (28) such volatile substances as ethyl chloride (kelene), ethyl bromide, somnoform, etc., may be sprayed into the machine through a short piece of rubber tubing carrying a clip (27). Still nearer the pump is another air-cock (30) through which less volatile substances such as ether or chloroform (or ethyl bromide) may be injected from a burette (31). This permits of very accurate dosage, but in this connection one must remember that it is necessary to saturate the air and solutions in the machine to a certain definite degree in order to secure and maintain any definite degree of anæsthesia in the animal. This can be done, however, approximately at least, by injecting some ether, etc., into the machine and running the

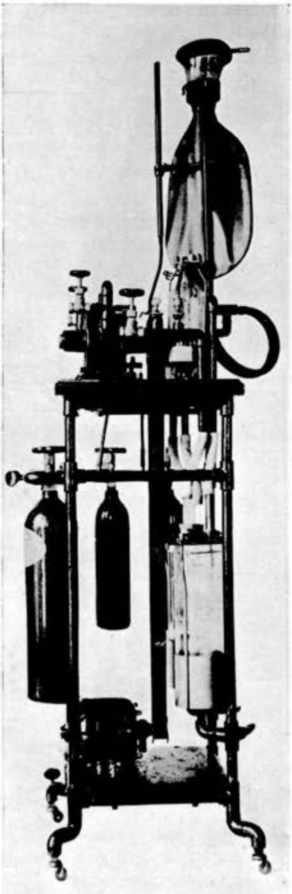

Fig. 7.—General view of the right-hand side of the apparatus. The face-piece and breathing bag as arranged for man are shown at the top of the apparatus. Just to the left of the bag is shown a twenty-five cubic centimetre burette (graduated to tenths of a c.c.) used for the injection of ether, chloroform, etc., into the air system.

pump for a little time before the machine is connected to the animal. It is advisable to do this also with nitrous oxide.

Still nearer to the pump is another valve (34) which is placed in the main air circuit. This valve corresponds with the valve (5) which is also placed in the main air circuit. Valve (33) opens to the outside air. If, while the pump is running, valve (4) be slightly opened a little air will be forced out of the system into the room. This will instantly reduce the quantity of air in the respiratory bag. By watching the bag as one opens the valve (4) cautiously the tension of the air in the bag can be immediately reduced to any desired degree. Conversely by slightly opening valve (33) any desired quantity of air can be drawn into the system. These two valves give the operator complete control at all times of the amount of air in the machine and these adjustments can be made in a few seconds. Through pipe (32) the air current again enters the pump and passes out through pipe (3). This completes the circuit of the air which has lost some of its oxygen to the animal but has gained some carbon dioxide and watery vapor. The carbon dioxide in the next few rounds will be taken up by the soda-lime while the watery vapor will be taken up by the sulphuric acid. The oxygen, however, must be replaced from the outside. This is accomplished by injecting oxygen from an ordinary commercial oxygen tank (35) into the air circuit. From the tank a tube (37) leads to a wash bottle (39) containing water or sodium bicarbonate solution through which the oxygen passes. From the top of this wash bottle a tube leads to the air-cock (6) through which the oxygen is passed into the air system. The extent of distension of the bag and the symptoms of the animal serve as guides for the administration of oxygen.

Nitrous oxide may also be administered in the same manner as the oxygen as shown in the diagram. Carbon dioxide may also be injected into the system from an ordinary commercial tank of the gas by way of the air-cock (11) just in front of the reservoir (12). Number 36 represents a tank of N_2O.

Theoretical Discussion

It is obvious at a glance that no anæsthetic can be used in this machine which will undergo decomposition or be chemically changed by contact with concentrated sulphuric acid or sodium or calcium hydrate solution. By a peculiarly fortunate coincidence sulphuric acid and sodium hydrate solution are the two most common reagents used in the purification of a majority of the anæsthetics in general use. And in this machine the anæsthetic undergoes a constant purification. I have suspected this might be of some real benefit practically. So far I have successfully used nitrous oxide, ether, chloroform, ethyl chloride, ethyl bromide,[2] and the proprietary preparation "somnoform." While my original object was mainly the production of a method by which nitrous oxide anæsthesia might be made cheaper and safer, thereby extending its use particularly to that large and unfortunate proportion of our population which must depend on charity for its surgery, I am now inclined to believe that the method may well be used for a majority of the anæsthetic substances now known.

It is one of the basic principles of pharmacology that most anæsthetic substances which are administered through the lungs by inhalation are almost totally excreted again by exhalation from the lungs. Such small quantities of the common anæsthetics as might disappear in the tissues would probably have no influence whatever on the use of this method. By means of the constant circulation of the air within the machine the exhaled anæsthetic is simply carried around, washed through the sulphuric acid and sodium hydrate solution and again returned to the animal for rebreathing. It is thus seen that so long

[2]Ethyl bromide "is with much difficulty saponified by potassium hydroxide and it is not attacked by sulphuric or nitric acids" (New and Nonofficial Remedies, 1915, p. 26). I have not experienced any difficulty in this direction in the use of ethyl bromide.

as no air is allowed to enter the machine from without and none is allowed to escape from within, the concentration of any given anæsthetic vapor within the machine and in the tissues of the animal must remain practically constant. Consequently the degree of anæsthesia should also remain constant. It is easy enough to carry this out with such a substance as ether. But it is somewhat more difficult with the milder anæsthetics such as nitrous oxide or ethyl chloride. With these bodies it is often difficult for one to interpret the degree of analgesia or anæsthesia present *in dogs.* I suspect it might be easier to do this in man. In dogs under ethyl bromide it may sometimes be found, for example, that touching the cornea will not cause winking and yet the animal may struggle about rather violently entirely independently of the carbon dioxide or oxygen present, and when one may feel very sure that the animal is entirely unconscious of painful sensations. One is always tempted then to give more of the anæsthetic, but a slight increase in the concentration of the vapor may throw the animal into a dangerous condition. It would seem probable in such cases that the drug may have been performing its full therapeutic function as an analgesic and if one could control the struggling this analgesia might easily be maintained for a prolonged period. I suspect that, particularly with ethyl chloride, this might be done in the human subject (e. g., in obstetrics) very much more satisfactorily than with the dogs on which I have experimented. With ether, however, one can check the struggling at an early stage of the anæsthesia and by carefully injecting small quantities (½ to 1 c.c.) at a time the animal may be brought to a condition in which it will just wink the eye when the cornea is touched and yet the skeletal muscles will all be relaxed and no voluntary movements may occur. One may stop giving the anæsthetic at this point and then maintain this stage of anæsthesia for twenty or thirty minutes. But if the degree of saturation of the tissues of an animal with an anæsthetic remains constant then the animal will tend to gradually fall more and more under the influence of the drug.

It is neither necessary nor desirable that the pump be running continuously. It has been repeatedly and most excellently shown by Yandell Henderson that a moderate accumulation of carbon dioxide may be of decided benefit to an animal under anæsthesia. By simply stopping the pump in this machine one can allow any extent of rebreathing or of carbon dioxide accumulation he may desire. And during this period he may or may not give the animal oxygen as he sees fit. Or he may even give the animal carbon dioxide from a tank if he wishes to do so. On the other hand if one prefers he may keep the pump running all the time and thereby almost entirely prevent any carbon dioxide accumulation within the breathing bag.

It has been repeatedly shown that warmed vapors are more satisfactory for anæsthesia than those which are cold. This machine automatically warms all gases or vapors circulating through it to approximately room temperature. This is accomplished first by the sulphuric acid which becomes warm from the absorption of moisture and second by the pump which develops heat from its friction in turning and by compression of the air passing through it. The alkali solution usually remains at practically the same temperature as the room and this determines the temperature of the air as it passes into the bag. The bag should be large, perhaps about one and one-half or two times the vital capacity of the animal (or even larger). I have tried several different bags. In every case I have found that the larger the bag is the better the results are. When the air reaches the bag, which is made of thin rubber and has a large surface, then the temperature of the air in the bag should soon reach almost exactly that of the surrounding atmosphere. In rebreathing the animal itself quickly warms the air in the bag.

The air breathed by the animal should be properly moistened (perhaps of between 50 and 70 per cent relative humidity). I have had no difficulty in this respect with the machine. But if desirable water may be placed in the reservoir (12) to moisten the air before it passes to the bag. Too much moisture in the air I believe can be satisfactorily provided against by increasing the quantity of sulphuric acid in the wash jar [or possibly by placing acid in the reservoir (12)].

I have, unfortunately, not been able so far to make any very careful *practical* determination of how much sodium (and calcium) hydrate may be required for this method of anæsthesia by the hour. The amount must necessarily vary greatly in different animals and with different anæsthetics. The cost of the oxygen will probably represent the chief expense of anæsthesia by this method. And this is determined by the amount of the gas *actually consumed* by the animal. The sulphuric acid may be purchased very cheaply and this expense cannot be great. It should be possible to calculate approximately the amount of hydroxide and of oxygen which would be required for an anæsthesia of any given length of duration. "In an average man weighing 70 kilos the mean production of carbon dioxide is about 800 grammes (400 litres) in twenty-four hours, and the mean consumption of oxygen about 700 grammes (490 litres).[3] But there are very great variations depending upon the state of the body as regards rest or muscular activity, and on other circumstances. In hard work the production of carbon dioxide was found to rise to nearly 1,300 grammes, and in rest to sink to less than 700 grammes, the consumption of oxygen in the same circumstances increasing to nearly 1,100 grammes and diminishing to 600 grammes. In rest, in moderate exertion, and in hard work, the production of carbon dioxide was found to be nearly proportionate to the numbers 2, 3, and 6 respectively."[4]

The production of carbon dioxide in an animal under deep anæsthesia must be very much less than during conditions of normal activity. And a corresponding decrease in the consumption of oxygen also occurs under the anæsthetics. It is often striking to observe during an anæsthesia by this method how small a quantity of oxygen is really required in order to keep the circulation and respiration in good condition. Using the above data as given by Stewart I have made a rather unsatisfactory theoretical calculation which shows that the cost of nitrous oxide anæsthesia for a dog weighing 15 lbs. (1/10 the weight of an adult man) should be approximately $0.0399 per hour. I believe that I have used more material than this figure would indicate in my experimental observations, especially of oxygen and sodium hydrate. The nitrous

[3]It will require 1,455 grammes (3.2 lbs.) of *pure* $NaOH$ to change 800 grammes of CO_2 into Na_2CO_3. This hydrate would cost about $1.28. Commercial $NaOH$ is seldom pure, however. Seven hundred grammes of oxygen per 24 hours corresponds to about 5.36 *gallons* per hour. In large cylinders oxygen sells for about 2 cents per gallon, in small cylinders at from 4 to 6 cents per gallon.

[4]G. N. Stewart, Manual of Physiology, 5th edition, p. 214.

oxide which I have used is, I suspect, within the limits of its relative proportion of the cost indicated. I have, however, wasted a good deal of oxygen and sodium hydrate in various experimental procedures. The cost should be less with ether or chloroform than with nitrous oxide. With respect to ethyl chloride, ethyl bromide or "somnoform" I have usually found from five to ten cubic centimetres sufficient for a fifteen pound dog. (From ten to twenty cubic centimetres would probably be sufficient for a man for the "dead space" of the machine requires as much vapor for a dog as for a man.) These drugs are best used when supplied in small glass ampouls of 3 c.c. or 5 c.c. capacity. A short rubber tube with a piece of cotton or gauze in the lower end is attached to the nozzle of the air-cock (28) and the drawn-out end of the ampoul is inserted like a cork (air-tight) into the upper end of the tube. The cock is then opened and the pump started. When all is ready the end of the glass ampoul is snapped off by bending the rubber tube and the drug quickly enters the air system. One must watch that the sudden entrance of a large volume of vapor does not over-distend the breathing bag. This can usually be checked by stopping the pump suddenly which tends to retard the passage of the vapor forward into the bag. For this reason small ampouls of very volatile bodies are better than large ones.

The duration of anæsthesia by this method is usually limited only by the convenience or desire of the operator. With nitrous oxide I have been easily able to keep dogs anæsthetized for periods of time extending up to a little more than *five and one-half hours* and the animals are in excellent condition at the close of the anæsthesia. The animal may often stand up and walk around the room within one and one-half or two minutes after it is removed from the nitrous oxide, but after a very long anæsthesia usually from five to nine minutes are required for complete recovery. With ethyl chloride one and one-half hours is the longest time that I have so far tried to keep an animal anæsthetized. (This is not a good anæsthetic for dogs.) With ethyl bromide I have kept dogs anæsthetized for periods up to a little more than an hour. With ether or chloroform the duration of the anæsthesia may be regulated practically entirely by the desire of the anæsthetist.

Summary

1. A new method for the production and maintenance of general analgesia or anæsthesia is described.

2. A description of the device required for the production of analgesia or anæsthesia by this method is given.

3. Great care has been exercised to confine the descriptions in this article strictly to results which have already been obtained by experiments on dogs. (But the conclusion is easily drawn that similar results may be obtained in man.)

Current Researches in Anesthesia & Analgesia

F. H. McMECHAN, A.M., M.D., *Editor*

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The Closed Circle Method of Administration of Gas Anesthesia.*

Brian C. Sword, M.D., Anesthetist, New Haven, Conn. President Eastern Society of Anesthetists.

THE CARBON DIOXID absorption method of anesthesia, as first advocated by Professor D. E. Jackson,[1] of the University of Cincinnati Medical College, and later developed by Dr. Ralph Waters, of the University of Wisconsin, has done more to minimize the difficulties with gas anesthesia than any other procedure in the past fifteen years. The fundamental principles upon which this method is based are *first,* the utilization of a given amount of oxygen by the patient; *second* the elimination of the carbon dioxid in the exhaled breath; and *last* the fact that almost complete elimination of all the usual anesthetic agents by the lungs, in exactly the same form as that in which they were absorbed through the alveolar membrane.

Apparatus

THE APPLICATION of the above principle is one of choice. The one which is more commonly employed—namely the cannister and bag at the face—has to me one objection, that it is too close to the field of operation. In an effort to continue with this method of anesthesia, and at the same time remove the cannister and bag away from the field of operation, I consulted Prof. Yandell Henderson of Yale University School of Applied Physiology, at which time the possibilities of this method were discussed. The present apparatus was constructed with the cooperation and aid of Dr. Richard v. Foregger.

The Apparatus.—By the closed circle method of anesthesia, an apparatus is so constructed that the inspiratory and expiratory phase run in the same direction. This requires a separation by means of valves and two tubes, one for inspiration and one for expiration connected by a "Y", so that it may be applied to a mask. The tubes in this apparatus are of soft rubber two feet in length and three quarters of an inch in diameter covered with a soft wire mesh to prevent kinking. These are attached to a cannister by means of flutter valves, one for inspiration and one for expiration. At the bottom of the cannister a 10 by 10½ inch rebreathing bag is placed. With the circle respiration it is physically of little influence where the bag is placed, although the bag becomes of less importance because, as far as concerns the mixing expiratory and inspiratory phases, like two streams running in the same direction, it is bound to occur and uniformly so, however, the bag hereto is an equalizer of pressure conditions.

Possibly at this point it would be advisable to review the relation of volume and pressure in a bag. The following test figures on the proportional increase of pressure and volume contents in a 10½ inch breathing bag are as follows:—

Capacity atmospheric pressure[2]	4405 cc.
Capacity atmospheric pressure at 1 mm. of mercury	4435 cc.
Capacity atmospheric pressure at 2 mm. of mercury	4767 cc.
Capacity atmospheric pressure at 5 mm. of mercury	5271 cc.
Capacity atmospheric pressure at 10 mm. of mercury	7161 cc.

I mention these figures because I find the best results are maintained when the closed circle method of anesthesia is being conducted with about 10 mm. Hg. of pressure in the bag. The tubes are so arranged that the inspiratory flow is direct from the bag and the expiratory flow through the soda-lime cannister. The soda-lime, by the way, I believe, should be the dry and size for 8 x 10 mesh. For those of you who are not familiar with soda-lime, it is a dehydrating agent composed of 50%

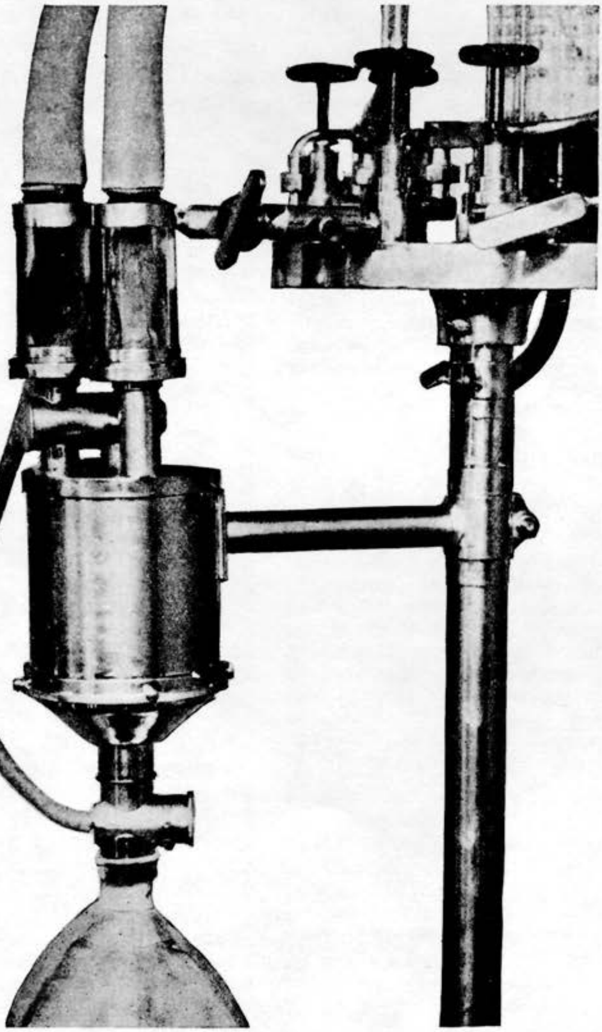
*Presidential Address presented during the Eighth Annual Congress of Anesthetists, the Associated Anesthetists of the United States and Canada in Joint Meeting with the International Anesthesia Research Society and the Mid-Western Association of Anesthetists, and the Eastern Society of Anesthetists, Clinical Congress of Surgeons Week, Congress Hotel, Chicago, October 14-18, 1929.

calcium oxid and 50% sodium hydroxid which removes expired carbon dioxid and moisture. At the top of the canister one valve is placed in such a manner that the expired carbon dioxid may be exhaled through the soda-lime, or passed directly to the rebreathing bag. This is essential for oftimes it is necessary to add carbon dioxid in the rebreathing bag, as for example in depressions of respiration resulting from the following causes:—

1. Psychic disturbance.
2. Preliminary medication.
3. Reflex from surgical manipulation.
4. Too deep or too light surgical narcosis.

Preliminary Medication

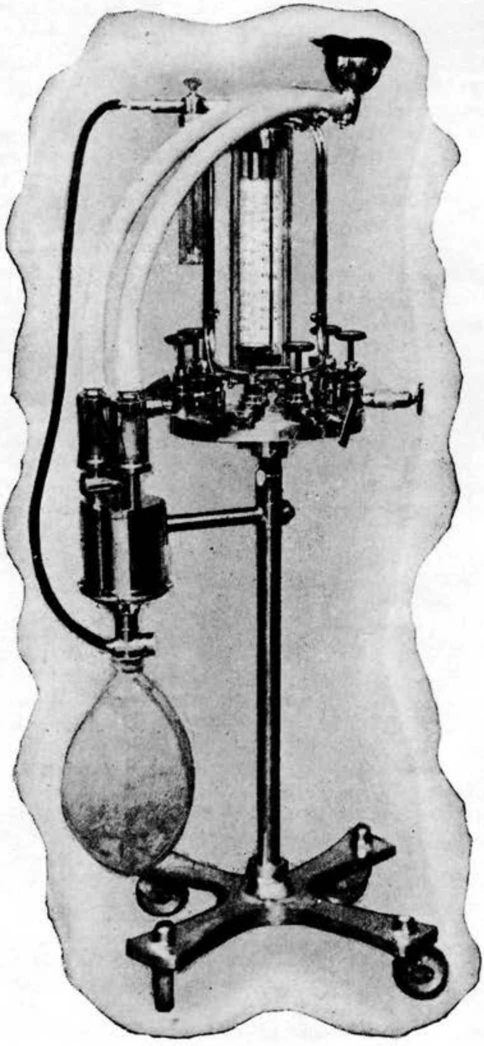
I BELIEVE, before, entering upon a description of the method of administering, we should first discuss or briefly mention some factors



which are paramount in the administration of any type of anesthesia:—

A. Patient.
  1. Temperament (neurotic).
  (phlegmatic).
  2. Age.
  3. Type of operation.
B. Surgeon.
  1. Temperament.
  2. Operative ability or his operative time.
  3. His method of handling tissue and hemostasis.

I am firmly convinced that the more care and study rendered to the patient, and the more intelligent the discussion of factors involved relative to the operation with the surgeon before hand, render a more satisfactory end result. My routine is to administer a ¼ gr. of morphin 45 minutes before induction time, and twenty minutes later 1/100 or 1/150 of scopolamin. I prefer scopolamin to atropin for the reason that I



believe it is the only true phychic sedative that we have in our armamentarium. In cases that last over 1½ hours where there is no contraindication, a second dose of morphin, gr. ¼. is administered.

Technique of Administration

AFTER THE PATIENT is placed on the operating table, I insert a rubber cork about ½ inch in thickness between the upper and lower centrals. To this is attached a short cord which connects the cork with a Miller airway. A Gwathmey face mask is then applied and over which one and sometimes two Boothby cuffs are tightly pulled down. This is, as you see, an attempt to avoid any possible leaks. If one is to succeed with this method it is essential that leaks be avoided, for in there presence nitrogen enters the circuit, and the following symptoms are observed:—

1. Resistance to breathing.
2. Cyanosis.
3. Sweating.
4. Smoothness of anesthesia impaired.

This is furthermore reinforced by a strap which is fastened around the head and is placed over the top of the mask. The rebreathing bag is now filled up with approximately 4 to 4½ liters of nitrous oxid. The "Y" connection to which the inspiratory and expiratory tube from the cannister are attached is placed on the mask and the bag opened for about 30 seconds, between 300 and 400 cc. of oxygen are allowed to run into the bag. The nitrous oxid is shut off, and 1 to 1½ liters of ethylene per minute are introduced. In cases where profound relaxation is required, the valve on the ether bottle is opened approximately half-way, so that a small amount of ether vapor will be taken into the circulation, but not enough to produce bubbling. As you all know it takes roughly 5 to 8 minutes to produce profound surgical narcosis with ether or, as Dr. Robt. Ferguson, of the Squibb Laboratories advocates, roughly, 4 oz. including the induction during the first hour. With the valve on the ether bottle set so that ether vapor is picked up, but no bubbling, we use approximately one dram a half hour. This is obviously a sufficient amount because we are working through the closed circuit, which prevents escape through expiration. At the present time there is work being done in the Henderson-Haggard laboratory which tends to show that there is a marked synergism between ethylene and ether, and while I am not permitted at the present writing to state figures, it would seem from this work that there might be an explanation for actual smaller amounts of both ethylene and ether required to produce surgical narcosis.

After the patient has reached the stage of surgical narcosis, the mask is lifted from the face, the rubber cork is removed and the Miller airway inserted, the mask re-applied and the anesthetic continued. This, as you see. insures at all times a patent upper respiratory tract. The maintenance of the surgical narcosis as to the amounts used varies in accordance with the particular type of operation, the length of time and the metabolic rate of the patient. I mention this last paragraph, for in my experience I find that the closed circle method of anesthesia is operated best between 300 and 400 cc. of oxygen per minute. This, by the way, is after the ethylene, nitrous oxid or combination, ethylene-nitrous oxid or ether, if used, have been shut off. I also find it necessary, because of the narrow limits of our operating narcosis, to have direct flows of both oxygen and nitrous oxid into the bag, for at times it is quite essential to increase either one quite rapidly. For those of you who are using a metric apparatus I would advise that you all have by-passes placed on the nitrous oxid as well as the oxygen.

Clinical Observations During Maintenance

DURING THE NARCOSIS, all other factors being equal, the *pulse* remains normal or close to normal for the particular patient anesthetized; the *respiration* is quiet, somewhat shallow, yet there is no dyspnea or resistance; the color is without cyanosis and there is an absence of dehydration. The blood pressure changes are varied more or less with the stage of the narcosis also surgical manipulation, hemorrhage, and so forth.

The rapidity in which the anesthetic may be deepened or lightened makes me often wonder if through certain periods we are not in an analgesic state rather than true anesthesia. This flexibility, is a great convenience to both the surgeon and anesthetist.

Post-Anesthetic Results.—The question of postoperative nausea and vomiting I am not going to discuss for the reason that I believe there are so many factors which enter into this, that it is an unfair comparison. Yet, however, I will say, there is no greater amount of nausea following this type of administration than any other. The patient usually awakens in from one to five minutes after termination of the anesthetic, and if the surgical procedure has not been too severe, the patient feels quite comfortable in from 15 to 20 minutes.

Summary and Conclusions

IN CONCLUSION, I have used this method in about twelve hundred cases and find it most admirably adopted for:—

1. Orthopedic surgery.
2. Obstetrics.
3. Gynecological surgery.
4. General surgery.

It offers some very interesting problems:

1. The absence of any sweating which, in operations of long duration is a very desirable feature.
2. The quietness of the abdominal viscera with practically no blowing or pushing in the presence of comparative light anesthesia.
3. No disturbance to body functions as evidenced by the pulse, blood pressure and respiration.
4. The amount of gas consumed per minute after surgical narcosis has been established varies to a great extent upon the following conditions:—

(a.) Effects of preliminary medication. (b.) Amount of ether used during the first fifteen minutes. (c.) Type and location of operation. (d.) Surgeon and his willingness to cooperate with the anesthetist.

In a previous paragraph I stated that after induction a liter to a liter and a half of ethylene a minute was turned on. This, by the way, is for cases in which continuous deep surgical relaxation is necessary when this is not needed, I might say roughly the amount consumed per hour is around 25 to 30 liters.

Advantages:—

1. Ease and rapidity of induction.
2. Flexibility.
3. The margin of surgical narcosis seems greater thereby insuring a smooth third stage anesthesia.
4. Simplicity.
5. Economical.
6. The ease in changing from one anesthetic to another.
7. The removal of the bag and canister from the field of operation.
8. Ideal for obstetrical analgesia.
9. Better relaxation.

Disadvantages:—

1. Danger from prolonged rebreathing.
2. Inability to change soda-lime during operation.

In closing if, in this brief paper, I have stimulated a desire for others to try this method, my time will have been well repaid.

1418 Chapel St.

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Spinal Anesthesia. A. S. Jackson, Madison, Wis. *Annals of Surgery*, February, 1930.

JACKSON IS AN ardent advocate of spinal anesthesia, when properly administered. He says that it offers the safest anesthetic from the standpoint of the patient and the most ideal one for the comfort of the surgeon. Among the 1,000 anesthesias reported on by him there were fifty complications: mild distension in twenty-five cases; headache in fifteen; transient paresthesia in four; pneumonia (aspiration) in one, and phlebitis in one. In two cases the needle broke but was removed successfully. The operations performed included appendectomies, cholecystectomies, perineal and rectal operations, cystoscopic examinations, pelvic laparotomies, hernias (all types), gastric and duodenal resections, orthopedic operations (leg, hip and spine), cystoscopies and prostatecomies and radical breast amputations.

(Reprinted from Anesthesia and Analgesia, February, 1924)

Clinical Scope and Utility of Carbon Dioxid Filtration in Inhalation Anesthesia.*

By R. M. Waters, M.D., Sioux City, Iowa.

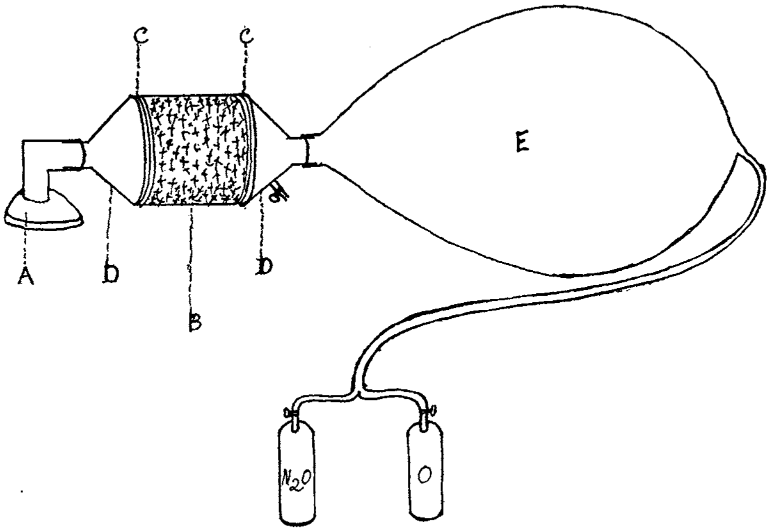
A CAREFUL SEARCH of the literature has not revealed reference to the use of carbon dioxid filters in connection with administration of inhalation anesthetics until 1916, when a paper by Jackson and Mann was published,[1] describing a cabinet in which they kept dogs anesthetized for long periods by filling the cabinet with nitrous oxid, a pump being attached to circulate the nitrous oxid through an alkali which absorbed the carbon dioxid. A tank of oxygen attached, which added oxygen slowly, cared for the metabolic needs of the dogs as to oxygen. No harm came to these dogs even after long periods of time. Since that demonstration of complete rebreathing, more or less successful use has been made of the principle for practical anesthesia of laboratory animals. It is a regretable fact that Jackson has not had an opportunity to further develop this excellent experimental work along clinical lines until very recently.

The Filtration Device

AFTER TWO and a half years of effort to demonstrate the practical usefulness of this principle, I feel that the results may be of general interest. Experimentation with complicated valves, tubing and motors had led to the usual conclusion: The simplest device is the most practical. This consists of a face mask, a container for granular soda lime of sufficient diameter to allow unobstructed respiration and of sufficient length to assure complete absorption of all the carbon dioxid during the time the expired gas is passing through it. This soda lime container or filter, opens into a large rubber bag opposite the opening into the face mask. A rubber tube leading from the filter or bag to nitrous oxid and oxygen tanks completes the apparatus necessary. An added opening through which to drop ether or chloroform into the soda lime filter, or through which ethyl chlorid may be sprayed into it, is necessary if these agents are to be used. Other gases than nitrous oxid, such as ethylene are attached parallel with the nitrous oxide tank.

The important point is to avoid leaks in the apparatus itself and in the contact of the mask with the face. No valves of any sort need enter into the construction. In fact, with the exception of the filter itself, parts of apparatus already in the hands of every anesthetist are quite sufficient to constitute a useful equipment for applying the principle of complete rebreathing.

*Read during the Second Annual Congress of the National Anesthesia Research Society, in Joint Meeting with the Interstate, Mid-Western and Chicago Anesthetists, Auditorium Hotel, Chicago, October 22-24, 1923.



DIAGRAMATIC SKETCH OF CARBON DIOXID FILTRATION PRINCIPLE.

A. Mask with well fitting rubber face cushion.
B. Cylinder of granular soda lime 3½ inches in diameter and 4 inches long.
C. Wire gauze dams to retain soda lime in place.
D. Cone shaped ends of filter, the distal one bearing a stop-cock through which to obtain gas for carbon dioxid test.
E. Rebreathing bag.

Practical Results

THE PRACTICAL results, I shall innumerate under several headings: 1. *Economy*: On theoretical grounds, one gallon of nitrous oxid with oxygen sufficient to supply the metabolic needs of the patient should suffice indefinitely. Practically, an occasional emptying and refilling of the apparatus may be necessary due to air leaks. Five to ten gallons of nitrous oxid an hour will usually suffice. With a drug requiring greater dilution, such as ethylene, one filling of the system and constantly added oxygen is enough.

2. *Convenience*: Small quantities of drugs are used. The apparatus is simple and easily understood. There is no waste of drugs into the operating room. Disagreeable odors of drugs such as ether and etylene can be kept away from the surgical teams and extremely volatile drugs such as ethyl chlorid are more easily controlled. This method solves the problem of continuous ethyl chlorid anesthesia.

3. *Welfare of Patient*: Body heat and moisture are not lost. The use of filters has changed my attitude toward rebreathing. The principle of fractional rebreathing as held by McKesson, causing the patient to rebreathe approximately his excess tidal air over waking conditions seemed sound if one accepts Henderson's work on carbon dioxid.[2] I believe now, however, that this bene-

fit was not due to retained carbon dioxid, but to retained heat and moisture. This belief is supported by work published from a Rio de Janeiro laboratory[3] some time ago inferring that Henderson's results in which he caused shock in dogs by means of induced hyperpnea, were due, not to excessive loss of carbon dioxid, but to loss of body heat and moisture. Attempts to duplicate Henderson's findings in Rio de Janeiro failed, because of the warm humid condition of the air in the Brazilian laboratory. Careful recording of pulse rate, systolic and diastolic reading, every five minutes during 200 anesthesias using the filter with complete rebreathing and complete filtration of carbon dioxid, as compared with many hundred such records made while fractional rebreathing was practiced, reveal fully as satisfying results with the filters.

4. *Limitations*: Requiring as it does, an air tight connection with the air passages, all mouth and nose work precludes the possibility of the use of the filter to full advantage.

Cautions to Be Observed

1. *A constant addition of oxygen* is necessary and must be maintained without fail. This fact must be clearly borne in mind and the addition of oxygen carefully kept up to physiological requirements. The longer the maintenance the more important this fact becomes.

2. *Fresh Filters*: Care must also be taken to replenish the alkali absorbent in the filter (I use granular sodium and calcium hydrate). Expired gases beyond the filter can be tested for carbon dioxid by bubbling through a weak solution of barium hydroxide or lime water. The barium hydroxide test results in a clouding of the solution with very small quantities of carbon dioxid. I have made it a rule to change filters after five hours use. The size and shape of filters must be taken into consideration, and one must err on the safe side. Filters used ten hours have been found efficient as to carbon dioxid absorption, but a certain amount of caking occurs, due to water absorption which may cause noticeable obstruction after several anesthesias.

3. *Bacterial Contamination*: The filters can be sterilized in autoclaves with the operating room linen. Ethylene corked in the filter for five minutes will also kill all bacteria, but leaves a disagreeable odor which must be thoroughly blown out. Whether pure nitrous oxid corked in the filter will accomplish a safe sterilization I am unable to state at this time.

In Conclusion

1. The total rebreathing of nitrous oxid and other anesthetic drugs is practical by means of the use of a carbon dioxid filter interposed between the face mask and a rebreathing bag.

2. This method is available for all closed mouth operations of whatever length.

3. The technic is not made more difficult, the two important points being the prevention of air leaking into the apparatus and the careful maintenance of oxygen supply.

4. For hospital use, the only distinct advantage which can be positively stated at this time is marked reduction of expense—one of the chief objections to nitrous oxid as now used. Twenty-five to fifty cents an hour should easily cover all

expense of nitrous oxid gas, oxygen and filter replacements.

5. For work outside the hospital, in addition to the small expense is the great advantage of reduced bulk and weight of apparatus and containers. For some time now, I have carried in my car an apparatus assembled from parts of my old equipment which weighs less than thirty pounds. This grip contains two 50 gallon nitrous oxid tanks, two 15 gallon oxygen tanks and a filter, rebreathing bag, and mask. There is also room for a tube of ethyl chlorid and a bottle of ether. With this apparatus, I am equipped for several hours anesthesia without the necessity of lugging apparatus and tanks into a private home and assembling them.

107 GILMAN TERRACE.

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