INTRATRACHEAL ANÆSTHESIA.*

A. BY NITROUS OXIDE AND OXYGEN.

B. BY NITROUS OXIDE AND OXYGEN UNDER CONDITIONS OF DIFFERENTIAL PRESSURE.

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A. The introduction of intratracheal anæsthetization by ether immediately suggested the desirability of using nitrous oxide and oxygen by the same method.

Much evidence exists that surgery may be made more successful by the more general use of nitrous oxide anæsthesia. Both nitrous oxide and intratracheal anæsthesia have acknowledged advantages, and it becomes, therefore, a matter of importance to combine the good features of each.

Cotton, Boothby, Gwathmey and others have successfully kept patients under surgical anæsthesia by nitrous oxide, after a preliminary etherization, by simply allowing the mixed nitrous oxide and oxygen to stream in through the intratracheal catheter in the same manner that ether vapor is given intratracheally.

Such a method is wasteful of the anæsthetic, which under these conditions must be supplied in such excess that, at each inspiration by the patient, there is a very little dilution of the anæsthetic within the trachea by air which, otherwise, would be drawn through the larynx around the intratracheal catheter. There must, in other words, be such a supply of nitrous oxide, that only a minimum amount of air is drawn in around the intratracheal catheter during inspiration. To supply such an excess of anæsthetic is not perhaps objectionable when ether is used, as ether is cheap in comparison to nitrous oxide, and further it is a comparatively easy matter to secure a sufficient degree of concentration of ether vapor

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to anæsthetize satisfactorily a patient by the usual intratracheal technic. Moreover, the escape of the air around the tube during the intratracheal anæsthesia by ether has been encouraged for the purpose of preventing the inhalation of blood and mucus during intra-oral operations.

Nevertheless, during ether anæsthesia the escape of large quantities of ether in the room is at least unpleasant, even if the waste of the ether is not considered a matter of importance.

In order to overcome these difficulties, in connection with anæsthesia by nitrous oxide, the writer has devised the little bag illustrated in Fig. 1. It is tubular in shape possessing a double wall so that it is capable of distention whether fitted over the catheter or not. It is pulled over the latter to a short distance above its extremity, and after the catheter is inserted into the trachea, the bag is distended with air through the fine rubber tube attached to it, thus effectually closing the space between the outside of the catheter and tracheal walls. The patient may now breathe in and out through the intratracheal catheter, and when the external end of the latter is attached to a respiration bag, receive the nitrous oxide and oxygen directly from the tanks undiluted with air.

Fig. 2 represents the arrangement of the various parts of the apparatus used for intratracheal anæsthetization by nitrous oxide and oxygen according to this method. (4) is a reducing valve, the legs of which are detachable so that everything necessary for this method of anæsthesia can easily be carried in a small bag.

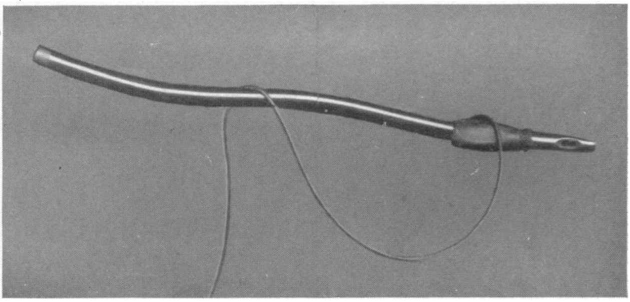
The tank is attached to the reducing valve, as illustrated, and because of the latter, a regular flow of the gas passes to the wash bottle (3) through the tube (2). Into the same bottle, upon the opposite side of a central partition the oxygen enters through the tube (8).

The purpose of the wash bottle is to furnish a visual method of estimating the flow of the gases. We are perfecting a more exact method of measuring the gases. By means of the third tube the mixed gases are conveyed to the respiratory bag (6). This bag must never be allowed to become completely filled and, in order to guard against distention, it is wise to insert a safety valve between it and the wash bottle. The respiratory bag is attached by its opposite end to a cylindrical valve. The latter is made of two cylinders, the external one of which possesses three openings upon one side (A, E, D) the intake side, and one (C) opening upon the opposite side, to which the tube passing to the intratracheal cannula (7) is attached.

The openings through the inner cylinder are so arranged that as it is rotated, one of the three openings (A, E, D) entering the cylinder upon one side, may be thrown into communication with the single opening (C) emerging upon the opposite side.

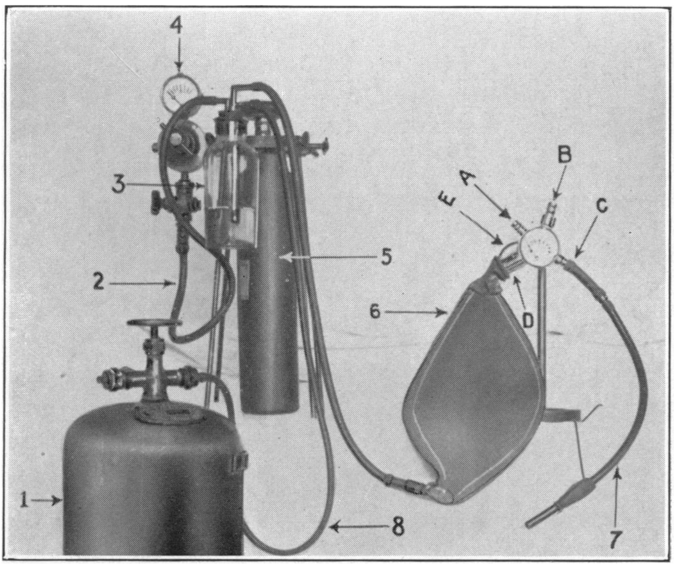
According as opening D, E, or A is placed in communication with the tube C emerging from the cylinder, the patient inhales, from the respiration bag and exhales through B into the external air or rebreathes back

FIG. 1.



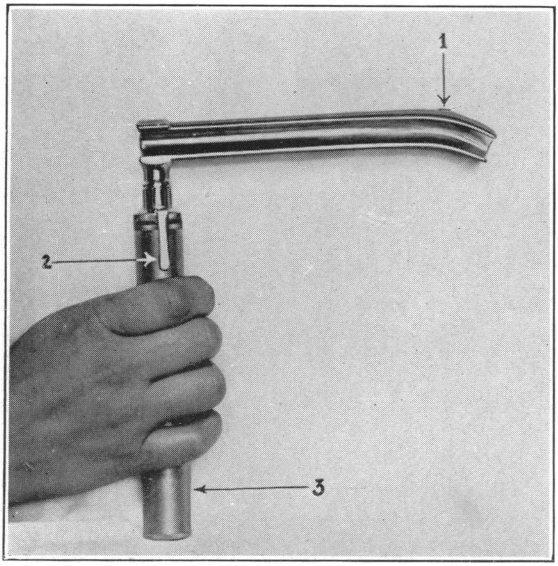
Intratracheal catheter surrounded by distensible rubber bag for occluding the trachea.

FIG. 2.



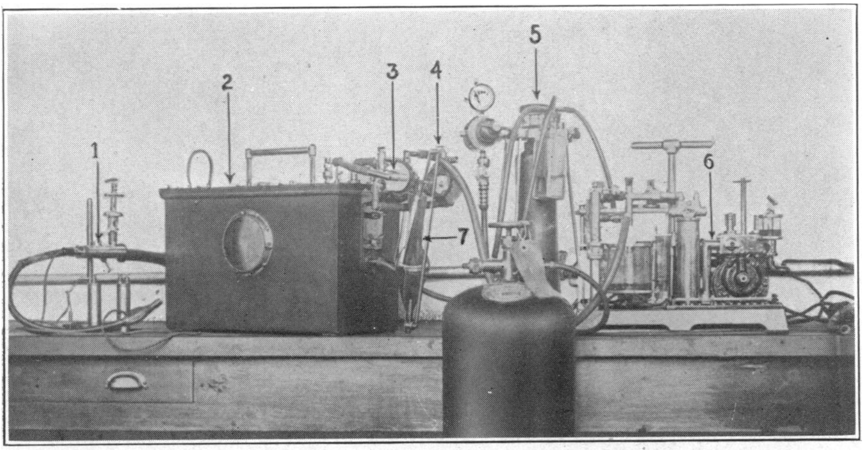
Arrangement for apparatus for intratracheal anæsthesia by nitrous oxide and oxygen. 1, oxygen tank; 2, rubber tube conveying nitrous oxide from the reducing valve (4) to the wash bottle (3); 5, nitrous oxide tank; 8, rubber tube conveying oxygen from the oxygen tank (1) to the wash bottle (3); 6, respiration bag; 7, intratracheal catheter. A, B, C, D, and E, openings in valve controlling the amount of rebreathing.

FIG. 3.



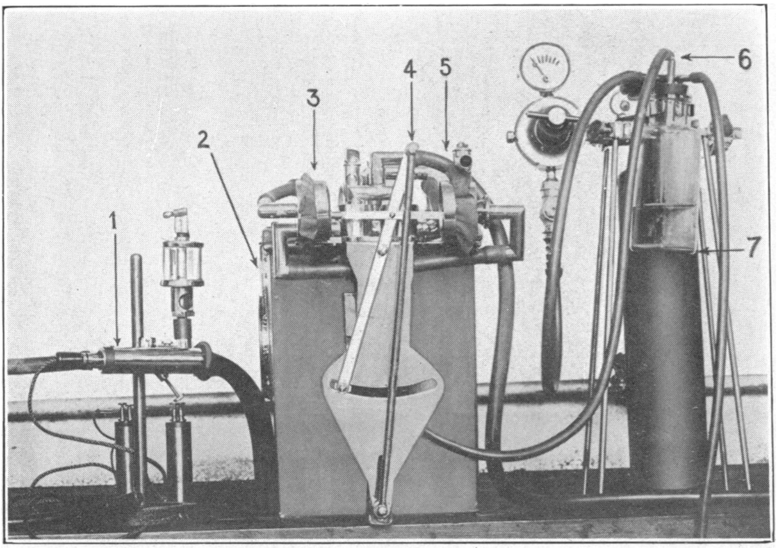
Speculum for catheterizing the trachea; 1, lamp; 2, spring which closes the circuit in the dry cells contained in handle (3).

FIG. 4.



Arrangements for apparatus for nitrous oxide anæsthesia under conditions of positive pressure. 1, valve controlling amount of rebreathing; 2, aluminum box containing respiration bag; 3 and 4, tambours controlling the position of valves which permits of rise and fall of pressure within the box (2); 5, nitrous oxide tank and reducing valve; 6, motor; 7, spring controlling height of pressure within box (2).

FIG. 5.



Arrangements for spring, tambours, and valves attached to the end of aluminum box described in Fig. 4. 1, rebreathing valve; 2, aluminum box; 3 and 5, tambours controlling position of valves; 4, spring controlling height of pressure within box; 6, nitrous tank with reducing valve attached; 7, wash bottle measuring the flow of nitrous oxide and oxygen.

and forth from the inhalation bag or may breathe pure air. In occasional cases, in which a more profound anæsthesia may be needed for short intervals, the action of the nitrous oxide may be intensified or pieced out by dropping a few drops of ether into the cylinder. Provision is also made by means of a little electric heater within the cylinders for rapid volatilization of the ether and the prevention of the condensation of moisture on the mica valves.

One-quarter of a grain of morphine and one-hundredth of a grain of atropine are administered one hour before the operation. Better than morphine is narcophine, which has given greater satisfaction.

The back of the tongue is touched with 10 per cent. cocaine. The patient is then anæsthetized, preferably by chloroform, in the usual manner and the catheter inserted into the trachea. This may be accomplished by means of the Jackson direct laryngoscope so modified that it is deficient at the side in a manner permitting of the withdrawal of the instrument without the necessity of pushing the catheter through it. By the use of such an instrument it is possible to insert the catheter without thereafter detaching it from the tubing connecting it with the gas bag.

The speculum represented in Fig. 3 is a convenient instrument for catheterizing the trachea. The curve is just enough to still permit of the direct view of the larynx and yet to direct the distal end of the catheter forward into the larynx. The lamp of this speculum is illuminated by dry cells contained in its handle.

After the tube has been inserted into the trachea, its external end is attached to the outlet tube of the three way valve which has been previously attached to the stand. The little rubber bag around the trachea is distended and the anæsthesia will now proceed uninterruptedly with nitrous oxide and oxygen alone and will give efficient relaxation in the normal individual for all the usual abdominal or mouth operations.

The rubber bag distended around the catheter, prevents the inhalation of blood and mucus into the trachea and in no way adds to the danger of the procedure, as the pressure of the gases can never exceed that in the inhalation bag. Two provisions prevent the gases in the bag from rising above the atmospheric pressure. First, the safety valve introduced between the respiration bag and the mixing bottle. Second, the respiration bag itself, which cannot become overextended without its being noticed by the anæsthetizer.

Rebreathing is an important feature of this method of anæsthesia—all that remains for the anæsthetizer to do after the intratracheal catheter has once been introduced into the trachea, is to turn the three way valve back and forth between the breathing tube (E) and the tube (D) as the respiration bag empties and fills. About one-half the time the average patient is rebreathing.

The dimensions of the catheter are important. It must have a lumen of at least $^5/_{16}$ inch. The author has used a very thin-walled, flexible metal tube covered with a piece of Penrose drainage tube.

Further experience with this method has demonstrated that care to avoid traumatism during the insertion of the catheter is necessary; and moreover that even though nitrous oxide alone be used as the anæsthetic it is possible for the anæsthesia to be complicated by pneumonia in those cases in which this complication is to be feared.

Nevertheless in properly selected cases this method of anæsthesia is a useful one.

B. BY NITROUS OXIDE AND OXYGEN UNDER CONDITIONS OF DIFFERENTIAL PRESSURE.

It will be appreciated that successful anæsthesia by the method previously outlined depends entirely upon active respiration by the patient. It is for this reason that narcophin, which exhibits a much less toxic effect upon the respiratory centre than morphine, has been found so valuable as a preliminary narcotic and that it is advised to give atropin if a preparatory injection of morphine is depended upon.

If the pleural cavity is opened and active respiration is rendered impossible, the lungs will be unable to fill and empty themselves with the gases during inspiration and expiration. In order to permit of passive inflation and deflation of the lungs with nitrous oxide and oxygen when the chest has been opened and also without that extravagant waste of the gases which is incidental to true intratracheal insufflation, provision has been made for exerting an alternating increase and decrease of pressure upon the outside of respiration bag described in this paper.

The arrangement adopted to produce this effect has been perfected in conjunction with the catheter and special devise for obstructing the trachea described in this article though it may be used in connection with a simple face mask. It provides for true artificial respiration synchronously with the patient's respiration, in other words, merely accentuating the patient's efforts of respiration.

The gases are forced in and out of the respiration bag by the alternating pressure upon it with provision for any desired amount of rebreathing as though the patient were doing his own breathing.

Actually, inspiration alone is assisted. Provision has been made for the loss of that amount of expired air in the passage back to the respiration bag which it may be necessary to replace from the gas tanks.

These results are accomplished by inclosing the respiration bag in an air-tight aluminum box, Figs. 4 and 5 (2).

By means of the attachment at one end of the box of which the important parts are four valves, a spring and two flaccid rubber tambours (3 and 5), air from the insufflation apparatus is allowed to pass alternately into the space around the bag within the box and outside the box into the room. When the air passes into the box it increases the pressure around the respiration bag which contains the nitrous oxide and oxygen. This increase of pressure is transmitted to the gases within the bag so that they are forced into the patient's lungs. It must be borne in mind that there is, of course, no communication between the interior of the respiration bag and the space enclosed outside of the rubber bag by the aluminum box. When the pressure within the box reaches a certain height for which the spring (4) may be set the air blows out the rubber tambour and reverses the position of the four valves. This reversal of the valves occurs suddenly, inasmuch as the rubber diaphragm cannot start its movement until the resistance of the spring is overcome; again the resistance offered by the spring is greatest at the extreme positions of its swing. In the reverse position of the valves the current of air from the machine no longer enters the box, but exhausts in part into the room and in part into the space enclosed by the second tambour. The stop-cock controls the amount of air acting on this tambour and, consequently, the time when the membrane of this tambour blows out, changing the valves back to their original position. It will be appreciated that the speed with which the position of the valves is changed back to their original position depends only in part upon the second tambour. If a minus pressure suddenly occurs within the aluminum box, this will tend to suck in the first tambour which of itself tends to change the position of the valves back to the first position permitting the entrance of air into the box. Because of this fact there is a strong tendency for the increase and decrease of pressure within the box to be synchronous with respiration.

The synchronism of the movement of the valves with respiration depends upon the fact that the changes in the pressure of the gases within the rubber bag transmit themselves to the space outside the bag and within the aluminum box and so to the rubber tambour. The piece (1) is a valve permitting of the loss of any desired amount of the gases exhaled from the patient's lungs. It permits, in other words, of any desired amount of rebreathing from no rebreathing up to complete rebreathing of the expired air. We have therefore, in this apparatus a means of true artificial respiration with whatever gas (either air or nitrous oxide and oxygen) that is allowed to fill the respiration bag.

Should it be desired at any moment to change from nitrous oxide to pure air, respiring the patient with only the latter, this change may be accomplished by moving a slide valve, which immediately connects the intratracheal catheter with the space outside the respiration bag.

It is important to remember that the only manner in which a minus pressure may be produced within the box is by a sudden inspiratory effort by the patient. While there is provision for artificial suction of the air out of the aluminum box yet the mechanism by which the valves are changed from the position permitting of expiration by the patient to that of inspiration is not accomplished by artificial suction. Particularly when the chest wall is open if during artificial respiration the expiratory phase depends upon an artificial suction a complete collapse of the lungs will result. This complete collapse combined with the replacement of the negative intrathoracic pressure during inspiration with a positive pressure which compresses the pulmonary vessels will so obstruct the pulmonary circulation that death will result in a little while.

For this reason the author believes that the principle of an extensively advertised machine for artificial respiration certainly when the chest is opened is a wrong one. It is much better to depend upon the elasticity of the lungs even when the chest is closed for expiration, except in rare intervals and then only for a few respirations.

During artificial respiration with the chest wall open as in thoracic surgery, it is absolutely necessary to depend alone upon the elasticity of the lungs for expiration and to absolutely avoid artificial suction.

The above described apparatus may be used with the intratracheal catheter provided with the little rubber occluding bag described in this article.

It may, however, be used in connection with a tightly fitting mask and therefore without the intratracheal catheter. When used with a mask it is better to provide the mask with an elastic band which passes around the head and by which it is tightly held over the mouth and nose.

Used in either manner, the apparatus furnishes a method of administering nitrous oxide and oxygen by true artificial respiration in a manner which will be synchronous with any of the more forcible respiratory efforts of the patient.

It will simply accentuate the voluntary efforts of inspiration and expiration. It increases the safety of nitrous oxide anæsthesia and for two reasons its efficiency. The first reason is that it administers the gas under conditions of increased pressure. The second is that morphine may be used with greater freedom with it. The preliminary injection of morphine has been always viewed as almost a necessary adjunct to the best nitrous oxide anæsthesia. Unfortunately morphine diminishes the respiratory movements to a marked degree and with them the power of the patient to inhale regularly the gas. This disadvantage, however, is not noticed if the gas may be introduced under conditions of differential pressure. The safety of nitrous oxide anæsthesia is increased because failure of respiration cannot take place, and may at once be relieved by respiration with air.

The slide valve described ensures against the possibility of excessive pressure within the lungs. Its exhaust opening is simply closed on inspiration, being guarded by a piece of mica which raises upon the slightest expiratory effort. During inspiration the spring never allows the pressure within the respiration box to exceed 10 mm. of Hg.