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Contributors

Squarey, Charles.
Royal College of Physicians of London

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ADMINISTRATION OF CHLOROFORM AND NITROUS OXIDE.

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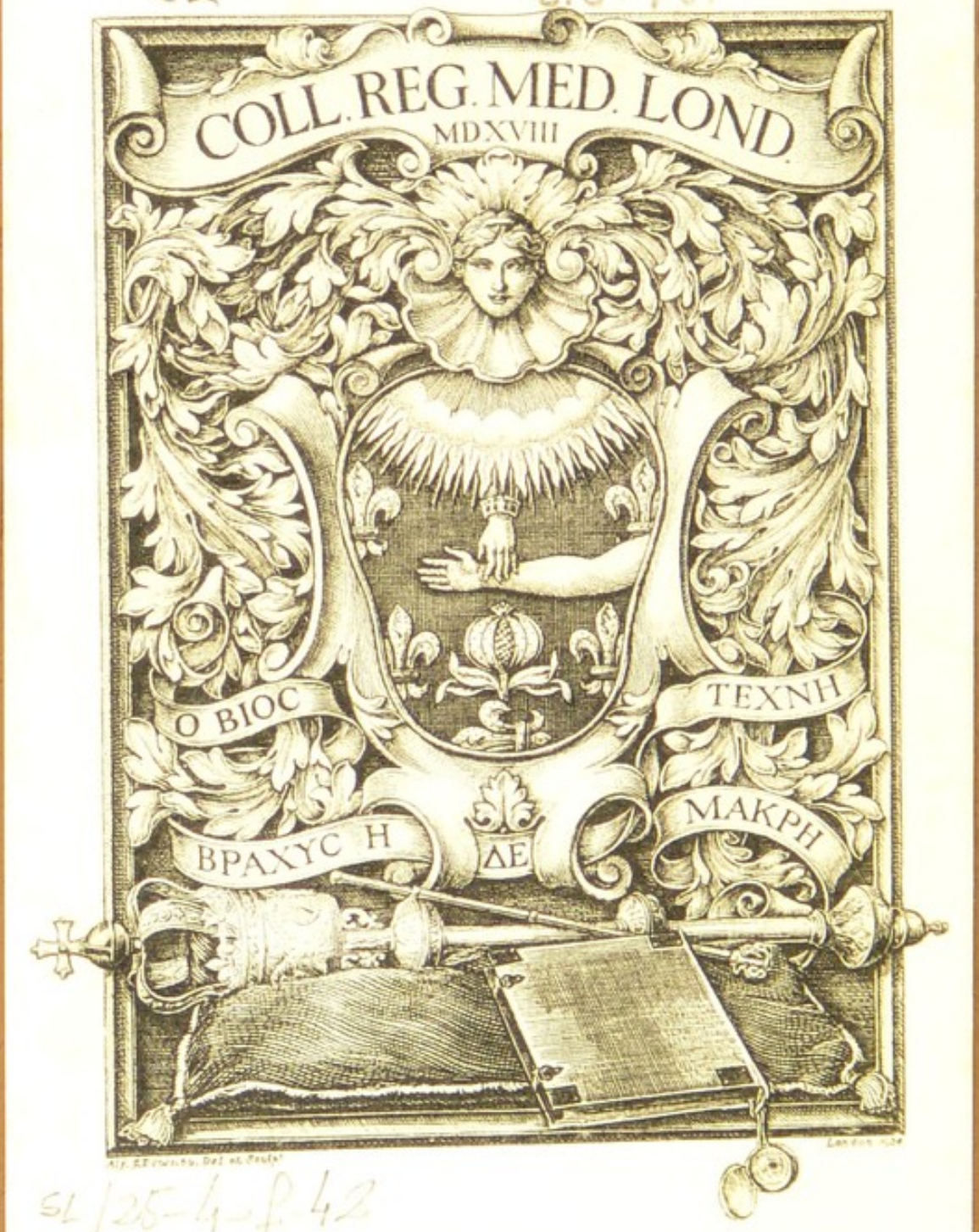

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ON THE

ADMINISTRATION OF CHLOROFORM AND NITROUS OXIDE.

BY

CHARLES SQUAREY, M.B. Lond.,

MEMBER OF THE ROYAL COLLEGE OF PHYSICIANS OF LONDON; ASSISTANT PHYSICIAN TO THE HOSPITAL FOR WOMEN, SOHO SQUARE; LATE RESIDENT MEDICAL OFFICER TO UNIVERSITY COLLEGE, AND THE LONDON FEVER HOSPITALS.

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PREFACE.

A NEARLY three years' experience in the administration of anæsthetics in one of the largest schools of medicine in London, has tempted the author to publish a few practical facts, which their constant use has forced on his observation, and which he thinks may prove useful to others so engaged. At the same time, he has taken the opportunity of collecting the published writings, at present scattered in various journals, of others far more experienced in this subject than himself.

By presenting in a small treatise an abstract of these various publications, a succinct account of what takes place during the administration of these anæsthetics, and an account of the various methods of administering them, the author trusts somewhat to

guide the Student in his first administration, and to allay, to a great extent, the anxiety which the inexperienced must always feel when using such powerful remedies.

13, Upper Wimpole Street,
Cavendish Square, W.

ON

THE ADMINISTRATION OF CHLOROFORM AND NITROUS OXIDE.

INTRODUCTION.

Chloroform was discovered nearly at the same time by Soubeiran (1831), and Liebig (1832). Its chemical composition was first accurately ascertained by Dumas and Peligot in 1835, who found that it consisted of 2 atoms of carbon, 1 atom of hydrogen, and 3 atoms of chlorine; or, to speak otherwise, of 1 atom of formyle and 3 atoms of chlorine.

Its chemical formula is, therefore, C_2HCl_3 or Fo_1Cl_3. Formyle is the hypothetical radical of formic acid, the latter was first discovered in the red ant, *Formica Rufa*, hence its name.

Chloroform is a clear limpid liquid, having a specific gravity of 1·480. It is very volatile; it boils at 141° Fahr., and it is not inflammable. Its odour is fruit-like and peculiar.

Before the discovery of its anæsthetic properties, it had been used internally by some practitioners. Guillot, for instance, prescribed it as an anti-spasmodic in asthma.

In the form of chloric æther, it was first used in

1847, by Mr. Jacob Bell, to produce insensibility to pain, and it was afterwards used in some of the London hospitals—at St. Bartholomew's by Mr. Laurence—but the uncertainty of its action and its expense soon caused it to fall into disuse.

In March, 1847, Flourens announced to the Academy of Sciences of Paris certain observations on the anæsthetic power of chloroform on animals; and in the November of the same year Sir James Simpson, by experiments on himself, discovered its wonderful power over the human body, and soon after introduced into daily use what has proved, to patient and surgeon, to be the greatest blessing of this century.

CHAPTER I.

THE ADMINISTRATION OF CHLOROFORM.

In all cases where chloroform is to be administered, a few directions should be given to the patient with regard to his conduct and feeding for a few hours before the operation.

The patient's bowels having been properly evacuated the previous day, or early the same morning, he should be directed to take, three or four hours before the operation, a light and easily digestible meal, and from that time till the surgeon arrives, to remain as quiet as possible. If feeling at all weak

or nervous, about five or ten minutes before the commencement of the administration he should take a glass of sherry, or a little weak brandy and water. By these means we lessen as much as possible the likelihood of vomiting occurring during or after the operation.

These points having been attended to, and the patient placed on the operating table, the administrator should see that everything is loose about the throat and chest, and being satisfied that all is right he may commence to give the anæsthetic.

With regard to the examination of the heart, it is always well to examine it beforehand, as it puts the administrator on the safe side if an accident should happen; but experience has proved to me that heart disease makes very little if any difference in the effects produced by chloroform. I have given it in nearly all forms of heart disease, and in one case, that of an old woman between 60 and 70 years of age, whose foot was removed on account of disease of her ankle-joint, and who died a few days after from the effects of the operation, not only was the heart found in a very fatty condition, the muscular tissue of both ventricles being very much diminished in thickness, and almost entirely destroyed by fatty degeneration, but her left pleura was found nearly half full of purulent fluid, yet she took the chloroform, and was kept under its influence for about half an hour without a single bad symptom.

At the commencement of the inhalation, the sensations experienced by patients vary immensely. In some they are of an entirely pleasurable character, so much so that they will inhale it simply for their sake, but these are, unfortunately, quite exceptional cases. In most people the sensations produced are anything but pleasant. Very few like the smell of chloroform, and so the first few breaths are disagreeable simply from this alone; in addition to which, especially if given at all too strong, a sense of suffocation is produced, sometimes so great as to cause coughing, or a constant attempt to swallow. If either of these symptoms persist for any length of time, more air should be given till they subside.

Within a short time, different in different individuals, and dependent too on their age, strength, and sex, the exciting effects of the chloroform become apparent, either by the patient's talking, or singing, or crying, or by muscular efforts, or in females by an hysterical condition being produced, accompanied by one or other of the following sensations. By far the most common seem to be a feeling of great oppression of the chest, a great beating of the heart, it getting more rapid and stronger, as if it were going to burst; a great throbbing in all the vessels, noises in the head like the rumbling of trains, and various other sensations too numerous to be mentioned; but in a very short time these subside, and the patient, though not through the exciting

stage, for the ideas that may be occupying his mind may cause the most violent struggles, yet is unconscious of anything that is said or done, or that occurs, though not by any means insensible to pain.

Immediately following this stage is that of complete unconsciousness, the condition necessary for all capital operations; this is ushered in in one of two ways. In some the struggles become less and less violent, the talking more and more incoherent and indistinct, till they quietly subside into a deep sleep; in others, immediately before the stage of complete unconsciousness sets in, a violent tonic contraction of all the muscles of the body takes place, the limbs become rigid, the chest fixed, the respirations stopped, the face is much distorted, the eyes injected and prominent, the lips become dusky, and the veins about the head and neck become much congested and stand out like cords, and the patient breaks out in a profuse perspiration; this condition lasting for half a minute or so, gradually subsides, and the next few breaths which the patient takes, during which he should be narrowly watched and the chloroform administered with great care, put him completely under the influence of the drug.

As a rule, this is a fairly accurate account of what takes place during the administration of chloroform; but there are cases which differ entirely from this, cases in which no stage of excitement is observed, in which the patient lies down, and after the first

few whiffs, which cause discomfort simply from the disagreeable smell, he passes off quietly into the relaxed condition necessary for capital operations. And these cases must be borne in mind, though they are only of exceptional occurrence, lest one day waiting for the stage of excitement to appear, an overdose may be given. From these exceptionally quiet cases, to those whose struggles are so violent as to require four or five assistants to restrain them, all gradations are observed.

The stage of complete relaxation of the muscular tissues is thus recognized: the patient lies quietly in whatever position he may be placed, his limbs quite flaccid, falling heavily when raised; his breathing regular, with or without some stertor; his pulse regular, and perhaps slightly more compressible than normal; the expression of his face natural and composed; the eyes, the conjunctiva insensible to touch, the reflex action of winking not being produced, and the pupils, generally, though not always, contracted, insensible to light. This condition of the pupil I have been for some months, closely observing, and to it I wish to draw particular attention, as my experience has convinced me that it is the sign above all others to be closely watched for, and when produced to be recognised as indicating that chloroform has been pushed as far as it may safely be. It is also a much more trustworthy sign of the patient being fully under the influence of chloroform than

that obtained by touching the conjunctiva. In operations on sensitive parts, I have known patients to shrink, when touching the conjunctiva produces no winking; but I have never known, this condition of pupil existing, any patient to make the least movement of any kind under any operation. In many cases it is not necessary to push the chloroform so far, but I am convinced it should never be pushed farther; once having brought the patient into this condition, he should, in those cases in which it is necessary, be kept so much under, that a score of breaths or so would, no chloroform being administered, bring him into such a condition that his pupil would act to light; and I may say, that since following out this rule I have neither felt, nor had reason to feel, anxiety in any case.

If, after the patient has been brought into this condition, the chloroform be still continued, dangerous symptoms very soon make their appearance, and they may appear in two ways; either the respirations become stertorous and shallow, the pupil dilates (this I have never seen), the pulse becomes slower and gradually weaker, the face becomes dusky, the breathing gradually stops, followed soon after by the pulse and the patient is dead; or else, without much warning of any kind, the heart suddenly stops, the patient having been breathing a moment or so before quite regularly, and even noiselessly.

In the first class of cases death seems to be due to

paralysis of the muscles of respiration; in the latter, to cardiac syncope. From death occurring in one of these two ways, it is, of course, seen that the signs of danger evinced during the administration of chloroform are connected with the respiratory and circulatory functions, and they, therefore, must be very carefully watched in every case.

Before proceeding to treat more minutely of these signs of danger and of their treatment, I would speak of various symptoms which may arise when chloroform is being given, and which frequently give great alarm to the friends, though really of no account at all.

First, then, of the hysterical condition, which is not unfrequently produced at the commencement of the administration in females between the ages of fifteen and thirty. Ushered in either by laughing, sobbing, and even screaming, it increases till the patient, struggling violently, breathes in an extremely irregular manner, at one time taking a succession of short, quick, shallow, breaths, and then again holding her breath as long as possible, the face getting congested and the veins full, standing out in strong relief, the pulse all the time being very small, weak, and rapid, till, to people unaccustomed to such vagaries, the patient looks in a very alarming condition. In such cases the chloroform must be pushed; it must be administered as strongly with respect to safety as possible, so as to get them

through this exciting stage in the shortest time. No anxiety whatever need be felt by the administrator.

The next symptom to be noticed, and one which may occur at any time during the administration, is the stertorous or noisy breathing, which is so great a bugbear to all inexperienced administrators.

Stertorous and noisy breathing is not of itself a sign of danger. In some people it is simply natural; in others it may be due to the position in which they are placed; and in others again it may be due to the nature of the operation which is being performed rather than to the chloroform. It occurs, as I have said before, at all times during the administration of the anæsthetic, in quite half of the cases before they are so completely under its influence as to be ready for operation. Yet as stertorous breathing is certainly one of the symptoms of an over-dose of chloroform; it should always on its appearance call for the strict attention of the administrator.

The explanation of this stertorous breathing being at one time dangerous and at another not, lies in the fact that it may be produced in two different ways. It is of two kinds:* one not dangerous—simply natural—is produced by the vibrations of the Velum Palati, and may therefore be called Palatine. It has a buccal or nasal character, depending on whether the air passes through the mouth or nose. The other—the true profound stertor, essentially

* Lister. *Holmes's System of Surgery*, vol. iii.

concerned with chloroform—is formed in the larynx, and results from the vibrations of the portions of the mucous membrane surmounting the apices of the arytænoid cartilages, these during stertorous breathing are carried forward to touch the base of the epiglottis, and as the stertor becomes deeper and deeper, they approach nearer and nearer together, till at last they completely close the larynx, and prevent any entrance of air into the chest.

Now, to distinguish these two kinds of stertor one from the other, the general condition of the patient must be looked to. If it is simply palatine stertor, the limbs will be found still rigid; the reflex winking of the eyelids will be produced by touching the conjunctiva, the pupil will act to light, the patient is safe, the stertor need not cause any anxiety; if, on the other hand, it be the true laryngeal stertor, the limbs will be found flaccid, the conjunctiva senseless, the pupils fixed, the face more or less dusky, the respiration shallow, and, more often than not, the cheeks will be flapping backwards and forwards with each respiration, the patient is thoroughly narcotised, and if not actually in danger, would undoubtedly be so in a very short time were the chloroform not to be immediately withdrawn from his face.

The pulse does not vary like the respiration. In all cases quicker than normal at first from nervousness and anxiety, it is increased during the exciting stage by the chloroform itself; then, as the patient

gets thoroughly narcotised, it sinks to its normal rate and power, getting directly, as the severity of the operation, more or less weak during its performance. The shock of the operation produces no effect on the pulse, except where any sensitive or important parts are concerned; for instance, in removal of the testicle I have frequently felt the pulse to distinctly intermit on the division of the spermatic cord.

Signs of Danger.

To be able to appreciate and to recognise at once the signs of danger which appear when an over-dose of chloroform is being administered, it is essential to know the ways in which it may cause death.

As far as is at present known, chloroform may kill in two ways. First, by paralysing the muscles of respiration; secondly, by paralysing the heart.

In the first class of cases—and Lister maintains that chloroform kills only in this way—the signs of danger are derived from the state of the respiration. Almost always the true laryngeal stertor is the first sign which attracts the attention of the administrator. This becomes rapidly more and more profound, the respirations getting shallower and shallower, the face gradually gets dusky and covered with a profuse perspiration, the eyes prominent and injected, the pupils fixed. The pulse all this time may be felt beating quite regularly, though getting gradually weaker and slower. At last the respirations stop,

the face assumes the ash-grey hue of death, and very shortly after the pulse ceases, and the patient is dead.

Occasionally the premonitory stertor is not very well marked. It was my fortune, about two years ago, nearly to have an accident of this kind. The symptoms presented by the patient were as follows, and were peculiar in that there was not any exciting stage, and that the laryngeal stertor was absent, except at the last few moments :—

The patient took the chloroform very quietly and well, breathing regularly and noiselessly. In the course of a few minutes, he became thoroughly narcotised, his conjunctiva on being touched not causing winking. I then gave him a few more whiffs, to keep him thoroughly under whilst being removed from his bed to the operating theatre, when I noticed a slight stertor; his pulse all the time was quite regular and full. I immediately took the towel and lint from his face, and then I saw that he was very pale, and that his respirations were very shallow and getting rapidly shallower. I kept him still on his bed, and watched. His respirations in a few minutes stopped completely; his pulse began to get slower and weaker, and the man was evidently rapidly dying. After waiting for about a minute, during which time no attempt at respiration was made, though his pulse was still beating, I commenced artificial respiration, and am thankful to be

able to say that in another minute or so he was all right again. I firmly believe that this was a pure case of over-dosing. The chloroform was administered on lint, and it being a very hot day, it must have evaporated and saturated the air to a much greater extent than usual.

This case has certainly convinced me that deaths from chloroform do occur, as Lister has so ably described in *Holmes's System of Surgery*, but yet I very much doubt this being the only way in which chloroform kills.

In such a case as the above, watching the pulse would not have been of any use; yet cases of death occur in which the pulse ceases before the respirations, and my friend Mr. Poore, the resident medical officer of University College Hospital, has lately had two cases in which the pulse distinctly intermitted before any sign of danger could be derived from the state of the respirations. In both cases the administration of the chloroform was at once suspended, and the patients recovered. In one, a little child, aged 4, artificial respiration had to be resorted to.

In my experience, the pulse does not give much sign of danger till after those given by the respiratory system; yet, as chloroform certainly does kill by paralysing the heart, the pulse should always be carefully watched, as in cases of this kind the

only chance of saving the patient depends on this cessation of the pulse being at once recognised, and means immediately taken to restore the circulation.

Sudden and rapid dilatation of the pupil is said to be another sign of danger which the administrator should always watch for. This I have never seen, and, therefore, can only quote from others who say that when an over-dose is being given, the pupils dilate rapidly and widely. This condition of pupil my experience has led me to disregard altogether. That in fatal cases the pupil is found widely dilated I have no doubt; but what I maintain is, that long before this dilatation takes place, the signs of danger evinced by the respiratory and circulatory systems will have been present, and, therefore, that this condition of the pupil, in appearing so late, is comparatively, if not entirely useless.

Again, dilatation of the pupil is the first sign of the patient's recovery from the influence of the chloroform, and if this recovery is hastened by any sudden, sharp pain, rapid dilatation of the pupil will immediately occur. This I have repeatedly observed in long operations, when the patient has slightly recovered from the effects of chloroform, and has then felt a sharp pain. The action of the pupil to light is, I believe, the first of the reflex movements of the involuntary muscles which chloroform abolishes, and it is the first to regain its power when the chloro-

form is left off. It, I believe, is the earliest and the surest sign of the patient's recovering from the influence of chloroform.

I limit, therefore, the signs of danger to the respiratory and to the circulatory systems:—

Stertor, conjoined with shallow respirations, duskiness of the face, lividity of the lips, and prominent eyes, with fixed pupils, being the signs given by the first—though it must be borne in mind that stertor is not always present; and a weakened and intermittent pulse, with great pallor of countenance, those given by the second.

These are, therefore, the symptoms which should be most carefully watched for when the patient is once fully under the influence of chloroform, and on their appearance it should be at once temporarily discontinued.

Treatment to be carried out in Cases threatening a Fatal Termination.

Directly any serious symptoms arise, the chloroform should be removed from the face, and artificial respiration immediately commenced. In those cases in which death seems approaching by paralysis of the respiratory muscles, artificial respiration will restore the patient, even after all attempts at respiration have ceased, and even, too, after the pulse has stopped. In addition to this, cold water may be thrown on the face and chest, and the limbs rubbed

with hot flannels. Lister recommends that the tongue be drawn out, firmly and sharply; and this, certainly may be done at first, but if it be not at once followed by a deep breath, artificial respiration should be immediately commenced. All stertor can be got rid of by firm traction on the tongue, and, in cases not far gone, an additional pull, which causes sharp pain, is frequently sufficient to re-establish the respiration.

Galvanism is recommended by some and opposed by others. The committee of the Medico-Chirurgical Society decided that it was certainly useful, but far inferior to artificial respiration. Its opponents think that a feebly-acting heart would be stopped by it altogether. Dr. Danzel, of Hamburg, relates a case where the application of the poles of a rotatory electrical apparatus—one to the region of the neck, the other to the epigastrium—restored a patient apparently dead from chloroform, after artificial respiration had been tried in vain. The first effect of the application was to cause contraction of the levator scapulæ and biventer maxillæ muscles, succeeded shortly by action of all the respiratory muscles.

In the *Pacific Medical and Surgical Journal* it is said that experiments on inferior animals show that they may be restored from apparent death by chloroform by the continuous galvanic current, the negative pole being put in the mouth, and the positive pole in

the rectum. It states that in some cases the animal was left for two minutes in a state of apparent death, and then restored.

Frequently the position of the patient is sufficient to cause serious impediment to the respirations; thus, in operations on the rectum, uterus, etc., when the patient is lying, for the convenience of the operator, nearly on the face, the breathing requires much more careful watching, and if it become at all shallow, the patient should be immediately turned on to the back.

In those cases which seem to die from paralysis of the heart, neither artificial respiration, nor anything else that I know of, seems to be of any use. Dr. Holmes, of Chicago, in these cases recommends that the patient be placed, with the head downwards, on an inclined plane, of about 40 degrees. He mentions one most appalling case in which, after the patient was apparently dead, the pulse was again felt 15 seconds after this position was assumed.

Dr. Holms holds that by far the larger proportion of cases of death by chloroform arise from syncope, and that this may be overcome by causing a column of blood to press on the vessels of the brain, and he gives preference to the position above recommended over galvanism, artificial respiration, or other means generally adopted to restore the patient. The whole body must be inclined, not the head and shoulders alone.

Numbers of people to whom I have administered chloroform, have been told by their doctor that they are not fit subjects for chloroform.

Are there any conditions which we can diagnose which should forbid its use?

In the majority of cases in which death has occurred, the heart has been said to be fatty; but the only fatal case that I have actually seen, occurred in a young girl, in whom we could discover at the post mortem no trace of disease of any kind.

Undoubtedly, in an aged person, with a weak, dilated heart, there is more cause for anxiety to the administrator than in a healthy person; but if proper care be taken, I do not think that in any case chloroform cannot be safely administered.

I have given it in nearly all forms of heart disease, to aged people with the arcus senilis well marked, to people with intermittent pulse, to people with various murmurs, and to others almost dead from exhaustion after a severe injury, and I have not noticed, either of these conditions existing, any difference in the effects of the chloroform.

As a general rule, it may be stated that the weaker people are, the less they require. When using so powerful a drug, the greatest care should be always taken; it should be always remembered, that whatever the operation, the administration of the chloroform requires the same great care. The necessity for care is frequently considered to be in a

direct ratio to the severity of the operation; it is altogether forgotten that the two are entirely independent of each other, and this I believe to be the reason why the greatest number of deaths from chloroform have taken place when some minor operation has had to be performed.

In concluding this chapter on the administration of chloroform, I would draw attention to the following rules, which I think should in all cases be strictly observed.

1. The administrator should, before commencing, see that everything is loose about the patient's chest and throat.

2. For the first minute or two the chloroform should be given very much diluted with air; it should not cause any coughing or spasm of the glottis.

3. In the hysterical condition so frequently produced in young females, it must be administered as rapidly as is consistent with safety to the patient, taking care that if the patient hold her breath for any considerable time, there should be plenty of air and little chloroform in the first few deep breaths that follow.

4. In the exciting stage, if the patient holds his breath whilst struggling violently, plenty of air should be given in the following deep breaths, lest the chest, being almost empty of air, they should take a poisonous quantity of chloroform into the

system. Again, in the violent tetanic contraction of all the muscles, which sometimes precedes the stage of complete unconsciousness, it is by far safer to take the chloroform from the face till it has ceased, and then to administer a weakened atmosphere of chloroform till they are under.

5. Lastly, the respirations should be carefully watched; if stertor is caused, the general condition of the patient should be at once looked to; the finger should be kept constantly on the pulse and the conjunctiva, and the state of the pupil should be frequently examined, and if the pupil be insensible to light, a weakened atmosphere of chloroform should be administered, just sufficiently strong to keep him in that condition.

CHAPTER II.

METHODS OF ADMINISTERING CHLOROFORM.

ALTHOUGH many forms of inhalers and face-pieces have been invented for the administration of chloroform, practically there is only one (Clover's) that fulfils the one requirement, namely, the power of regulating the percentage of chloroform and air inhaled, necessary for its safe use.

From experiments on animals, Mr. Clover has found that a percentage of chloroform greater than

5 per cent. is dangerous to life; that when it is not greater than 5 per cent., the heart continues to beat long after the respirations have ceased; that when stronger than this, the difference between the arrest of respiration and of circulation is less marked, and if the dose is very strong, the heart stops before the movements of respiration.

In inhalers like those of Drs. Snow and Sansom, although the chloroform is carefully measured, yet the proportion of vapour mixed with the air inhaled is always greater when the chloroform is first applied.

When given on lint or on a handkerchief the same is the case; and here again other conditions, such as the temperature of the air, the extent of surface of chloroform exposed, the warmth of the administrator's hand, the distance the handkerchief is held from the face, are continually causing alterations in the percentage of chloroform and air inhaled.

Various face-pieces have been invented on which to pour the chloroform, instead of the lint or handkerchief being held in the hand; and these are advantageous in that they remove one condition causing variation in the rapidity of the evaporation of the chloroform, namely, the effect of the temperature of the administrator's hand.

Now the amount of chloroform vapour taken up by the air varies according to the temperature. At

a temperature of 60° F., air will take up twice as much as at 40° F.

At 60° F., a temperature which may be said to be the usual temperature of the wards of our hospitals, air will take up 12 per cent. of chloroform vapour, an amount far above that which has been proved by Mr. Clover to be dangerous to life; and this, or nearly this percentage may be undoubtedly given at any time when chloroform is administered by either of the above methods.

By Clover's apparatus, the chloroform vapour is diluted with air before it is inhaled. Other methods of dilution have, however, at various times been brought forward.

One, recommended by Mr. Ellis, by volatile media. Another recommended by Dr. Sansom, by the use of anæsthetic mixtures, by which means he says that the strength of the atmosphere can be regulated with sufficient precision for all practical purposes. The mixture Dr. Sansom recommends is chloroform and absolute alcohol, in the proportion of one of the former to two of the latter.

The slight experience of mixed vapours, however, that I have had, certainly does not predispose me in their favour, the exciting effects being always greater and more prolonged.

The following description of Clover's apparatus is taken from a paper read by him before the Odontological Society, in March, 1868 :—

"The apparatus, when ready for use, consists merely of a bag suspended at the back of the administrator, filled with a mixture of air and chloroform. A flexible tube three feet long passes from the bag to the face-piece, which is formed of flexible metal, and lined with chamois leather, so as to fit air-tight over the nose and mouth. The face-piece is provided with valves, one opening with inspiration, and allowing the atmosphere to pass from the bag into the lungs; the other opening during expiration, and allowing the escape of respired air. There is also a sliding door in the face-piece, by opening which additional air is admitted, and the percentage of chloroform is diminished.

"For the purpose of 'charging the bag,' there is a bellows, shaped like a concertina, and measuring 1,000 cubic inches of air. The nozzle of the bellows is joined with an evaporating vessel, and this is provided with a mount, for the purpose of connecting it with the inhaling tube. The centre of the evaporating vessel is occupied by a metallic bottle for containing hot water, and covered with blotting paper, upon which the chloroform passes when supplied through a hole in the lid of the evaporating vessel. The chloroform is supplied by means of a glass syringe, adjusted by means of a screw-nut on the piston-rod, to take up thirty-two minims. This quantity is put into the evaporating chamber each time that a bellows-full, or 1,000 cubic inches, of

air is passed into the bag, and falling on blotting-paper, kept warm by the arrangement described, is evaporated and mixed thoroughly with the air passing over it. The process is repeated six or seven times, and the bag then contains a uniform mixture of about $3\frac{3}{4}$ inches of chloroform with each 100 inches of air, a minim of liquid chloroform being equivalent to about $1\frac{1}{8}$ cubic inch of its vapour.

"The patient cannot inhale a stronger dose than the bag contains, but by opening the sliding-door in the face-piece the percentage may be reduced to 3, 2, or 1 per cent."

From this description it will be seen that, by Clover's method, the patient cannot inhale an atmosphere containing more than 4 per cent., an atmosphere which he has proved from experiments on animals, and from his unfailing success on men and women, to be as safe as possible.

The only objections that are ever made to this method being used, is that it takes longer to put the patients under the influence of the anæsthetic, the extra trouble given, and the bulk of the apparatus; objections which, when the life of a human being is concerned, are confessedly too slight to be regarded.

The time generally taken to produce complete anæsthesia in this way, varies from four to seven minutes.

ADMINISTRATION

OF

NITROUS OXIDE.

CHAPTER III.

NITROUS OXIDE; PROTOXIDE OF NITROGEN.

INTRODUCTION.

NITROUS OXIDE was discovered by Dr. Priestley, in 1776, who named it dephlogisticated air. In 1800, Sir Humphrey Davy ascertained that it might be respired for a few minutes; and from its producing a singular species of transient intoxication, attended in many instances with an irresistible propensity to muscular exertion, and often to uncontrollable laughter, it acquired the popular name of "laughing gas." Sir H. Davy first named it nitrous oxide.

It is obtained by heating the nitrate of ammonia (NH_4O, NO_5) in a glass retort; the salt quickly melts, and at a temperature between 400° or 500° Fahr. it undergoes decomposition, and is resolved into the gaseous protoxide of nitrogen and steam.

An ounce of the salt furnishes about 500 cubic inches of the gas.

The decomposition occurs thus:—

$$NH_4O, NO_5 = 2NO + 4HO.$$

At ordinary temperatures, nitrous oxide is a transparent, colourless gas, with scarcely any smell or taste, soluble in cold, much less so in hot water. Under a pressure of 50 atmospheres at 45° Fahr.,

it is reducible to a colourless liquid of a specific gravity at 45° Fahr. of 0·908; it boils at about—126° Fahr.; and may be frozen into a transparent solid at about—150° Fahr.

The gaseous protoxide has a specific gravity of 1·527.

It supports the combustion of many bodies with a brilliancy resembling that with which they burn in oxgyen. It is distinguished from oxygen by its solubility in water.

Nitrous oxide consists of two volumes of nitrogen combined with one volume of oxygen, the three volumes in the nitrous oxide being condensed into the space of two volumes, so that, when united into nitrous oxide gas, the gasses occupy two-thirds of the bulk which they did when separate.

In 1800, Sir Humphrey Davy suggested that this gas might be used to alleviate the pain of surgical operations, but there is no account of its having been so used successfully at that time. Dr. Horace Wells, of Hartford, Connecticut, first discovered its anæsthetic properties. In December, 1844, he had the gas administered to him by Dr. Colton, and had a tooth extracted under its influence, without feeling any pain. The introduction of ether inhalation, by Morton and Jackson, soon after, in 1846 superseded the use of the gas, and it was not much used, till, in May, 1863, Dr. Colton again brought it forward. Ever since this, its use has been gradually spreading

throughout the United States, where it is now considered to be the most available and the safest anæsthetic for dental operations.

It was not, however, introduced into London till the spring of last year, when Dr. Evans, of Paris, administered it for some patients at the Dental Hospital, Soho Square, in the presence of many medical men.

The result was so satisfactory in every way that it was then immediately adopted, and a committee appointed to enquire into and report upon its action.

The following is a condensed account of their report :—

First, from experiments on the lower animals, they found that, when perfectly free from atmospheric air, it was a powerful anæsthetic, more rapid in its action, although more evanescent than chloroform and other anæsthetics, and that although, if pushed, it produced death, still the animals have often been speedily brought round, when apparently dead, by the admission of air.

As an anæsthetic in man, they considered it to be as safe for short operations as any other anæsthetic at present in use.

From upwards of 2,000 carefully authenticated cases, they came to the conclusion that its advantages for short operations were much greater than its disadvantage, the latter being chiefly the trouble required in its preparation, and the complicated apparatus necessary for its administration.

In America it has been administered in nearly 30,000 cases without, as yet, a fatal case.

CHAPTER IV.

THE ADMINISTRATION OF THE GAS.

By far the majority of people to whom the gas has been administered have taken it without previous preparation of any kind. It should not be given too soon after a full meal, but, with this exception, there is no time when it cannot be safely administered.

If asked by a nervous patient for general directions as to her conduct before taking the gas, those advised for chloroform may be given. Vomiting occurs so rarely that it may be said not to occur.* Any nausea that may be felt afterwards is due rather to the swallowing of blood than to the gas.

Before commencing to give the gas, the administrator should see that the dress is loose about the chest and throat; that the gag, in dental operations, with a string attached, is firmly placed between the teeth—not too far back, or it may cause retching—

* Since this has been in type, I have given the nitrous oxide gas to a lady for the removal of a small scirrhous tumour of the breast. The tumour was removed without the least pain to the patient in from 3 to 5 minutes. Vomiting however occurred immediately after the operation, and continued for nearly 48 hours afterwards. This patient for a previous operation had chloroform administered, and then suffered as at this time from incessant vomiting for about the same period.

and then, after carefully fitting the face-piece, and applying the finger to the pulse, the inhalation may be commenced.

After a few seconds, varying from twenty to thirty, slight lividity of the face is noticed; this gradually increases till, between fifty and sixty seconds, in some cases longer, from the commencemencement of the inhalation, the lividity becomes extremely well marked. Generally slight twitchings of the hands, and some unsteadiness of the eyes now occur; the pupils are slightly dilated, and the breathing is slower and deeper than natural. At this time, if the operation is very short—a single tooth to be extracted, or an abscess opened—it may be done; but generally it is necessary to induce a deeper state of anæsthesia, and the inhalation must be continued for from ten to fifteen seconds more, when slightly stertorous breathing is produced, the pulse all the time remaining full and regular.

If pushed still further, the respirations become slower, the stertor becomes more profound, the lividity increases, the pupils dilate widely, and the pulse becomes unsteady and irregular. All or either of these symptoms calling, on their appearance, for the immediate cessation of the administration. Some patients have a fit of tetanic spasm just before or just after the commencement of the operation, and they may in such a condition hold their breath for from ten to fifteen seconds. This need not cause

any alarm, provided the pulse be full and beating regularly.

Complete insensibility rarely lasts for more than thirty or forty seconds, though for some little time after, there is a period during which, although conscious of the operation—that is that in tooth extraction, that the tooth is being taken out—yet no pain is felt.

The amount of lividity present is in all cases very great, and gives to the patient a very unpleasant and dangerous-looking appearance; but the first deep breath that is taken after the removal of the face-piece causes the greater part of this to disappear, and in a very few seconds the patient again recovers his normal colour and expression.

Not unfrequently in men, as well as in women, slight hysterical symptoms supervene, but these rarely last any length of time. As a rule, in about five minutes from the commencement of the inhalation, the patient is well enough to walk out of the room.

The symptoms which on their appearance call for the cessation of the administration are slowness and shallowness of the respirations and unsteadiness of the pulse. The respirations in experiments on animals invariably stop before the pulse; in men the respirations become slow and stertorous before any alteration can be detected in the pulse. It may, therefore be said that as long as the pulse is beating

regularly the patient is safe; yet it is advisable, the breathing being slow and accompanied with much stertor, to stop the administration, although the pulse be beating regularly.

The treatment to be followed in any case threatening a fatal termination, consists in at once commencing artificial respiration, the patient being placed at the time flat on the back.

The rapidity of recovering from the anæsthetic condition, as yet has prevented this anæsthetic from being used, except for short operations. It is used now chiefly for the extraction of teeth. The anæsthetic state can, however, be prolonged by continuing the administration, and allowing, every now and then, the patient to have one full respiration of pure air. Gas should be given during from four to six respirations, depending on the state of the pulse, and then be intermitted for one respiration of air. In dental operations, from the operator being at work at the mouth, the anæsthetic state can only be kept up for a limited time. I have, however, in bad cases, where one inhalation has not given time for the removal of the tooth, renewed the administration before the patient's recovery. This, however, is not advisable, on account of the liability of blood collecting in the mouth and running into the larynx.

Mr. Clover has also, in dental operations, prolonged the anæsthetic state by supplying gas through the nostrils by means of a cap fitting closely over the nose.

I have seen Mr. Clover administer it very successfully for cataract, and has also given it for other eye operations, though he says that the unsteadiness of the eyeball which it sometimes produces, causes delay in their performance. I have given it frequently for the opening of abscesses, for forcible dilatation of the urethra, and such short operations, with invariable success.

For such as these, it contrasts most favourably with chloroform in the rapidity with which the anæsthetic state is produced, in the rapidity of recovery, and in the absence of unpleasant after effects.

Patients having once had it, rarely object to taking it a second time.

The sensations experienced by the patients vary considerably. At first there is generally a sensation of fulness and ringing noise in the head, followed in a very short time by dreams which, in my experience, have almost invariably been of a pleasurable character. Not unfrequently patients cry out, scream, and even struggle a good deal during the operation, yet after recovering from the anæsthetic state are quite unconscious that the operation has been performed, and of anything that they may have said or done during its performance.

Up to the present time, only two fatal cases from administration of this gas have been recorded. In one case the patient was in an advanced stage of phthisis. Death occurred within an hour of the administration.

The other fatal case was caused by the gag used to keep the patient's mouth open being sucked into the pharynx, and so causing suffocation.

Mr. Braine mentions, that in the case of a girl aged 19, with cavities in the apices of both lungs, the respiration suddenly became very shallow and panting, that the recovery was not so quick as is usual, and that for more than half an hour afterwards the respirations were very shallow and hurried.

Mr. Clover has given it in cases where moderate disease of the lungs has existed without noticing any untoward effects; yet from the above two cases, it is advisable in all cases where serious disease exists, not to administer it unless absolutely necessary.

With this exception, there are not any cases in which its administration is not advisable. It has been given to the young and old, to fat and to thin people, to people with various forms of heart disease, to aged people with the *arcus senilis* well marked, and as yet there is no authentic case recorded in this country of its having caused death, or any unpleasant after-effects.

In the administration, the finger must be kept constantly on the pulse, the breathing carefully watched, and the pupil occasionally examined, especially as the patient is getting under the influence of the gas; this done, and the face-piece withdrawn as soon as the patient is fairly under, there need be no anxiety on the part of the administrator or of the operator as to the result.

Physiological Action.

Nitrous oxide is supposed to produce its anæsthetic effect by preventing the oxygenation of the nervous centres. Although containing a large quantity of oxygen, it does not when respired part with any of it; it is expired in the same form as it is inspired; it does not undergo any decomposition.

From researches by Dr. Hermann, it appears, that whilst it is very readily absorbed by the blood, it neither enters into combination with, nor produces changes in, nor suffers changes from, the action of the blood. It is now generally believed, that the oxygen present in the blood exists in a peculiar loose combination with the blood-corpuscles, and is not retained by simple physical laws of absorption. Laughing gas, on the contrary, is merely physically absorbed, and blood will take up rather less of it than it will of water.

One hundred volumes of blood at the temperature of blood, will absorb 60 volumes of the gas. Blood saturated with laughing gas shows no signs of change, the spectrum appearances are the same, the blood-corpuscles are unaltered, and, according to Hermann, the oxygen is not drawn out. In the blood, and probably in the body, laughing gas itself suffers no change. It goes out as it comes into the body, pure and simple laughing gas.

At the same time, it allows the escape of carbonic

acid from the blood. Recognising this condition, Mr. Coleman, of the Dental Hospital, has invented a little apparatus, in which the expired air is made to pass over hydrate of lime; this absorbing the carbonic acid, purifies the nitrous oxide, and renders it fit for inhalation again.

In experiments on dogs, conducted by Drs. Burdon Sanderson and John Murray, they found that although no diminution of arterial pressure took place until the animal had been for some time under the influence of the gas, yet convulsions had taken place in several instances, during which the arterial pressure was enormously increased; and as in man such convulsions may unavoidably occur under similar circumstances, they argued, that in patients with diseased arteries, there is in such conditions danger of cerebral, pulmonary or other hæmorrhage from rupture of these arteries. As yet, however, I am not aware of any such accident having happened.

Nitrous oxide produces cessation of the functions of the brain proper before those of the medulla oblongata, of the medulla oblongata before those of the ganglia of the heart. Hence we have loss of consciousness before failure of the respiration, and failure of the respiration before cessation of the heart. Therefore it will be seen, as has been said before, that symptoms of failing respiration, and a weakened and irregular pulse are the signs for the immediate withdrawal of the anæsthetic.

CHAPTER V.

METHODS OF ADMINISTERING NITROUS OXIDE GAS.

When first introduced, nitrous oxide was breathed backwards and forwards into a bag, by the patients pressing their lips against a tube connected with the bag, there being valves in the tube to prevent the re-inhalation of the gas, the patient's nostrils being at the time compressed by an assistant. Given in this way, many cases were not very successful, owing to the apparatus allowing air to be sucked during the inhalation.

Many improvements have, however, been since made.

Mr. Clover has modified his instrument for chloroform-giving, so that it can be used for the gas, the bag being filled with the nitrous oxide instead of chloroform vapour, but the most convenient and portable apparatus for its use is the iron cylinder containing the compressed gas, the Cattlin's bag and the Clover face-piece.

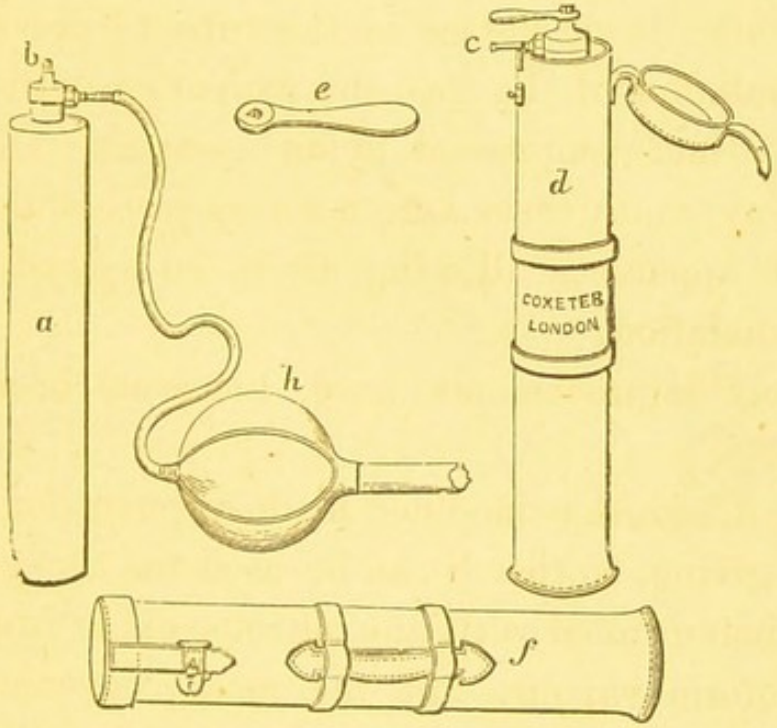
The engraving represents an apparatus made by Mr. Coxeter, of Grafton Street, which is now very generally used.

The small iron vessel (Fig. 1, *a*) measures 28½ inches by 4½ inches, and contains 36 gallons of the

compressed gas, with which, for portability, is supplied a leather case (*d*), made with a firm foot, for convenience of use, the same being shown, closed and padlocked (*f*), containing the bottle.

The Cattlin's bag, the face pieces, and the gags are fitted into another small case, which can be conveniently carried in the hand.

Fig. 1.



When giving the gas, the Cattlin's bag (*h*) is connected to the bottle by the union (*e*), and to the face-piece (Fig. 2) by means of Clover's two-wayed stop-cock and tube mount (*g h*). The gas is then allowed to run into the bag, by turning the valve (*b*) with the key (*e*).

To fit this iron cylinder, Mr. Coxeter has made

an economising apparatus, on Mr. Coleman's principle, shown in Fig. 3.

In the small round chamber are put, through the

Fig. 2.

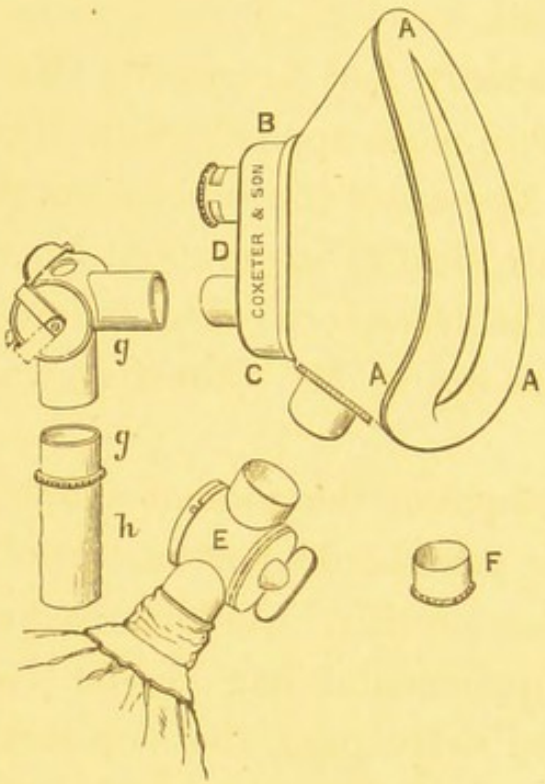
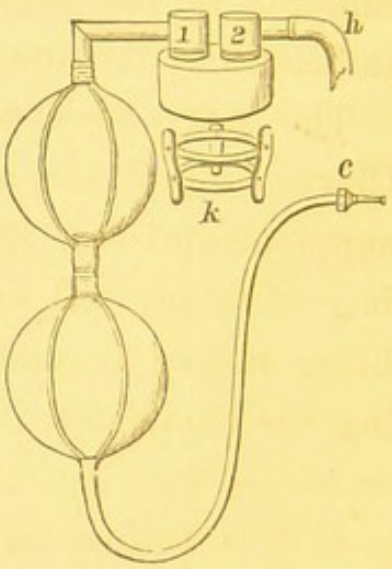


Fig. 3.



apertures (1 and 2) some small lumps of lime ; the bags are attached to the bottle and face-piece in a similar way to Cattlin's bag at *c* and *h*. The economiser rests on a small tripod (*k*), which fits on the top of the leather case (Fig. 1) containing the bottle. The valve (*b*) is opened until the two bags are full, and the patient breathes the gas from the top bag backwards and forwards through the reservoir. The bottom bag contains a supply of fresh gas in case it is needed, and has an inlet valve,

that will allow the gas to flow up into the top bag, but not return.

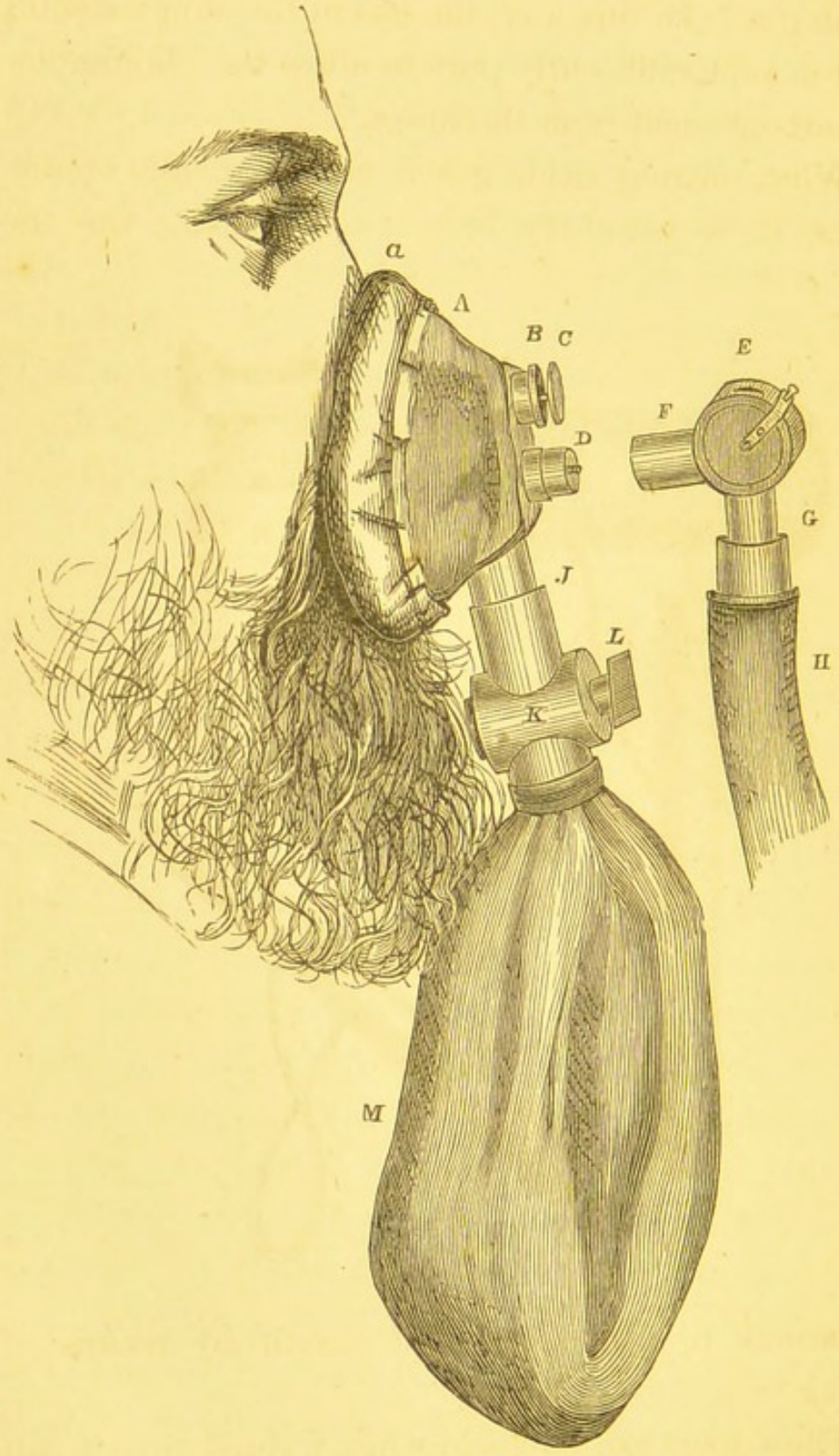
This plan economises the gas to a great extent, and is thus especially applicable to Hospitals, the contents of the top bag—about 1½ gallons—being sufficient for the anæsthesia.

The next wood-cut, kindly lent to me by Mr. Clover, represents his face-piece applied, with the supplemental bag (M). The use of the supplemental bag is to prevent any air, during inspiration, from being sucked in under the face-piece. The following directions for its use are in Mr. Clover's own words :—

Whilst fitting the face-piece, the patient should breathe air only, and the gas should not be turned on till the patient breathes steadily. As long as he breathes calmly, the supplemental bag should be empty; but when he begins to pant, the stop-cock (L) should be opened, and the supplemental bag brought into use. As soon as the stop-cock is open, a great part of the expired gas rushes into the supplemental bag, the rest escaping through the expiratory valves of the face-piece, and this is again so readily yielded during inspiration that there is not any air sucked in under the face piece when the breathing is irregular, or so weak as scarcely to raise the inspiratory valve leading from the Cattlin's bag.

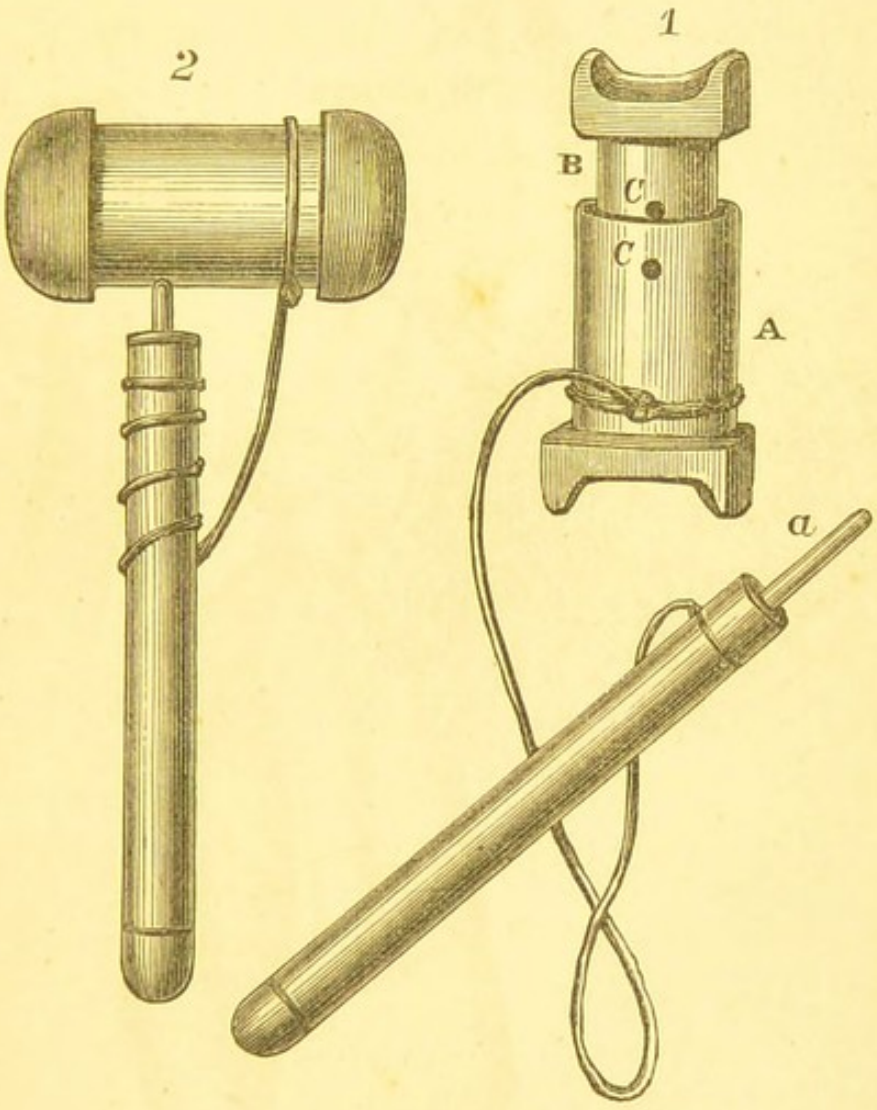
When the breathing again becomes so calm as to scarcely raise the expiratory valve in the face-piece,

the supplemental bag should be compressed every



five or six respirations, and allowed to refill with fresh gas. In this way, the gas in the supplemental bag is kept sufficiently pure to allow the elimination of carbonic acid from the lungs.

When nitrous oxide gas is used in dental operations, it is necessary before commencing the in-



halations to plug open the mouth by means of a gag.

These gags can be made when wanted from a soft

piece of wood, cut to the necessary size ; or a set of wooden or vulcanite gags, of various sizes, can be bought at any instrument makers, and are advantageous in that they are always ready for use.

Mr. Clover has invented a telescopic spring gag, which has this advantage, that if after the patient is under the influence of the gas he opens his mouth wider than when the gag was first introduced, the spring causes the gag to elongate, and to keep its ends in apposition with the teeth.

In the preceding wood-cut, fig. 2 represents the instrument ready to be placed between the teeth, and fig. 1 shows it elongated on removal of the bolt.

Whatever gag is used, a strong piece of string or silk should be attached to it, so that it may be easily withdrawn in case of accident.