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can be greatly ameliorated, if not cured, by operation, and that the earlier the patient reaches the surgeon the better the result.

Although the following conditions are insisted upon by Drummond and Morison, namely: that cases selected for this method of treatment should not be complicated by cardiac, pulmonary or renal disease, and should have survived one or two tappings, still the contra-indications are practically nil. Most of the patients come to us as a last resort, when there is no opportunity to build them up before operating. So that the cases at best are desperate, and we cannot be blamed if they die during or soon after operation. On the other hand, the results in some cases have been so brilliant that they encourage the surgeon to advise the operation even in seemingly hopeless cases.

The question of drainage is also a debatable one, the English surgeons advocating it and the American surgeons opposing it, mainly on the grounds of the liability to sepsis. In view of the fact that in the majority of cases reported in which drainage has not been used, anywhere from two to more tappings subsequent to the operation were required to free the abdomen of fluid, it would seem that the use of drainage, for a few days at least, is desirable. With careful technique and careful after treatment of the patient, the danger of sepsis can be reduced to a minimum, and we run no more risks from sepsis by drainage than we do from frequent tappings. Therefore, I firmly advocate the use of drainage in all cases.

In conclusion, it is my opinion that the operation of omentopexy is a justifiable one and that the ideal technique is, under general anæsthesia, a median incision below the umbilicus, suturing as much of the omentum to the anterior abdominal wall as possible; and, above all, drainage for at least a week. This latter feature I believe to be especially essential in the after treatment.

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NITROUS OXIDE-OXYGEN-ETHER ANÆSTHESIA: NOTES ON ADMINISTRATION; A PERFECTED APPARATUS[1]

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PROFESSOR ANDREWS of Chicago, in 1868, and Professor Bert of Paris, in 1879, showed that a mixture of 80 per cent of nitrous oxide and of 20 per cent of oxygen would produce an ideal anæsthesia in many cases. Further experience in the use of nitrous oxide and oxygen showed that for practical work these percentages must be easily variable within wide limits, in order to meet the peculiarities of the case and the stage and duration of the anæsthesia. More recently it has become generally accepted that in some patients, in order to obtain relaxation, a varying amount of ether vapor must be administered in conjunction with the nitrous oxide-oxygen mixture.

All experimental and clinical work has emphasized the fact that a *constant* mixture (rightly proportioned for the particular case in hand) produces a smoother anæsthesia than a mixture of varying composition; in

[1] This research has been performed in part under the grant of a Bullard Fellowship by the Harvard Medical School to W. M. Boothby. Through the courtesy of Prof. W. T. Porter much of the work was done in the Laboratory of Comparative Physiology.

other words it has been shown that an intermittent and irregular supply of either gas does not conduce to a smooth surgical anæsthesia.

Consequently an ideal apparatus must be one that delivers to the patient a mixture of the two gases in any desired constant proportion and at the same time provides for the addition of as much ether vapor as is needed. For practical use such an apparatus must require no more attention from the administrator than is necessary to set the valves controlling the delivery of each gas.

Hewitt of England was the first to develop an apparatus at all applicable to general surgical use. His method of overcoming the terrific pressures of the nitrous oxide and oxygen is to use semi-elastic bags, which are kept more or less full from the high pressure tanks, by means of an intermittent flow of the gases controlled directly by hand valves on the tanks, acting against the high pressures. From these bags the flow of gas to the patient is regulated by a specially constructed and graduated valve that allows definite proportions of gas to pass from each bag, providing the pressures within the same are equal.

In practice it has been found very hard to maintain the two bags evenly and equally distended, even if great pains and constant attention are being given by the operator to the manipulation of the hand valves; therefore the pressure in the two bags varies greatly and, consequently, the mixture actually received by the patient must of necessity vary greatly.

McKesson has recently described an apparatus which, like that of Teter, is built on the Hewitt principle. While McKesson's apparatus is an advance in the development of this type of machine, yet it does not actually accomplish all that it is possible for an apparatus to do, in rendering the anæsthetist free from the trouble of valve manipulation, nor does it allow for the addition of ether vapor in a quantity and with a rapidity sufficient to meet the needs of all cases.

As a result of the inadequacy of any apparatus built on the principle of the Hewitt, we took up, now over a year ago, the study of the problem. We laid down four fundamental requirements which we agreed must be met or the problem given up. These requirements are:

1. There must be an absolutely *regular flow of each gas* at any rate desired, without the necessity of frequent valve manipulation.

2. The flow of the gases must be rendered *visible* so that their proportions can be approximately estimated at a glance.

3. An *efficient method of adding ether vapor* gradually yet rapidly up to any amount, that even an extreme case may require, must be available.

4. The face-piece must be so modified as to be absolutely *air-tight* and also practically self-retaining.

The first point, the crucial one, is to obtain an even flow of nitrous oxide gas from its liquefied form, compressed into steel tanks under a pressure of 700 pounds to the square inch. This necessitates the use of an automatic reducing valve. The same is true of oxygen (although not in liquid form) in similar tanks under a pressure of 1,500 to 1,800 pounds to the square inch. The province of such a valve is to reduce these terrific pressures to a working basis of 20 pounds to the square inch; a good valve is absolutely automatic and requires no attention on the part of the anæsthetist; experience has shown that the reducing valves can be absolutely relied on and that they do not freeze or become otherwise obstructed.

This principle of the automatic reduction of high tank pressures is so fundamental that we consider it essential that this feature be actually an integral part of the apparatus and not secondarily attached to tanks which are then connected with an apparatus designed on the Hewitt type. For general use a tank of moderate size (containing 75 gallons of oxygen and 250 gallons of nitrous oxide) is the most practical and convenient; accordingly we have designed our apparatus for that size of tank. The smaller size can of course be used and is preferable for transportation in house operating.

The second desiratum, namely, rendering

the rate of flow of gases visible, so that the relative proportion of each gas can be estimated at a glance, also assuring the administrator of the fact that the desired flow is actually taking place, has been solved by having *each gas bubble separately through water into a glass mixing chamber.*

The volume of gas delivered to the patient is controlled by means of a hand valve of fine adjustment acting against the *low* pressure delivered by the reducing valve. This is entirely independent of the automatic reducing valve. The hand-valves can be set to give any desired volume, which will continue unaltered for hours; a change in the rate of flow is obtained by simply turning the valve-handle a trifle till such volume per minute as is desired is seen to bubble through the water of the mixing chamber.

The aim of the anæsthetist is to determine as early in the anæsthesia as possible the proportion of nitrous oxide and oxygen suited to the patient under his care. The greater his experience the earlier will he be able to do this with certainty. After this proportion is once ascertained the apparatus will deliver the same mixture as long as desired, thus reducing the work of the anæsthetist to a minimum; in fact it is not uncommon for him to sit for more than half an hour with nothing to do but watch the patient quietly breathing, apparently in a natural sleep, and having no need of either touching the apparatus, the mask, or the patient.

The value of being able to estimate by the eye the relative rates of flow of each gas is of inestimable value. After a brief experience one is enabled to approximate the desired proportion solely by the eye, thus rendering it easier to obtain quickly the constant mixture needed for the particular patient in hand. Further, in difficult cases it greatly helps the anæsthetist to determine whether his patient needs more or less oxygen or nitrous oxide, also in case the patient becomes rapidly cyanotic (and this is not a rare occurrence with beginners) the surgeon can see at a glance that the cause of the difficulty is obstruction of the respiratory passages and not due to an insufficient proportion of oxygen in the mixture being administered to the patient.

The third essential point, which consists in being able, gradually yet rapidly, to add to the respired mixture as much ether vapor as even an extreme case may need, has been met by providing a second chamber, containing ether. The gases, after leaving the mixing chamber, pass to a three-way valve by which they are allowed to pass by the ether chamber entirely, or are made to pass either partly or wholly over the surface of the ether, or they may be forced (if desired) to bubble *through* the ether.

Thus *any amount of ether vapor required,* from the minutest trace to a relatively high percentage *can be almost instantly obtained.*

The possibility of gradually and yet rapidly increasing the strength of the ether vapor is of material advantage, for it allows the anæsthetist to just "catch" the patient within a few seconds after he gives a sudden warning of being "light" by moving the legs, contracting the abdominal wall or showing symptoms of impending vomiting. At such moments one may gradually but rapidly increase the ether percentage to that obtained by bubbling through the ether; after a few respirations the patient is seen to relax or the symptoms of impending vomiting disappear, at which time the ether should be entirely shut off. It is best as a rule at the beginning of trouble indicating a "light" condition to make no change in the rate of flow of the gas or oxygen, for when ether is administered a slight excess of oxygen is desirable; but as soon as the impending trouble is overcome the rate of oxygen may be slightly decreased, or that of nitrous oxide increased depending on the amount of rebreathing desired. In all probability the new mixture will maintain the patient for the rest of the operation in a perfect condition of anæsthesia, possibly without the necessity of again touching the valves.

Because we have emphasized the necessity of having available an appliance by which strong ether vapor can be administered we must not be misunderstood; in at least one quarter of the cases no ether at all will be required; in perhaps another quarter about two minutes inhalation of ether will be needed during the last stages of the preparation of the patient; in another small proportion an occasional addition of ether vapor for one or two minutes through the course of the administration will be found advisable; only very rarely and in rebellious alcoholic cases will more than a total of ten minutes respiration of ether in addition to the gas mixture be needed for an hour's operation; and even in these difficult cases practically no more ether is needed after the first hour, no matter how long the operation is prolonged. Accordingly, little or no nausea and vomiting follows a properly conducted nitrous oxide-oxygen-ether anæsthesia in a great majority of cases. Of course that small proportion of cases that require the larger amounts of ether do not have such an ideal recovery as those needing very small amounts or none; such recoveries resemble those following the ordinary ether vapor method which Gwathmey has found so desirable.

The cases run somewhat more smoothly, and perhaps with an average decrease in the amount of ether vapor needed, resulting in a more nearly ideal recovery if moderate doses of morphine (gr. 1/8 to 1/4) and of atropine (gr. 1/120 to 1/100) are given hypodermically one half hour before the beginning of the anæsthesia.[1] At the Hospital this is a standing order but if it is omitted for any reason we are not concerned except in the case of bad alcoholics. In other words the preliminary injection of morphine is by no means essential though it is desirable unless contra-indicated by some known peculiarity of the patient.

The fourth point necessary for a gas-oxygen anæsthesia is to exclude even the minutest trace of air from leaking in between the mask and the face. This necessity holds true for every case and must be accomplished in spite of peculiarities of the facial contour or the presence of beard and whiskers. Again we emphasize the fact that such exclusion of air must be absolute and not relative. One of us (B.) has recently described a collar that is not only air-tight but practically self-retaining (Boston Medical and Surgical Journal, 1912, clxvi, 9,328), to which article the reader is refered. To those using this collar we call attention, elsewhere more fully dealt with, of the dangers of positive pressure; the expiratory valve must be so set that an outflow of the gases may occur whenever the pressure inside the mask exceeds 2 mms. of mercury, which is a pressure just sufficient to maintain the rebreathing bag full but not distended.

For an even anæsthesia and as an aid to the avoidance of surgical shock a certain constant amount of rebreathing is of benefit; approximately the rate of flow of the gases should be such that from a quarter to a half of the volume of each respiration is of freshly added gas mixture. Such a proportion reduces to within reasonable limits the expense of gas-oxygen anæsthesia; too much rebreathing is apt to be followed by post-operative discomfort, usually in the form of headache; and it may cause an increase of post-operative nausea and vomiting. Vomiting during the progress of the anæsthesia is often an indication of excessive rebreathing for that particular patient although it may, in comparison with other patients, not appear excessive; at all events, increasing the volume per minute of the gas mixture, frequently clears up the symptoms.

Henderson's excellent series of papers on acapnia and its relationship to surgical shock deserves careful reading. Our observations on the effect of rebreathing, so far as they go, agree clinically with the laboratory findings of Henderson; we hope shortly to be able to adopt more scientific methods in the study of this problem in the clinic. Our observations of the blood pressure under nitrous oxide-oxygen (ether) anæsthesia with moderate rebreathing is that there is a distinct rise not only at the commencement but also throughout the operation. After the removal of the mask with its accompanying necessity for rebreathing there is a distinct and rapid fall in the blood pressure. In two instances, both on very sick and debilitated patients,

[1] In the beginning, following the lead of Crile, we used scopolamin with the morphine. Often an efficient hypnotic, scopolamin has seemed to us too uncertain in its action to be worthy of routine use and we have come to use atropin, which does at least reliably insure us against trouble from excess of mucus.

this fall was sufficient to abolish the radial pulse; the appearance of the patients and their mental attitude remained good; recovery was prompt and within one half hour they were in fine condition and remained so. This picture may very probably be interpreted as due to a temporary relative acapnia. If this should prove to be so it would be very easily dealt with by having the patient rebreathe into a paper bag in addition to routine treatment.

It is necessary once more to emphasize the fact that *a surgical anæsthesia is never obtained when the patient appears in the least degree cyanotic* on account of asphyxial spasm and rigidity. On the contrary the *patient must always be pink.*

We have no sympathy for the surgeon who allows his anæsthetist to beguile him into the belief that cyanosis is necessary for a gas-oxygen anæsthesia and, by permitting it, tacitly to assent to the hypothesis that such a condition is safe. We thoroughly believe that any anæsthesia accompanied by cyanosis is dangerous. Reports of deaths under gas-oxygen are rapidly coming in much to the apparent discredit of the method; they are obviously due to conducting the anæsthesia according to this erroneous idea of the necessity and safety of cyanosis; no deaths have been reported in which the patients color was maintained pink. Neither of us would permit an administration of gas-oxygen with cyanosis in any patient of ours; how any surgeon can or will operate under such conditions we do not understand.

In an earlier paper we suggested that some cases, even when respiring a mixture of gas and oxygen in which the proportion of the latter is sufficient to maintain the patient pink, might even then be brought under too profound influence of nitrous oxide and the anæsthesia be made dangerously deep. Our use of an absolutely air-tight face piece has enabled us to demonstrate that such a condition occurs not seldom but frequently. In fact toward the end of a long operation it is often necessary to use equal parts of oxygen and nitrous oxide.

The symptoms of an overdose of nitrous oxide in the presence of sufficient oxygen to keep the patient pink is, first, stertorous respiration and the onset of an excessive secretion of mucus; unless the percentage of nitrous oxide is decreased the patient's face and hands then take on a death-like pallor (not cyanotic), there is an absolute loss of all the facial reflexes, the respirations become shallow and, probably, the blood pressure falls (that is, the temporal cannot be found so readily although the rate is not excessive). This condition if pushed would probably lead to death from paralysis of the respiratory centre, though we know of no experimental evidence to support this hypothesis.

The point we wish to make is that an excess of nitrous oxide may be given even with a proportion of oxygen that, if respirations were proceeding normally, is sufficient to maintain the patient pink; if a death-like pallor with the other symptoms noted should then supervene while respiring such a mixture the patient is rapidly approaching the danger point of excessive anæsthetisation. In such a condition no time should be lost, for as yet we do not know how soon actual respiratory failure and death may occur. In brief the mask should be removed and if necessary artificial respiration instituted together with the administration of oxygen.

We do not wish to imply that this method of anæsthesia is more dangerous than that of straight ether, in fact, we firmly believe that it is the safest when in proper hands. We have had no serious trouble but believe trouble might have developed had we not recognized and appreciated the signs of excessive nitrous oxide dosage. The use of nitrous oxide for prolonged anæsthesia is still in its infancy and its danger limits are not well understood; in consequence for several years yet its effects, good and bad, must be carefully watched.

Even a slight degree of cyanosis distinctly increases the general venous ooze from the incision, apparently by decreasing the coagulation time of the blood; we have never observed this to any serious extent and consider the point of only minor importance.

Although the patient is rapidly rendered unconscious (two minutes) by gas-oxygen yet it is nearly ten minutes before the body

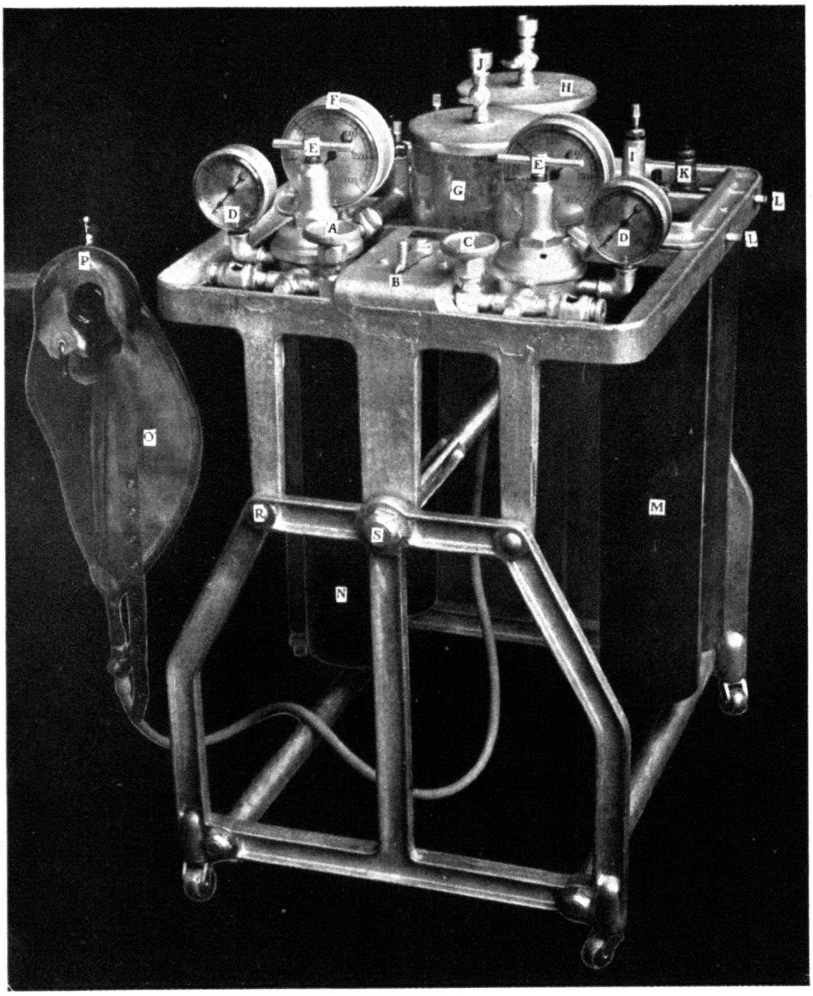

Fig. 1. A. Hand valves: to regulate the volume supply of oxygen; it works against a low pressure of about 25 pounds to the square inch therefore it can be set for and will continue to deliver any constant amount and this can be estimated by seeing the rate of flow as the gas bubbles through the water in the glass mixing chamber (G).

B. Ether valve: when pushed over to the left the mixed gases from G go directly to the patient; when in the centre (as illustrated) the mixed gases pass over the surface of the ether in chamber H; when pushed over to the right the gases must bubble through the ether.

C. Hand valve: to control the volume of nitrous oxide in same manner as A regulates oxygen.

D. Low pressure gauge: the one on the left indicates the pressure of oxygen, and that on the right nitrous oxide, after being automatically reduced by the reducing valve.

E. Regulating handle on the reducing valve: this after being set for the desired low pressure (20 lbs.) does not need to be again touched.

F. High pressure gauge: to show the pressure in the supply tank.

G. Glass mixing chamber: contains water through which each gas bubbles separately thus giving a ready means of estimating at a glance the rate of flow of both the oxygen and the nitrous.

H. The ether chamber: by valve B the gases after being mixed in G are allowed to pass around the ether chamber, or made to pass partly or wholly over the surface of the ether, or forced to bubble through the ether thus adding any desired amount of ether vapor to the respired mixture.

I. One of four valves: introduced so that any one of the tanks may be removed and replaced by a full one without interrupting the use of the apparatus.

J. Cups to fill the chambers with water and ether.

K. Valve on tank.

L. Screw by which each tank is clamped into its yoke.

M. One of the two nitrous oxide tanks on right side.

N. One of the two oxygen tanks on left side.

O. Rebreathing bag.

P. Mask with celluloid face-piece and the Boothby air-tight self-retaining collar.

Q. Two of the four lag bolts which may be removed by unscrewing the thumb nuts on the inside to allow the top of the table to invert into the lower half.

S. Centre axis on which the top half swings.

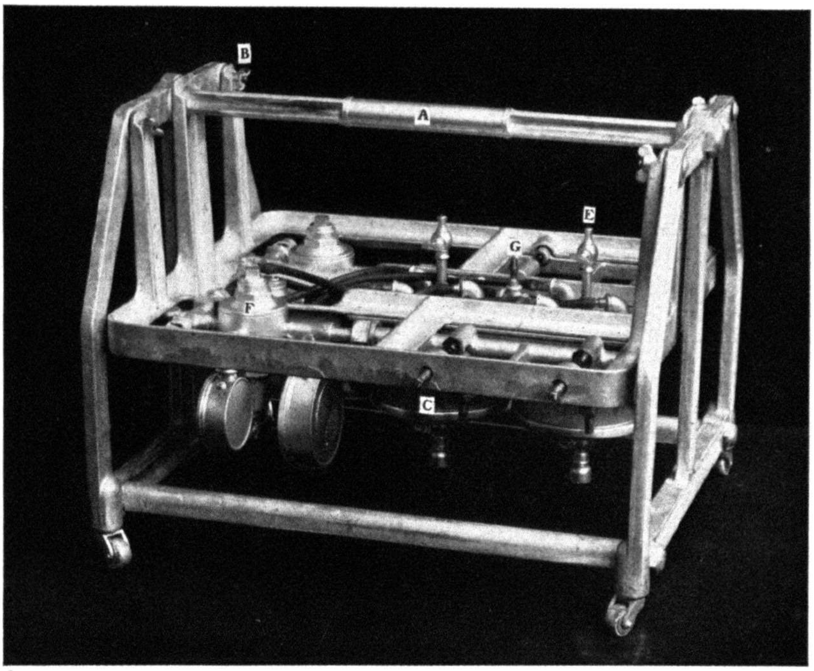

Fig. 2. A. Centre axis on which the top half swings; the middle portion serves as a handle.
B. One of the four thumb nuts which are removed to invert the table.
C. Mixing and ether chamber protected by the frame when top is inverted for transporting.
E. Pet-cocks for drawing off the water and ether from the chamber before inverting.
F. The under side of one of the automatic reducing valves.
G. The metal nipple to which the rubber tube is attached that leads to the rebreathing bag.
Size: Height, 17 inches; length, 22 inches; width, 17¼ inches; weight, 50 pounds (aluminum castings).

is sufficiently saturated with the nitrous oxide to permit the beginning of an abdominal operation. During this period which may be occupied by the preparation and draping of the patient, we allow the anæsthetist to depart somewhat from our rule in regard to avoidance of cyanosis; but even here we permit only the slightest degree of duskiness and never entertain the possibility of deep cyanosis. By the time the incision is made the patient must be actually pink and remain so throughout the operation. If then a mixture of nitrous oxide and oxygen with a proportion of the latter sufficient to maintain the patient pink will not produce sufficient relaxation to meet the demands of the surgeon the anæsthetist must add ether vapor till relaxation is complete.

For the best results close co-operation on the part of the surgeon and the anæsthetist is essential. During the greater part of the majority of operations complete relaxation is not needed; when such relaxation is required by the surgeon he should so inform his anæsthetist who will be able within two minutes, by the proper administration of ether, to provide the same; as soon as such need is over the ether may be discontinued.

A cyanotic condition of the patient, however, sometimes quickly develops even with an evidently liberal supply of oxygen as shown by the flow through the mixing chamber. In such cases the trouble is without question an obstruction of the air passages and must be quickly remedied. Contrary to the generally accepted opinion *cheek and tongue obstruction of the air passages is extremely common under gas-oxygen anæsthesia and its prevention is absolutely essential.* The most frequent cause is an obstruction of the nares together with a valve like action of the lips or cheeks against the teeth that occurs in mouth breathing when there is muscular relaxation. A ready means of overcoming such a condition is to slip up under the face-piece or collar a piece of gauze or a thin ribbon retractor into the angle of the mouth to keep the lips apart and the cheek away from the teeth; or pieces of rubber tubing about six inches long, guarded by safety-pins, may be introduced through the nares into the oro-pharynx. In rare cases the tongue may drop back and cause obstruction in spite of every effort to prevent the same by holding the jaw forward; in such cases a silk-worm-gut stitch should be passed through the tongue and brought out under the collar, with a dental mouth prop placed between the teeth to prevent biting of the tongue. An absolutely free air passage for the gases must always be maintained; any slight obstruction, most common on inspiration, causes a labored respiration under which conditions a smooth anæsthesia is impossible, besides throwing an extra exertion onto the patient.

Teter has, at various times, recommended an increase of pressure in the mask and in the rebreathing bag as an aid to inducing a more profound nitrous oxide anæsthesia, basing his claims for the procedure on the well known experiments of Paul Bert in 1879. In one of our earlier articles we disagreed with Teter as to the advantages of increased tension of the respired mixture, on the basis of its causing labored abdominal respiration which interferes with the surgeon's work. We wish now to go further and strongly discountenance the use of *positive pressure because it is a dangerous procedure.* In the first place the Bert and Teter methods are not comparable; Bert increased the pressure of the mixed gases as breathed to about 20 per cent of an atmosphere, but this was done in a pressure chamber in which the patient as well as the operator and assistants were likewise placed. In other words the increased intra-pulmonary pressure was compensated for by an equal increase in the atmospheric pressure surrounding the patient's body, thus causing no circulatory disturbance.

It is well known that the right heart is filled from the venæ cavæ on account of a slightly greater pressure within the latter, which, however, under certain surgical conditions may be as low as 10 mms. of mercury; as the cavæ pass for some distance through the thorax where normally there is slight negative pressure, it can be readily understood that an increase in pressure within the thorax (as produced by Teter's method) without a corresponding increase in external atmospheric pressure may hinder the filling of the heart with the consequent evil train of symptoms. An increase of the intra-thoracic pressure above that of the abdominal venæ cavæ will therefore cause sudden death from obstruction of the circulation by preventing the heart from filling. Frantic efforts to save the patient by turning on the oxygen and jamming down the mask renders matters worse.

The theoretical benefit to be obtained from an increase of pressure is less than one per cent in efficiency; accordingly, a procedure involving the dangers of collapse and of sudden death, with such a meagre beneficent return, should not be used.

In practice, therefore, the rebreathing bag should just become taut at the end of an expiration; this corresponds to a pressure of one or two mm. of mercury which is sufficient to open the respiratory valve at the end of the expiration and thus to allow the last part of the expired gases, that part which (as McKesson points out) contains the largest percentage of Co_2, to escape into the air.

The experimental apparatus recently described by us,[1] built on the principles enunciated above without regard to lightness and portability, has been most satisfactory and has met all expectations. In that apparatus we included other factors such as an efficient warmer for the gases and an electric motor to drive an air pump in case air should be desired as a carrier of ether vapor instead of the mixture of gas and oxygen. These accessories have been proved useless, and in consequence have been discarded. Because

[1] Cotton and Boothby: Nitrous oxide-oxygen anæsthesia with a description of a new apparatus. Surgery, Gynecology and Obstetrics, xiv, 2, Feb., 1912, 195–211.

gases absorb heat very rapidly we found that by the time they reached the patient their temperature, without any heating apparatus was nearly that of the room; by means of the heater originally described the gases could be delivered 10 to 20 degrees (F) higher. The frequent complaint by the patient, following the use of the heater, of dry parched lips which caused considerable, though of course, not serious discomfort, led us to the conclusion that an efficient heating apparatus was a disadvantage; as an inefficient appliance is an unprofitable complication, we have reversed our former opinion as to the desirability of having an attachment for warming the gases on the apparatus.

An apparatus to meet all the requirements described above must have some size and weight. These items however, have been reduced to their lowest terms by great care in the design and arrangement of the various parts. For the purpose of transportation the apparatus can be collapsed to a reasonable carrying size (height 17″; length 22″; width 17¼″:) by the simple removal of four lag bolts, set up with thumb screws, which allows the top half of the machine to swing down into the lower half; the centre bar or axis acts then as a convenient handle and the framework forms a protecting cage for the valves and the glass chambers. To reduce the weight the patterns have been made as small as is consistent with the strength requisite for hard hospital use and transportation for house operating, and the castings are made of aluminum alloy (except the valves). The carrying weight is just under fifty pounds.

SUMMARY

I. To be safe, effective and suitable for major surgical work a nitrous oxide-oxygen anæsthesia must be so conducted that the patient is never in the least degree cyanotic; on the contrary the patient must always be pink.

II. No attempt should be made to use the dangerous procedure of increasing intrathoracic tension of the gases for the purpose of deepening the anæsthesia.

III. In those cases that cannot be sufficiently relaxed for the purpose in hand by the use of nitrous oxide with a sufficient proportion of oxygen to prevent cyanosis, the anæsthesia should be deepened by the addition of as much ether vapor as may be needed; experience has shown that the total amount of ether used is small and has little and often no effect on the quick and agreeable recovery incident to this form of anæsthesia with its absence of postoperative "surgical shock."

IV. We believe an anæsthesia without cyanosis to be safe in expert hands. The anæsthetist, however, must have skill and experience to recognize the warning signs of too much nitrous oxide even without cyanosis (a picture not striking enough to appear to the tyro) as well as the signs of too much ether.

V. Therefore to be practical for surgical work an apparatus for the administration of nitrous oxide-oxygen-ether anæsthesia must posses the following fundamental features:

1. The apparatus must deliver, *for any length of time, any desired proportion* of nitrous oxide and oxygen, without requiring constant attention from the administrator; in other words the high pressure of the supply tanks must be automatically reduced to an easily controllable working pressure; the importance of this feature necessitates that the reducing valves be an integral part of the apparatus.

2. It must be possible to add *ether vapor in any strength* from the merest trace to a high percentage; and any desired variation in this percentage must be gradually and yet rapidly made.

3. There must be a method of instantly estimating by the eye the approximate proportion of each gas being administered.

4. The face-piece must be not only air-tight but practically self-retaining.

5. The apparatus must be strong, light and reasonably portable.

VI. The apparatus herewith described and illustrated is designed to meet the clinical and the physiological requirements of surgical anæsthesia and it effectively overcomes the mechanical difficulties attendant to the successful administration of nitrous oxide-oxygen-ether.

THE EFFECTS OF URETERAL LIGATION; EXPERIMENTAL AND CLINICAL[1]

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DURING the past three years the writer has been carrying on experimental work in the Laboratory of Surgical Research, at the Harvard Medical School, on the effects of sudden and complete occlusion of the ureter by ligature in animals. The results are of importance and interest, but as the work progressed it became evident that the problem was of such magnitude that its various aspects would have to be dealt with separately.

As experimental work is of value chiefly for its bearing upon human problems, it follows that any such investigation must be viewed quite as much from the standpoint of the clinic as of the laboratory. The results of experimental ligature of the ureter are so uniform, and so striking (Figs. 1, 3 and 4) that we have sought to compare them with those of a similar procedure in man. Also, as we have already pointed out, in our forthcoming paper on experimental work, the statements of textbooks are not only conflicting, but largely erroneous. This paper is written in the hope that an analysis of a fairly large group of such cases will settle at least some of the aspects of this problem.

For this purpose the literature was searched with some care and thirty-two cases answering our requirements have been gathered, many of these having been already collected by Sampson, of Albany. Through correspondence with most of the representative surgeons and gynecologists of this country we have gathered together thirty more cases.[2] With a total of sixty-two authentic cases of sudden and complete occlusion of the ureter by the ligature or clamp we feel that deductions from them will be of value.

Of these sixty-two cases the ureteral injury was unilateral in forty-six, bilateral in sixteen, the large majority occurring in the course of a hysterectomy, vaginal or abdominal. In forty-eight the ureters, one or both, were ligated with or without division; in seven the obstruction was produced by a clamp. As by the latter method the ureteral lumen is as suddenly and completely closed as by ligature these cases have been included.

The ureteral injury produced no immediate symptoms whatever (except of course anuria in those of double occlusion) in twenty-six cases or forty-one per cent. Of the unilateral cases ten or twenty-one per cent had no symptoms referable to the injury, either immediate or remote, and all made a full recovery. Were it stated in the reports how long after operation these patients had been followed we might be obliged to modify the figures. The only one about whom we have definite information died nine months later of recurrent malignant disease (for which the original operation was done) and during this time there was nothing to call attention to the injured ureter.

As we see anuria not uncommonly from interference with the function of one kidney either by calculus or other process, this condition was hopefully sought for in the cases of unilateral injury. It occurred but once, the patient dying after thirty-six hours of acute uremia. The rarity of its clinical occurrence is striking, but is entirely in accord with our experimental results. Of thirty-three animals, seven rabbits and twenty-six dogs, whose ureter was ligated, the reno-renal reflex, as evidenced by anuria, did not occur in a single instance.

Anuria was present, as was to be expected, in all of the bilateral cases, and was the only symptom. Its duration was variable, but in no case was it allowed to continue for more than ninety-six hours. In the latter, and in another after forty-eight hours, a double

[2] Our gratitude for their courtesy was expressed at the time to those surgeons and gynecologists who contributed material. As the cases are not to be given here in detail it seems unnecessary, and, in some instances, a breach of confidence to record the names of these gentlemen. The writer wishes, however, to assure them again that his sense of gratitude is none the less keen.

[1] Read at the eleventh annual meeting of the American Urological Association held in New York City, April, 1912.