ANÆSTHESIA BY COLONIC ABSORPTION OF ETHER.

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THE high efficiency of the intestinal mucous membrane of vertebrates in general as a transmittor of gases to and from the blood-stream has long been recognized. As early as 1808, Erman[7] opened the abdomen of *Cobitus fossilis* and observed that when air was swallowed the liver and the intestinal veins of the fish became bright red; while when hydrogen or nitrogen was substituted the color of the organs changed to dark purple. Baumert[2] in 1855 analyzed the gas passed per rectum by the same fish and found a marked decrease in the oxygen content and corresponding increase in nitrogen when swallowing of air had been prevented for several hours. Jobert[8] in 1877 discovered that in *Callichthys asper,* a Brazilian fish, air-swallowing is essential to life, the fish dying in about two hours if prevented from the exercise of this form of accessory respiration. In mammals, also, similar phenomena have long been known. Thus, Paul Bert[3] in 1870 found that if the trachea of a kitten be clamped the animal will die of asphyxia in about 13 minutes, but if the intestine be inflated with air, life may be prolonged for 21 minutes. A similar absorption of oxygen by the intestinal circulation in man is indicated by the results of Tappeiner[13] in 1886 who, on analysis of gases from various portions of the alimentary canal of an executed criminal, found in the stomach 9.19 per cent. of oxygen, in the ileum only a trace, and in the colon and rectum none at all; while the percentage of carbon dioxide showed a regular increase from stomach to colon.

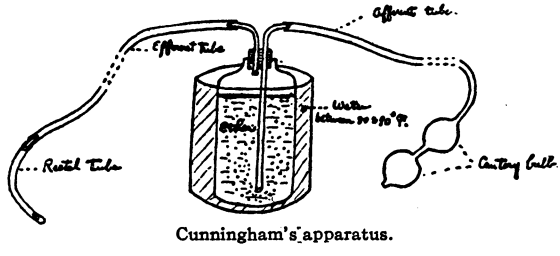
Recognizing this activity of the intestinal mucosa the early experimentors with ether as an anæsthetic attempted its

administration by this route. Even in Pirogoff's work on etherization, published in 1847, the method is mentioned as having been used to produce complete narcosis. Since that time efforts have been made in many quarters to establish the real value of the method. In the earlier experiments ether was injected pure or carried into the bowel as a solution or as a mechanical mixture in water. Later, the pure vapor was used, being generated by placing a bottle of ether in a vessel of warm water, and forced into the bowel by the pressure incident to its formation. This latter procedure is the one which was employed in a number of the larger hospitals of our Eastern cities about 15 years ago and which resulted in the general abandonment of the method. In a number of quarters it was found that hemorrhagic discharges followed the use of ether in this manner, and at least three deaths are accredited to it.

DEVELOPMENT OF THE APPARATUS.

After nearly 60 years of desultory experimentations in the hospitals of many countries, it remained for Dr. John H. Cunningham, Jr., of Boston, to introduce a technic which

FIG. 1.



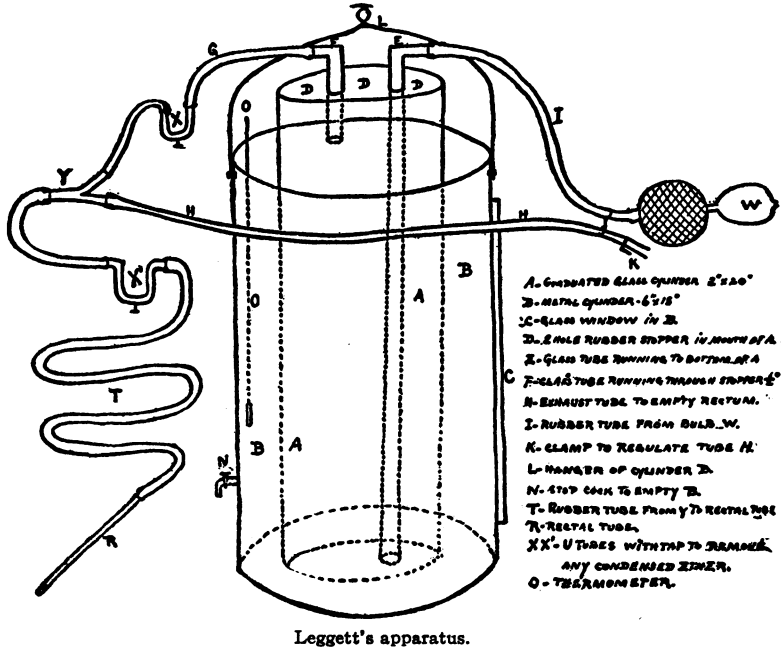
Cunningham's apparatus.

permits administration of ether by absorption from the bowel with safety to the patient.

This technic, which Dr. Cunningham has described in two papers [5], [6], was used by himself and his associate Dr. Leahy in 43 cases with satisfaction to the operating surgeons and with no ill-effects to the patients. The salient feature of the method employed by these investigators was the use of air

as a vehicle for conveying the ether into the intestine. As shown by the accompanying sketch (Fig. 1) copied from their publication, the ether was placed in a closed vessel partly immersed in a water-bath at a temperature between 80° and 90° F. Into the bottom of this vessel, air was forced by any convenient means—preferably an ordinary cautery bulb—and, bubbling up through the liquid, was led

FIG. 2.



Leggett's apparatus.

with its load of ether vapor through a rubber tube into the rectum. Too great pressure was prevented by the incompetence of the patient's *sphincter ani* or by the insertion of the finger into the anus beside the rectal tube, allowing the gas to escape between the two.

Incited by the results of Cunningham and Leahy, Dr. Noel B. Leggett, of the Surgical Research Laboratory of the College of Physicians and Surgeons of New York City, after repeated experiments upon animals, conducted a series of cases—some 15 or 16 in number—in the surgical service

of Roosevelt Hospital. The apparatus used by Dr. Leggett, as shown by the reproduction (Fig. 2) taken from his paper [9] on the subject, was modified from that of Cunningham by the addition of an exhaust tube *H* connecting with the efferent tube to the gut and by the introduction of U-tubes *X* and *X'* for the purpose of collecting any ether which might condense in the tubing as the vapor passed from generator to rectum. This arrangement represented the "state of the art" at the beginning of the series of cases about to be described; and, with the exception of the U-tubes, which have never formed a part of our equipment, was essentially the apparatus used in our earlier cases. In a number of these cases it gave entirely satisfactory results, but in others obstacles were encountered which made difficult or even prevented entirely the attainment of satisfactory surgical narcosis. The study of each of these difficulties has resulted in some modification of, or addition to, the apparatus.

Thus it frequently happened that semi-solid fecal matter escaping with the gas on opening the exhaust tube became lodged in the tubing and prevented the free passage of gas in either direction. To prevent this, a special form of tube was made and arranged to stand between the patient's thighs close to the anus in such a position that any fluid or semi-solid matter passing in either direction would drop down into the branch of the tube leading to the exhaust. Also the calibre of the entire exhaust tube was made considerably greater than that used for carrying the ether vapor to the intestine. To meet the changed condition brought about by the new position of the branch tube, the rectal tube was shortened to about 8 inches in length; and since the one or two eyes of the ordinary rectal tube frequently became closed by prolapse of rectal mucosa or by the lodgement of fecal matter, tubes with from 5 to 7 eyes have been adopted. Again, on account of the frequency of leakage around the rectal tube, preventing the maintenance of sufficient pressure to inflate the gut, a bulb from ¾ to 1 inch in diameter has been made on the tube at a point which in use lies just

inside the sphincter. Still another accident which at times prevented free passage of gases to and from the patient was the occasional compression, by the operator or by the weight of the patient's thigh, of the flexible afferent and efferent tubes.* This difficulty was met by winding the exposed portions of the tubing with stiff wire or by the substitution of tubing having a very heavy wall.

The observation that in some cases a diminution of gas-pressure in the gut resulted in a deepening of the narcosis led to recognition of the fact that too great pressure produces ischæmia of the gut and a consequent interruption of absorption. To guard against this accident a mercury manometer was added to the apparatus so that the pressure of the gas in the gut might always be kept below that of the blood in the intestinal capillaries. For the more easy recognition of the escape of gas on opening the exhaust, the distal end of the latter was immersed in a bottle of water placed under the operating table; and to prevent confusion as to whether the gas there seen or heard to escape is coming from the gut or from the generator, a combination clip was devised which necessitates the closure of the afferent tube before the efferent one can be opened.

Since, as will be explained later, it has sometimes been necessary to administer a certain amount of the anæsthetic by mouth as a supplement to the quantity absorbed by the intestine, a tube has been provided by means of which ether vapor can be diverted from the main afferent tube and allowed to escape into the mouth or nose of the patient. Finally, on account of the instability of the cylinder form of ether generator and of the more and more frequent use of oxygen as a vehicle for the ether vapor, a compact metal generator has been devised, which, though no more efficient in maintaining narcosis than the cylinder form, presents a number of advantages which will be detailed later.

* These terms are not used in the sense in which they are employed by Cunningham as afferent and efferent to the vapor generator, but as afferent and efferent to the patient.

DISCUSSION OF CASES.

Up to the present time I have administered ether by this method to about 140 cases on the surgical service of Roosevelt Hospital. Of this number, careful records were taken of the first 100 cases. Of the remaining 40, mostly private cases, no detailed records have been made. I may say, however, that all were satisfactory and that untoward results occurred in none. In only one case—the second of the series—was an attempt made to administer the anæsthetic per rectum from the beginning. This proved so slow and was so uncomfortable and distasteful to the patient that after about 20 minutes a cone was used to complete the initial establishment of anæsthesia. Inasmuch as there is no real indication for beginning the administration by rectum, I have never made a second attempt to do so.

Of the 100 cases in the recorded series, 91 were ward patients and 9 private patients. The age range was 2 to 77 years. The character of the operations done was as follows:

Tumors, glands, etc., of neck	31
Amputations of breast	9
Goitres and thyroglossal cysts	8
Craniotomies	6
Correction of old fractures of limbs	5
Resections, sutures and osteotomies of inferior maxilla	5
Partial excisions of tongue	4
Staphylorrhaphy	4
Tracheotomy	3
Mastoid	3
Inguinal hernia	2
Removal of parotid tumors	2
Resection and osteotomies of superior maxilla	2
Removal of Gasserian ganglion	2
Skin grafting	2
Orchidopexy	1
Hydrocele	1
Appendectomy	1
Nephrotomy	1
Ludwig's angina	1
Enucleation of eye	1
Resection of knee	1

Cervical laminectomy	1
Axillary adenitis	1
Excision of sternomastoid	1
Plastic for stricture of œsophagus	1
Laryngectomy	1
Neurorrhaphy	1

The longest operation of the series consumed 2 hours and 20 minutes, the shortest, 5 minutes, the average time being 53 minutes.

The average consumption of ether was 87 grams per hour in the 64 consecutive cases in which record of this point was kept.

Twelve of the 100 cases had a preliminary injection of morphine and scopolamine.

In 25 cases, oxygen was used as a vehicle for the ether vapor.

Forty-three cases had at some time in the operation a supplementary administration by mouth of ether or chloroform.

Twelve belched gas from the stomach in the course of the anæsthesia, indicating a possible distention of the small intestine with regurgitation of the gas from the stomach. Of these only 4 occurred in the 71 cases following the adoption of a 20 mm. maximum pressure in the bowel.

Only 18 cases showed any perspiration whatever and in none of these was there profuse sweating.

Forty-three cases vomited or regurgitated stomach contents after operation; of these several disclaimed any sensation of nausea.

Twelve had abdominal pain.

Five had bloody stools or blood-streaked return from the post-anæsthetic enemata. All cleared up in from a few hours to three days and in none was the loss of blood accompanied by noticeable weakness or abdominal pain.

The most severe of the cases continued to pass small quantities of blood for three days during which she also vomited persistently. This case, Case XXVI of the series, was the last save one in which any hemorrhage (beyond the

negligible amount occasionally caused mechanically by the rectal tube) has occurred.

Case XCVII, as an incident to the introduction of a new form of ether generator, was treated to an excessively concentrated vapor, so that great care was necessary to prevent narcosis from becoming too deep. In the first three days following the operation, this patient had five bloody stools. He felt no discomfort, however, and was discharged on the fifth day in perfect general condition.

In the series of cases to date there have been 5 deaths from all causes. In none of these, in the judgment of the operating surgeon, was the method of administering the anæsthetic a contributing factor. A brief statement of the conditions in each of these cases follows:

Case I.—Large, heavy man, moderately alcoholic. Operation, partial excision of the tongue for epithelioma. Patient somewhat blue and pulse was small and rapid throughout operation. Died—apparently of operative shock about two hours after return to ward.

Case II.—Large, heavy man. Age 35. Moderately alcoholic. Operation, tracheotomy and removal of cervical glands as a preliminary to laryngectomy for carcinoma of larynx. Anæsthetic was "shallow" throughout, patient coughing and groaning frequently. Made prompt ether recovery but died two days later of pneumonia.

Case XXV.—Fairly well nourished man. Age 53. Moderately alcoholic. Operation, hemi-excision of tongue and removal of right cervical glands for epithelioma. Patient took initial anæsthetic slowly and was markedly cyanotic. Color and general condition improved after beginning of the administration per rectum. Anæsthesia was shallow throughout, patient swallowing frequently. Late in operation there was marked hemorrhage, and shortly afterward—1 hour and 35 minutes after the beginning of the operation—the patient died.

Case XLIV.—Muscular man. Age 24. Brought to hospital almost moribund with compound depressed fracture of skull. After operation lasting 35 minutes the patient left the table improved but never regained consciousness and died two days later.

Autopsy showed extensive fractures of vault and base with extensive laceration of brain and marked subdural and epidural hemorrhage. The colon was normal, showing no injurious effects from the ether.

CASE XLVII.—Slender negro. Age 31. Brought to hospital in ambulance with extreme dyspnœa of sudden onset. Operation, low tracheotomy done in sitting posture on account of orthopnœa. On account of this position, the rectum was compressed by the weight of the upper bowel and introduction of ether vapor and oxygen into the colon was almost impossible. The operation gave little relief but ether recovery was satisfactory. Dyspnœa and cardiac weakness progressively increased and two days later the patient died. Autopsy showed a large false aneurism of the descending arch of the aorta.

One other death has occurred after administration of ether by this method in Roosevelt Hospital. This case though administered by another member of the interne staff came under my own observation both during and after the operation. The patient was a well-nourished child of five years which had been anæsthetized on two previous occasions for the correction of hare-lip and the removal of adenoids. The operation in question was a staphylorrhaphy lasting about 50 minutes. Throughout the operation there was a noticeable difficulty in maintaining a smooth narcosis, the latter being too deep and too shallow by turns. In the course of the shallow intervals a little chloroform was given several times on a "sponge-stick." There was no excessive loss of blood. Toward the close of the operation, the patient's color became very bad and the pulse small and rapid. She was hurried to the ward, stimulated and given external heat. In the course of a half hour she became restless and talkative, calling for water and asking to be taken home, but apparently recognizing no one about her. She did not vomit. The pulse continued rapid and small and an intravenous infusion was given with slight temporary benefit. After this, she gradually relapsed again into unconsciousness and about two hours after the operation, she died. Unfortunately an autopsy could not be obtained.

It is the author's belief that this method, safeguarded by the improved apparatus to be described hereafter and by the use of oxygen as a vehicle for the ether vapor, is one of extreme safety in the absence of definite intestinal lesions.

THE PHYSIOLOGY OF COLONIC ANÆSTHESIA.

Theoretically the administration of any anæsthetic should presuppose a full knowledge of the physiological action of the drug on the part of the anæsthetist. Practically, however, in the case of pulmonary anæsthesia, this knowledge may be, and, in the vast majority of cases is, dispensed with in favor of an accurate knowledge of the symptoms of incomplete and excessive narcosis and the practical means of correcting each. This knowledge, gained by extensive observation and supervised experience in the pulmonary method of administration, is not sufficient basis for the undertaking of administration by the colonic method.

In the pulmonary method the drug is taken in by the automatic respiratory efforts of the patient, and is eliminated in the same way if pure air be only substituted for the anæsthetic mixture. No anæsthetic-containing reservoir remains to continue imparting the drug to the blood plasma. Further, as the only means of elimination of the anæsthetic is the same as the means of absorbing it, only so great an amount of the drug need be given as is necessary to produce in the general circulation the required one-fourth per cent. for the narcotization of the central nervous system (cf. Overton[11]). Also, the absorbing surface of the lungs is so great and so well adapted to the purpose that a comparatively low concentration of anæsthetic vapor in the respired air is sufficient to produce the required percentage in the circulating blood.

When we turn to a consideration of the colonic method of administration we find all these conditions changed. The drug cannot be taken in by the muscular action of the patient nor can any unabsorbed excess be eliminated in that way. In case of over-deep narcosis the unabsorbed residue of the drug must be evacuated by the active intervention of the operator. There must be considered in the use of this method, the fact that the blood after leaving the intestine with its load of ether is obliged to pass through the lungs before reaching its goal

in the central nervous system, and that in so doing a considerable portion of the contained ether will be eliminated into the air. The concentration of the drug at the point of absorption, therefore, may not be the one-fourth per cent. of the pulmonary method but one-fourth per cent. plus the percentage necessarily lost by exhalation.* Again, the absorbing surface of the colon is much smaller than that of the lungs and the arrangement of the vessels perhaps less favorable to gaseous interchange, so that a higher partial pressure of the anæsthetic vapor, in other words a higher concentration, is required.

Each of these differences requires the intelligent attention of the anæsthetist. Since the anæsthetic mixture must be forced into the intestine, we are immediately confronted with the question of the proper degree of pressure to be used in the process. Sufficient must be used to obtain moderate distention of the entire colon else the available absorbing surface will be too small. Too much pressure must not be exerted lest by over-distention the vessels of the gut be flattened out, circulation impeded or abolished, and absorption minimized; and the ischæmic mucosa left unprotected by its normal circulation to resist the irritant effects of the ether vapor. The contention may be raised that experiments in which narcosis has been produced by the use of excessive pressure are sufficient to disprove this statement. The error in this contention arises from the fact that excessive pressure breaks down the resistance of the ileocæcal valve, as observed by Leggett on dogs, and that the narcosis is obtained by absorption under diminished pressure from the coils of the small intestine. The author's attention was first directed to the

* In connection with this point it is important for those who make use of the colonic method of etherization to watch for symptoms of the so-called "delayed ether poisoning," since from the foregoing it is plain that the liver—the great sufferer in this condition—is treated to a higher concentration of ether than in the same grade of narcosis from pulmonary administration. No case of this kind has come to the author's attention, however, unless the peculiar death mentioned on page 465 has some affiliation with this class of cases.

necessity for the use of a moderate pressure by the repeated observation that reduction of pressure often resulted in deepening of the narcosis.

The optimum pressure to be maintained in the colon has been determined experimentally to be about 20 mm. of mercury, which is approximately equal to the sum of the positive pressure in the intestinal capillaries and the negative pressure in the portal vein. This would be varied according to the blood-pressure of the patient; *i.e.*, should be reduced to 10 or 12 mm. in young children and may be increased in individuals with abnormally high blood-pressure.*

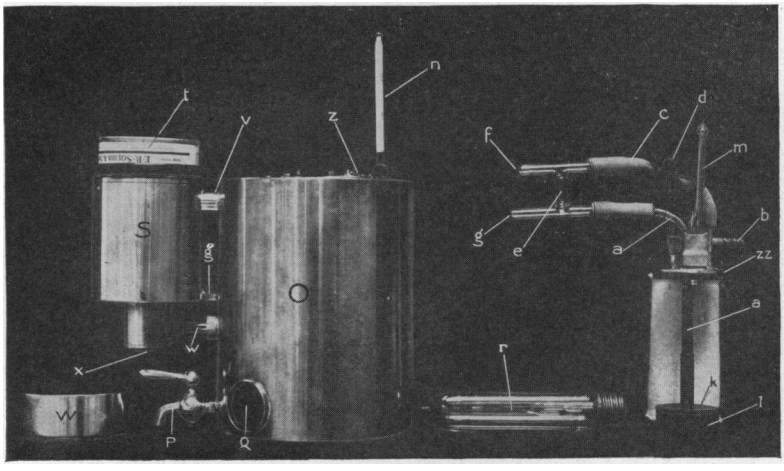
On account of the inevitable loss of ether from the blood in its passage through the lungs, it is sometimes necessary to adopt means, to be mentioned later, for keeping the respired air more or less laden with ether.

For the same reason and because of the smaller and less efficient absorbing area of the colon as compared with that of the lung, a relatively high concentration of the anæsthetic mixture must be used. To meet this last requirement, a number of early investigators and unfortunately, some recent ones [1], [10] as well, adopted the expedient of passing *pure* ether vapor into the gut under the pressure incident to its generation. This doubly dangerous procedure has resulted in a number of deaths, in one of which (reported by Professor Baum, *l.c.*) autopsy showed a gangrenous and perforated cæcum and general suppurative peritonitis.

The danger of too great concentration of ether is obviated in the method used by the author by employing oxygen (or air) as a vehicle and by keeping the ether from which the vapor is derived well below its boiling point. By maintaining a uniform temperature in the ether, with a fairly constant flow of oxygen and a definite period of association of the oxygen stream with the liquid ether, a fairly constant degree of concentration may be attained.

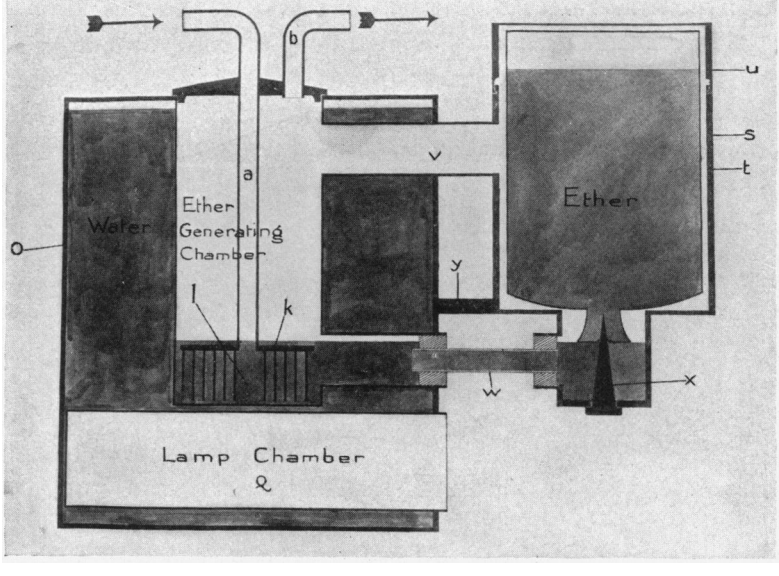
* In connection with this question it is well to have in mind the experiments of Qurin,[12] in one of which a normal healthy cat having a blood-pressure of 85 mm. died after 5 minutes of an intra-abdominal pressure of 10 mm.

FIG. 3.



Parts of vapor generator.

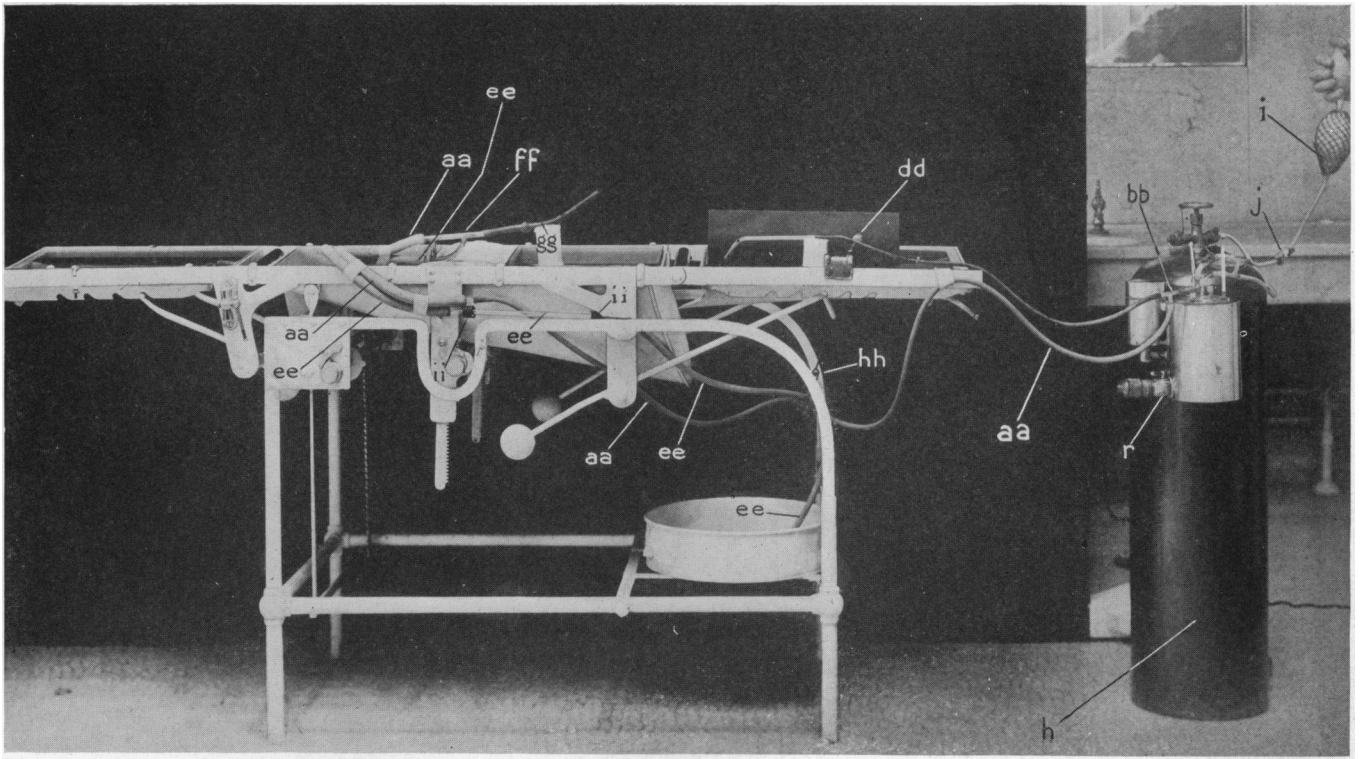
FIG. 4.



Schematic section of vapor generator.

a, Oxygen (or air) inlet; *b*, Connection to afferent tube system; *c*, By-pass for inflating intestine with pure oxygen (or air); *d*, Clip for closing by-pass; *e*, H-tube connecting oxygen tank and air bulb with generator and by-pass; *f*, Connection of H-tube with air bulb; *g*, Connection of H-tube with oxygen tank; *k*, Disc forming top f spiral wier; *l*, Spiral wier; *m*, Manometer; *n*, Thermometer projecting out of w ter-jacket; *o*, Water-jacket; *p*, Cock for draining water-jacket; *q*, Lamp chamber in water-jacket; *r*, Tubular incandescent-bulb for heating water-jacket; *s*, Ether reservoir; *t*, Ether can inverted in reservoir; *u*, Screw cover for reservoir; *v*, Metal tube connecting upper part of ether reservoir with upper part of generating chamber; *w*, Glass tube connecting ether reservoir with generating chamber below level of ether; *x*, Flattened spike for perforating seal of ether can; *g'*, Metal brace between reservoir and generating chamber; *z*, Cover over hole for filling water-jacket; *zz*, Cover of generating chamber.

FIG. 6.



aa, Afferent tube system; *bb*, T-tube for connecting accessory mouth tube; *dd*, Clip for same; *ee*, Efferent tube system; *ff*, Y-tube; *gg*, Rectal tube; *hh*, Combination clip on afferent and efferent tube system; *i*, Air bulb; *j*, Clip on air-connection which is closed when oxygen is being used, to prevent leakage through air bulb; *ii*, Sliding clips for holding tube systems on table; *h*, Oxygen tank. Tell-tale bottle not shown, should sit in drip pan of operating table and receive distal end of efferent tube.

THE AUTHOR'S APPARATUS.

The original apparatus in use at Roosevelt Hospital was that of Cunningham, the simplest possible means of forcing air through warmed ether and carrying the mixture into the intestine—plus a branch tube used for exhausting the contents of the gut when occasion required. The latter feature introduced by Leggett is one of the valuable points in the apparatus with which this chapter is concerned.

The complete apparatus may be regarded as made up of three parts: (1) a generator in which the mixture of oxygen and ether is produced, (2) an afferent tube system which carries this product into the intestine, and (3) an efferent tube system for the purpose of exhausting the contents of the gut.

The Generator.—This portion of the apparatus consists of a small generating chamber proper surrounded by a water-jacket and connected with an ether storage chamber which automatically maintains a given level of ether in the generating chamber. The arrangement and working of the various parts will be most readily understood by a glance at the photograph of the dissected apparatus (Fig. 3) and the schematic sagittal section shown in Fig. 4. Only one feature will require special description. This is the spiral wier, *l*, which determines the prolonged intimate contact of the oxygen (or air) with the fluid ether. This device consists of spirally wound strip of thin brass three-quarters of an inch wide and about 14 inches in length, soldered to the bottom of the circular disc, *k*, with which the oxygen inlet tube, *a*, connects.

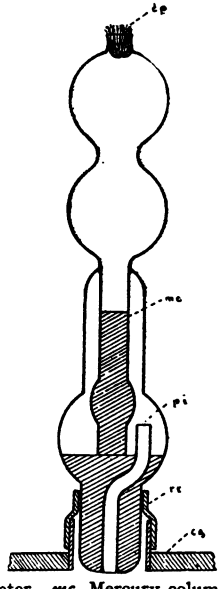
The level of the ether in the generating chamber is automatically maintained at such a height as just to cover this wier and disc. The oxygen (or air) is admitted to the apparatus through this tube, *a*, emerges below the level of the ether under the plate, *k*, and finds its way to the surface only after traversing all the windings of the spiral. This necessitates intimate association of oxygen with ether for a distance of 14 inches and has been shown experimentally to bring about a complete saturation of the former with the latter.

The ether-saturated oxygen rises into the upper part of the generating chamber and is carried by the tube, *b*, into the afferent tube leading to the intestine. The main body of the ether remains in the original package, *t*, which is inverted in the ether reservoir, *s*. To charge the generator, a *sealed* ether can (this apparatus is designed to take a Squibb's 250-Gram can) is inverted in the reservoir, the seal being penetrated in the act by a flattened spike, *x*, which projects from the bottom of the reser-

voir. A twist of the can then serves to ream out a fair-sized opening. Ether then flows out into the lower part of the reservoir and into the generating chamber until it has reached a level above the perforation in the seal when, the entrance of air being interrupted, the outflow of ether ceases until the level of the fluid has been again reduced so as to allow more air to bubble up into the dome of the ether can. This principle of the kerosene "student lamp" must be familiar to all my readers. Before any pressure is put on the generating chamber, the cover, *u*, of the ether reservoir must be screwed on air-tight.

Surrounding the generating chamber is the water-jacket, *o*, which is maintained at a temperature of 88 to 90 degrees (not higher) by the

FIG. 5.



Sectional view of manometer. *mc*, Mercury column; *pi*, Pressure inlet; *cp*, Cotton plug in pressure vent; *cg*, Cover of generating chamber; *ri*, Short piece of rubber tube connecting manometer with cover.

10 candle power tubular incandescent electric lamp, *r*, inserted into the blind tube, *q*. A thermometer, *n*, projecting from the top of the water-jacket readily shows the temperature of the contained water.

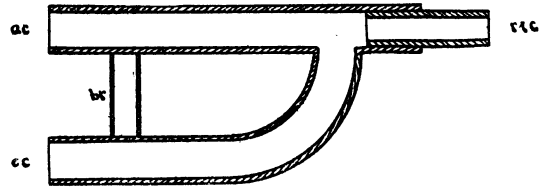
A manometer, *m*, projecting from the cover, *ss*, of the generating chamber, shows at all times the pressure maintained in the generating chamber and hence in the intestine of the patient. This manometer, of which an enlarged sectional drawing is shown in Fig. 5, also serves the purpose of a safety valve, being so constructed that when the pressure reaches a point a few millimeters above the optimum, the oxygen-ether mixture of the generating chamber is permitted to bubble up through the mercury and escape into the air. This point is of importance since

the needle-valve of the oxygen tank may be accidentally opened too wide, which, in the absence of such a safety-valve would put a dangerous pressure on the gut. When such excessive pressure has subsided, the mercury falls back from the upper chamber of the manometer and the safety-valve is closed.

The H-tube, *e,* makes it possible to have, at the same time, means of passing either oxygen or air through the generator and also of inflating the intestine with pure oxygen or air without appreciable admixture of ether. This latter procedure is accomplished by simply opening the pressure-clip, *d,* which allows the oxygen or air to pass into the afferent tube and on into the intestine without making its way through the generator itself. The generator may be either hung by a bracket from the oxygen tank as shown in Fig. 6, or set upon a small table.

For those who wish to make their own apparatus a simpler form of generator will be found quite satisfactory. This may be made by the use of the spiral wier in any wide-mouthed bottle capable of containing 250 to 400 Grams of ether with 4 or 5 inches of free space between the

FIG. 7.



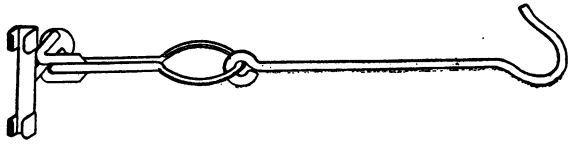
Sectional view of Y-tube. *ac,* Afferent connection; *ec,* Efferent connection; *rtc,* Rectal tube connection; *br,* Brace.

fluid and the cork. The manometer is inserted through the cork and the proper afferent connections provided. In the place of the water-jacket a pail of warm water is provided and the bottle partly immersed in it. The temperature is registered by a floating thermometer and is kept up to the proper point by occasional addition of very hot water.

The Afferent and Efferent Tube Systems.—These, as will appear from a glance at Fig. 6, run a parallel course for the greater part of their length—the efferent or exhaust tube being led to the head of the table in order that it may be controlled by the anæsthetist sitting in that situation. The afferent tube is of small calibre since it conveys only gas, while the efferent tube, which is frequently called upon to conduct water and semi-fluid fæces, must have a much greater inside diameter. Both tubes have very thick walls in the portion which passes over the edge of the table and under the patient's thigh. This is to obviate the danger of compression in this situation. The rectal tube is a short single tube having a bulb about 3 inches from its outer end and supplied with from 5 to 7 fenestræ. This bulb in use aids to prevent leakage in case of a lax sphincter, while the multiple fenestræ are a safeguard against closure of the tube due to prolapsed mucosa or to

fecal particles when the exhaust tube is opened. Communication between the rectal tube on the one hand and the afferent and efferent tube system on the other is established by the use of a Y-shaped tube of glass or metal (Fig. 7) which stands horizontally between the patient's thighs close to the anus. The upper straight arm connects with the afferent tube while the lower curved branch leads to the efferent connection. By reason of its position and construction this Y-tube acts as a trap to catch either

FIG. 8.

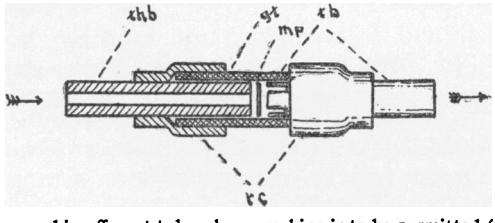


Combination clip with hook.

condensed ether from the afferent tube or fluid or semi-fluid matter coming from the rectal tube when the exhaust is opened.

A strong glass tube is introduced into the efferent system as shown at *ee*, Fig. 6. This serves the double purpose of preventing a sag in the exhaust tube at this point and of furnishing a rigid support for the sliding hooks *ii*, which form the principal means of attaching the apparatus to the table. The end of the efferent or exhaust tube is immersed in a few inches of water in the bottom of a wide-mouthed bottle which sits either on the floor under the head of the table or in the drip-pan connected with the latter. This bottle serves both as a collector of any

FIG. 9.



Check-valve used in afferent tube when coughing is to be permitted (partial sectional view). *thb*, Thick-walled brass tube connecting with generator; *tb*, Thin-walled brass tube notched on end toward valve connecting with main afferent tube; *gt*, Glass tube surrounding valve chamber; *mp*, Mica-plate valve; *rc*, Cuffs of rubber tubing connecting glass and brass tubes.

fluid return from the intestine and as a "tell-tale," since the amount of gaseous return following the opening of the exhaust is readily appreciated when it is seen or heard bubbling through the water. Continuous leakage from the exhaust is prevented by a spring-clip, *hh*, which I have modified as shown in Fig. 8, so that the afferent tube is held in relation with one of the finger-rests of the clip. This relation of clip and afferent tube insures the closure of the latter by the same finger pressure which opens the former. Gas is thus prevented from entering the intestine as long as the exhaust is open. For the sake of keeping it in a definite

position, this combination clip is attached to the table by a long wire hook. Since, in some cases, it is necessary temporarily to supplement the colonic administration by the addition of ether by mouth, a T-tube, *bb*, Fig. 6, is placed in the efferent system close to the generator and a small rubber tube led off and closed by a spring clip.

In mouth and throat cases, where it is desirable for the patient to retain an active coughing reflex, it has proved of advantage to introduce a small mica-plate check-valve beyond the origin of the accessory mouth tube. Coughing produces a very marked increase in intra-abdominal pressure and in some cases before the introduction of this valve a paroxysm of coughing has resulted in the driving of fecal-stained fluid back into the generating chamber. With the check-valve as shown in Fig. 9, this cannot occur. When violent coughing is permitted, it is necessary to open the exhaust during each paroxysm lest the rectal tube be extruded by the effort; or an automatic safety valve may be arranged by leaving off the exhaust clip and immersing the weighted end of the exhaust tube in about 18 inches of water. This height of water will be sufficient to prevent escape of gas at 20 mm. pressure but readily permits escape at the higher pressure incident to coughing. When this device is used the intestine may be emptied of gas by simply raising the end of the exhaust tube to the surface of the water.

TECHNIC OF METHOD.

Preparation of the Patient.—As observed by all workers with intestinal anæsthesia, one of the most important considerations is thorough cleansing of the colon. This is accomplished by a cathartic of castor oil given the night preceding the operation and following in the morning by high soapsuds enemata repeated until the return is clear. In the author's cases three enemata 1½ to 2 hours apart have been regarded as the minimum number. In alcoholic and very muscular subjects and in operations on the mouth or upper respiratory tract, it has been found useful to give $^1/_6$ to ¼ gr. of morphine and $^1/_{120}$ to $^1/_{100}$ gr. of scopolamine hypodermatically, 1 hour before operation.

The Administration.—Before the patient is brought to the etherizing room, the anæsthetist affixes the apparatus to the table as shown in Fig. 6, except that the rectal tube is not attached and the Y-tube and its connections are allowed to hang down at the side of the table while the accessory mouth tube is permitted to hang from the side of the generator. The ether reservoir is charged if it does not already

contain ether left from a previous case, the water-jacket filled with water at about 90 degrees and the electric lamp connected with a plug in the wall, *but not lighted at this time.* The end of the exhaust tube is placed in the " tell-tale " bottle under the table.

The anæsthetic is then started by the pulmonary method and carried to a stage of partial relaxation when the patient is brought to the operating room and placed on the table. The rectal tube—well greased, is then quickly inserted until the bulb lies just inside the sphincter, the anæsthetist before starting the initial anæsthetic having protected his left hand with a rubber glove for this purpose. The patient's left thigh is then raised and the branch tube brought under in to its proper position and connected with the rectal tube. For this brief period, the cone has been held over the patient's face by a nurse. The anæsthetist then removes his rubber glove, takes his place at the patient's head and slowly turns on the oxygen. As soon as this is done the cone may be removed from the patient's face. If the operation does not involve the patient's mouth, it is best to cover the latter and, if possible, the nose as well, with 3 or 4 large sterile towels, which by causing a certain amount of rebreathing, impede the elimination of ether from the lungs. If during the change from the pulmonary to the colonic method, the patient has " come out " and begun to make troublesome voluntary movement, he can be quickly " put under " by admitting ether vapor to the space under the towels through the accessory mouth tube.

As soon as pressure in the colon has been raised to the required 20 mm. the exhaust should be opened and the gut allowed to empty itself. This process of filling and emptying the intestine should be repeated three or four times in order to eliminate as thoroughly as possible the natural gases of the bowel. The needle valve of the oxygen tank is then set at a point which just maintains the required 20 mm. pressure and usually demands little or no further adjustment during the rest of the operation. If the patient tends to come out from the influence of the anæsthetic the bowel may be

emptied from time to time to carry out any intestinal gases which tend to dilute the anæsthetic mixture. If, on the other hand, the anæsthesia continues sufficiently deep, no further use of the exhaust need be made until the end of the operation. This is because the oxygen is absorbed by the bowel with the same rapidity and ease as the ether vapor so that no residue remains.

When air is used as a vehicle, the bowel must usually be emptied every 5 or 10 minutes, as in this case a nitrogen residue tends to accumulate and act as a diluent of the freshly added anæsthetic mixture. Whenever possible, oxygen should be used as a vehicle in place of air—first, because it reduces the dangers of anæsthesia; secondly, because it greatly diminishes the rapidity and depth of respiration, in some cases even causing the phenomenon of apnœa of hyperoxygenation, thus greatly reducing the loss of ether through the lungs; and, thirdly, because of its obviating the necessity of frequent use of the exhaust and hence contributing to the smoothness of the anæsthesia and the comfort of the anæsthetist. It was not possible in our cases to estimate exactly the amount of oxygen consumed as the same tank was used for other purposes, but the quantity was surprisingly small—the cost reaching something like 10 or 15 cents per hour.

In the ordinary case, a smooth anæsthesia continues from this point with little further active intervention on the part of the anæsthetist. The needle valve of the oxygen tank may require occasional adjustment and the thermometer must be watched to see that the temperature of the water-bath does not become too high. When the temperature tends to rise above 90 degrees the incandescent lamp may be partly withdrawn from the water-bath or it may be turned off for a few minutes, being lighted when the mercury has fallen to 88 or 89 degrees. If, with a lighted 10 candle power lamp inserted the full length into the water-jacket a temperature of 90 degrees cannot be maintained, it is certain that there is a leak in the apparatus or from the patient's sphincter, necessitating an excessive flow of oxygen to maintain the required pressure,

and hence an excessive evaporation of ether with its accompanying increase in refrigeration.

Too shallow narcosis is met by adjusting the face towels so as to cause increased rebreathing of the exhaled ether (this does not cause cyanosis on account of the constant absorption of oxygen from the bowel), and, if this is not sufficient, by introducing anæsthetic mixture under the towel from the accessory mouth tube.

Too deep narcosis is met by temporarily shutting off the stream of oxygen and allowing the exhaust to remain open for a short time, or by markedly reducing the pressure without opening the exhaust.

The depth of narcosis is determined by the pupils, which are usually at maximum contraction in complete anæsthesia by this method (if morphine and scopolamine have not been administered when of course they have little value), by the degree of muscular relaxation, and by the color which may be noted from the lips and face but better from the color of the blood in the wound. The character of the respiration is of less value, as the patient may have excellent color though breathing very infrequently. Short, shallow, jerky respiration, especially when associated with a dusky color, is a danger sign, as in the pulmonary method.

I rarely take the pulse except in cases which are manifestly doing badly or where cardiac complications are known or suspected. Muscular tone is best determined from the tension of the jaw muscles and from the presence of voluntary movement of the tongue. It is the author's habit in using this method to keep one finger in the patient's mouth to detect the first active tightening of the jaw or voluntary movement of the tongue. Sufficient ether need not be given to make the lower jaw entirely relax but merely enough to prevent actual biting of the finger. Difficulty in breathing is readily overcome by extending the head on the neck by simply pulling with the finger upon the upper incisors. This has always been sufficient, so that in the entire series of cases here reported neither mouth-gag or tongue forceps have been used to improve the respiration of the patient.

At the end of the operation, the bowel is filled with oxygen to a pressure of 20 mm. and emptied several times, these "oxygen enemata" serving to carry off the greater part of the unabsorbed ether. Occasionally it seems advisable to massage the abdomen in the direction of the colon before removing the rectal tube, but this is usually unnecessary. The rectal tube is then withdrawn and disconnected from the Y-tube.

After Treatment.—As soon as the patient is returned to bed a high soap-suds enema is given, being siphoned off after a few minutes if necessary. A half hour later a second treatment of the same sort is given. Recovery is rapid and vomiting usually absent. When present it is very rarely severe and not a few of those patients who do vomit curiously enough disclaim any feeling of nausea.

To prevent any possibility of transmission of typhoid, amœbic colitis or other intestinal infection from one patient to another, the rectal tube and the Y-tube are kept between cases in a 1 per cent. solution of formalin. The glass tip of the accessory mouth tube is kept when not in use in the same solution.

CONCLUSIONS.

From what has preceded, it is evident that the colonic method of administration of ether is more complex than the pulmonary method in general and requires from the anæsthetist a broader appreciation of the physiological factors involved. For these reasons alone its field of usefulness is limited to cases in which it presents distinct advantage over the pulmonary method. It is therefore not a method adapted to the experimental use of the tyro but rather a valuable addition to the armamentarium of the trained anæsthetist.

We may summarize the indications and contraindications as follows:

Indications.—(1) Operations upon or about the respiratory tract (head, neck and chest) especially such as lay open the mouth, larynx, pharynx and trachea.

2. Operations upon patients in whom ether absorption must be minimized on account of lung, heart or kidney lesions.

3. Operations upon cases already suffering from respiratory embarrassment.

Contraindications.—(1) Operations upon cases presenting lesions of the alimentary tract, especially such as might cause weakness of the wall of the colon.

2. Laparotomies in general, except such as do not open the general peritoneal cavity, *e.g.*, suprapubic cystotomy. This because of the interference of the inflated colon with the work of the surgeon.

3. Operating upon cases with markedly incompetent sphincter or with large complete fistula in ano. A patient with an open appendicostomy would offer the same difficulty of leakage.

4. Operations upon cases suffering with orthopnœa. In these cases it is usually impossible to inflate the colon because of the obstruction caused by the weight of the other viscera resting upon it.

5. In emergency cases in general because of the lack of preparation of the colon.

The points in favor of the method in cases in which its use is indicated may be summed up as follows:

1. Freedom of operative field from contamination by the anæsthetist.

2. Ability to maintain a smooth and continuous anæsthesia in operations involving the respiratory tract, thus shortening the time and reducing the shock of operation.

3. Uniform depth of anæsthesia, causing light narcosis and a marked saving in ether.

4. Lessening of pharyngeal and bronchial secretion and of tonic contraction or troublesome relaxation of jaw muscles.

5. Ability to administer oxygen without interruption of anæsthesia.

6. Minimized loss of heat during operation because of diminished sweating and ether refrigeration.

7. Reduction of postoperative vomiting and nausea.

The only point against the method in cases where its employment is indicated is the occasional difficulty in maintaining profound anæsthesia without the use of the supplementary mouth tube.

In justice to myself, I am forced to disclaim responsibility for the premature appearance of some of the figures herewith given and of a partial description of my apparatus which appeared in a recent article on the subject of rectal anæsthesia.[4] The photographs and letters which formed the basis of the article in question were furnished the author solely to assist him in his use of the method and their publication was without my knowledge or consent.

It is a pleasure to acknowledge my indebtedness to Drs. Jos. A. Blake and Geo. E. Brewer, on whose services in Roosevelt Hospital this work was done, for their hearty encouragement and assistance.

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