ANAESTHETICS IN DENTAL SURGERY

ANAESTHETICS

IN

DENTAL SURGERY

BY

FRANK COLEMAN

M.R.C.S., L.R.C.P., L.D.S.

ASSISTANT DENTAL SURGEON, ST. BARTHOLOMEW'S HOSPITAL
AND THE ROYAL DENTAL HOSPITAL

AND

HARVEY HILLIARD

M.R.C.S., L.R.C.P.

ANAESTHETIST TO THE ROYAL DENTAL HOSPITAL
LATE ASSISTANT INSTRUCTOR OF ANAESTHETICS AT THE LONDON HOSPITAL
ASSISTANT ANAESTHETIST TO THE CANCER HOSPITAL AND CHARING CROSS HOSPITAL

WITH SIX PLATES AND 38 ILLUSTRATIONS
IN THE TEXT

LONDON

H. K. LEWIS, 136 GOWER STREET, W.C.

1912

LONDON
H. K. LEWIS, 136 GOWER STREET, W.C.

PREFACE

Since the Study of Anaesthetics is now a compulsory subject in the Dental curriculum, candidates for the Diploma in Dental Surgery are expected to possess a practical and a theoretical knowledge of the anaesthetics employed and the methods of their administration. We therefore feel that a demand has been created for a practical handbook upon these subjects, and venture to offer this summary of our experience in the hope that it may be helpful to both students and practitioners.

We are of opinion that for the production of a book of this nature, the co-operation of a dental surgeon and of an anaesthetist is advantageous for elucidating the many practical points in the domain of each.

In order to avoid confusion, to save unnecessary reading and to keep the size of the volume within the limits of a handbook, the authors have described only those forms of apparatus and methods of employment which their experience leads them to believe to be the best.

The chapters upon Ethyl Chloride, Ether and Chloroform have been written by Mr. Harvey Hilliard, that upon the Choice of the Anaesthetic in collaboration, and the remaining chapters by Mr. F. Coleman.

For some of the information on the history of anaesthesia contained in Chapter I. we are indebted to Alfred Coleman's *Manual of Dental Surgery*.

Our best thanks are due to Messrs. Claudius Ash for kindly placing one of their rooms at our disposal for obtaining the photographs that were executed so well by the Photochrome Co., and for much valuable assistance in other ways, including the loan of a large number of blocks. To Mr. J. W. Ellis, of Salisbury Court, we are indebted for several of the drawings, and to Messrs. Allen and Hanbury, G. Barth and Co., Dental Manufacturing Co., J. J. Griffin and Sons, Krohne and Sesemann, Mayer and Meltzer, and J. H. Montague for the loan of illustrations and instruments.

F. C.
H. H.

LONDON,
February, 1912.

CONTENTS

CHAPTER VI.

CHAPTER VII.

CHAPTER VIII.

LIST OF ILLUSTRATIONS

CHAPTER I.

THE HISTORY OF ANAESTHESIA.

The history of anaesthesia is so intimately connected with dental surgery that a brief reference to it may not be out of place in this book.

Previous to the introduction of respirable anaesthetics, as at present known, patients were rendered drowsy before surgical procedures by the employment of various drugs, by depletion of the cerebral circulation and by hypnotic suggestion.

Most of the drugs used contained opium in some form, the other ingredients commonly being cannabis indica and hyoscyamus. Alcohol was employed for a similar purpose.

Depletion of the cerebral circulation was brought about by compression of the carotid arteries.

Numerous operations were performed by Braid (between 1841 and 1860) and his followers, anaesthesia being induced by means of hypnotic suggestion.

Mesmeric anaesthesia was used, especially in India, and between 1846 and 1851 Dr. James Esdaile performed a large number of operations under its influence.

The earliest attempts to produce stupor or loss of consciousness to annul pain are said to have arisen from the Chinese before the commencement of the first century A.D. The Chinese discovered that insensibility could be induced by inhaling the vapours arising from burning hemp and in later years the Greeks and Romans used mandragora for a like purpose. Bullion, an Englishman, revived these methods fifteen hundred years later; while, in the interval this method of producing insensibility fell into disuse.

While bearing in mind that the ancients had made attempts, more or less successful, to alleviate or wholly obliterate the pain attendant upon surgical operations, the history of anaesthesia must really date from the hour when a dental practitioner had, at his own suggestion, a tooth removed under nitrous oxide with a total absence of sensation.

Nitrous oxide, or protoxide of nitrogen, was discovered by Priestley, in 1776, and its properties investigated by Sir H. Davy, in 1780, who actually suggested that it might be used as an anaesthetic; but this suggestion probably never met the eye or reached the ear of Horace Wells, and, so far as we are cognisant, was not, as such, ever acted upon. Wells's inspiration came in 1844, from witnessing a slight accident occur without pain being felt, at a popular lecture in America by Colton, who was illustrating upon one of his audience the exhilarating properties and ludicrous effects of nitrous oxide gas—a very common practice some years ago. The failure of Wells, when attempting to employ this agent for long surgical operations, owing no doubt to defective apparatus, led him to discontinue his investigations, and to embark in unsuccessful speculation resulting in an early death. Fortunately for humanity, a former associate of Wells took up the matter with more successful results. With Morton, to whom we are alluding, must be associated the name of Jackson: the latter supplied, while the former administered, ether, for the extraction of a tooth, in 1846. The result was a perfect success, and ether, being more easy of administration than nitrous oxide, soon proved available also in extensive surgical operations.

The news of this great discovery soon crossed the Atlantic, and Robinson, a dentist, had the honour of first administering ether in this country. The pungency of ether, together with a degree of difficulty in its administration, led to the investigation of the properties of bodies of the same class, and amongst these chloric ether was administered by Jacob Bell. As often happens in such experiments, the cases selected proved unfortunate ones; the after-effects were unsatisfactory, and this discouragement led to the abandonment of what no doubt would have anticipated the brilliant discovery of Sir J. Simpson. Chloric ether we now know to be a mixture of chloroform and alcohol, but its composition was not at this time understood, because chloroform, as such, had not been isolated.

In 1847 ~~Waddy~~, of Liverpool, obtained this fluid Waldi pure, and sent some of it to Sir James Simpson, who established the value of its anaesthetic properties; and in a little time chloroform, owing to its more agreeable flavour and more easy administration, almost entirely superseded ether in this country. The agent soon became employed almost whenever requested, and administered with probably even less precaution than is nitrous oxide in the present day; when lo! a patient died suddenly under its influence: "because they do not know how to give it," remarked one whose great experience had led to a rash confidence in himself; but a few days had scarcely passed when the like sad event occurred under his own hands. A reaction set in, and, as might be expected, stronger than was warranted; some medical authorities refusing almost entirely to sanction its use in any case. Other compounds were carefully investigated, mixtures of chloroform and ether, chloroform and alcohol, or the three together, were tried, but with little better results, while some reverted to ether, which had never been wholly discarded.

Nineteen years had elapsed since the short-lived triumph of Horace Wells, and little had been done in the meanwhile to further investigate the anaesthetic properties of nitrous oxide; still from time to time we in this country heard of our associates in the New World speaking cautiously, yet on the whole favourably, of it for dental purposes.

Colton had not forgotten how well people took nitrous oxide and, in comparison with other anaesthetics, how much better they recovered from it, and was led to introduce its employment upon a large scale in New York. Armed with such credentials as the record of 20,000 successful administrations, Colton visited Paris in the Exhibition year of 1876, and there exhibited this agent. The faculty in France did not appear to espouse it warmly, but it was otherwise with some American practitioners resident there, notably T. W. Evans, a dentist, and Marion Sims, a surgeon-accoucheur. In the spring of the following year, the former visited London, and administered the gas before the staff of the Dental Hospital. The value of an agent evidently so safe, and so well suited for dental purposes, was only too apparent, and within a week of witnessing Evans' administration, Coleman (Alfred) had arranged an apparatus, prepared the gas, and given it successfully to four patients. Our readers, acquainted with the present modes of, and appliances for, administering nitrous oxide, would be amused at the cumbrous and rough apparatus at first employed. A large india-rubber bag or balloon contained the gas, connected by a long tube terminating in a wooden mouth-piece with inlet and outlet valves. The mouth-piece was placed between the patient's teeth, and the lips compressed over it by the fingers, whilst the finger and thumb of a bystander unceremoniously closed the patient's nostrils. To the liberal donations of Evans, who contributed a fund for investigating the merits of nitrous oxide, must be attributed in a great degree the rapidity with which our knowledge of the properties of nitrous oxide and the improved modes of its administration, have come about.[1]

The greatest of these improvements has been the vending of the gas, first in a compressed and finally in a liquid form ; otherwise its bulk, or the inconvenience to the practitioner of having to prepare it on his own premises, would ever have been a serious drawback to its general use.

In 1876, Clover introduced his method of administering nitrous oxide and ether; in which the former preceded the inhalation of the latter, so that the patient was spared the unpleasant smell and irritating effect of the ether.

In 1886, Dr. Hewitt introduced a method of administering nitrous oxide with definite quantities of oxygen. This method has been found especially useful for short operations, both in general and dental practice.

In 1898, Coleman (A.)[2] read a paper before the Society of Anaesthetists on a method of administering anaesthetics through the nose, and showed an apparatus that he had devised for the purpose. This consisted of a nose-piece connected by a flattened tube, adapted to fit accurately over the forehead, to an ordinary gas-bag, an intervening two-way stop-cock containing a valve

[1] *Vide* report of a committee to inquire into the "Value, etc., of Protoxide of Nitrogen as an Anaesthetic, etc.," *Trans. Odont. Soc.* vol. i. (new series) p. 31 and vol. v. (do.) p. 11.

[2] *Transactions of the Society of Anaesthetists*, March 17, 1898.

which opened towards the nose, and an air-padded face-piece completed the apparatus. The face-piece was sufficiently large to cover both the nose-piece and the patient's mouth, and was removed as soon as anaesthesia was procured.

Coleman's apparatus was originally designed for administering ether through the nose, the ether-chamber being interposed between the gas-bag and the gas-cylinders.

The afferent tubing of the ether chamber was connected by means of a bifid mount, with the gas-cylinders and with some foot-bellows. The ether-containing vessel was so constructed that by turning a two-way stop-cock the gas from the cylinders or air pumped from the bellows could be passed over the surface of the ether on their way to the gas-bag.

The administration was commenced with gas alone and continued until the patient was nearly unconscious. At this stage ether was passed into the gas-bag. When complete narcosis had arrived, the gas was turned off at the cylinders and air pumped through the ether chamber into the bag, when after a few inspirations air impregnated with ether alone was inhaled.

Nitrous oxide by itself, however, was found to be so capable of maintaining anaesthesia, that further experiments were conducted in the absence of the ether arrangement.

With this apparatus Mr. H. J. Paterson anaesthetised fifteen patients and secured an average anaesthesia of two and a half minutes, all of which, he stated, could probably have been continued for a longer period had the dental operation necessitated such.

At the same meeting Mr. Coxon showed an apparatus for maintaining nitrous oxide anaesthesia by means of a tube passed into the mouth, and Mr. Harvey Hilliard [1] also showed an apparatus with which he could prolong nitrous oxide anaesthesia during operations upon the mouth. Hilliard's apparatus consisted of a soft tube which was passed through the nose into the naso-pharynx, and connected to the gas-cylinders by rubber-tubing, but having two small rubber bags interposed for producing a continuous and even flow of gas to the nasal tube; the proximal bag adjoined the nasal tube, and the amount of its distension was an indication of the pressure of gas employed.

In both these latter forms of apparatus the patient was first rendered unconscious by the administration of nitrous oxide in the ordinary way, after which the supply tube for maintaining anaesthesia was introduced.

In the earliest attempts at nasal administration of anaesthetics, chloroform was employed, and the credit of these experiments should be given to Dr. Fauré,[2] of Paris, who in 1859 described a method of inhaling chloroform through the nostrils.

In 1900, the use of ethyl chloride as a general anaesthetic was again revived, chiefly through the advances

[1] *Vide Lancet*, May 7, 1898.

[2] *Gazette des Hôpitaux*, July 7, 1859.

made by Dr. M'Cardie, of Birmingham. Over sixty years ago this drug was employed by Heyfelder for the purpose of inducing anaesthesia in the human subject, and since then the drug has been revived on at least three occasions, the last of these being associated with the name of M'Cardie,[1] at the beginning of this century.

While the idea of producing general anaesthesia was occupying the minds of some, others were giving their attention to local anaesthesia. Acting on the fact that a frozen part is painless, Arnott, in 1848, froze small tumours with a mixture of ice and salt, as a preliminary to their removal. Teeth were frozen in their sockets by Blundell, a dentist, and removed painlessly.

Bartholin and Severino in the sixteenth century are said to have investigated the properties of cold, as a means of diminishing sensibility, and early in the eighteenth century this method was employed by Larrey.

Electricity also had a trial, on the supposition that a nerve could only convey one species of sensation at a time, and that while it was occupied in conducting an electrical stimulus, it would fail to convey the sense of pain. The more recent discovery of Brown-Séquard—that for various sensations special channels of conduction exist, did not enter into the calculation. Patients who had teeth removed while under the influence of an electric shock were puzzled to realise how much of what

[1] *Lancet*, March, 1902.

they felt was shock and how much was pain ; but their general conclusions were, that it was as unpleasant with the electricity as without it.

Reuss, in 1807, employed the galvanic current for introducing solutions of narcotic drugs into the tissues, and claimed that he could produce loss of sensibility in a part by this means. The method now known as cataphoresis probably owes its origin to Reuss' experiments.

In 1858, Mr. J. P. Francis,[1] of Philadelphia, introduced a method of producing local anaesthesia for tooth extraction by means of galvanism.

The negative pole from an electro-galvanic machine was attached by means of flexible wire to one handle of the tooth-forceps, whilst the patient grasped the metallic handle of the positive pole, thereby completing the circuit.

The power of the current was graduated by withdrawing or closing in the piston of the coil, while the patient held one pole of the battery in each hand ; a current sufficiently powerful to be distinctly felt was regarded as being the strength required.

After determining the strength of current to be used, the circuit was made and the operation commenced.

The making and breaking of the current throughout the operation was managed by the operator's foot or by an assistant.

[1] *British Dental Journal*, May 16, 1910. S. D. Hey.

The method does not seem to have been attended with success, as in about half the cases there was little or no effect, and in a quarter the pain is said to have been aggravated.

That pressure upon a nerve may give rise to a paralysis of motion or sensation or both, according to the type of nerve involved, is a fact observed in everyday life. These phenomena gave rise to a form of anaesthesia known as "ligation" anaesthesia, in which the sensibility of a limb was dulled by being firmly constricted by a rubber tube or bandage. Probably the pressure had to be sufficiently severe to injure the nerve-fibres before the conduction of impulses was impaired, but some dulling of sensation was no doubt brought about by the induced anaemia.

Motor nerves, which are now believed to convey also the sense of pressure, are more easily injured by trauma than sensory nerves, but the latter recover more quickly and completely.

In 1854, the evaporation of sulphuric ether was used by Richet for producing anaesthesia, and this, no doubt, was the parentage of the ether spray introduced by Richardson (later Sir Benjamin Ward Richardson) in 1866, and which in a modified form is in use at the present day.

Ethyl chloride has the same effect as ether, when sprayed on to a part, but its action is more evanescent.

The discovery of the anaesthetic effect of cocaine was made by a pharmacologist named von Aurep (B.) [1] in 1880.

Koller discovered that instillation of cocaine into the conjunctival sac produced a loss of sensibility, and, in 1884, demonstrated the anaesthetising properties of cocaine at the Ophthalmological Congress at Heidelberg.

In 1885, Halstead and Raymond injected a solution of cocaine around the inferior dental nerve, for tooth extraction.

In 1891, Schleich found that solutions of cocaine less than 0·1% in strength were capable of producing anaesthesia if injected into the tissues under pressure.

In more recent years the names of Reclus, Braun and in this country Barker, have been intimately associated with advances in local anaesthesia.

Reclus, who has published the results of over 7000 operations performed under cocaine anaesthesia, insists on the recumbent position being employed for the most trivial operation and urges that this position should be maintained for twenty minutes to three hours, according to the severity of the operation and its effect on the patient.

Braun showed that the local effect of cocaine was enhanced and prolonged by the addition of adrenalin chloride.

Barker's work has been largely confined to spinal analgesia and it is his conviction that different portions

[1] "Ueber die physiologische Wirkung des Cocain." *Archiv f. Physiologie* (Pflüger), 1880, xxi. p. 38.

of the spinal cord are influenced owing to the specific gravity of the injected fluid, rather than to its diffusion. In support of this view Barker uses fluids of a higher specific gravity than those usually employed and of a viscid consistency, both properties of which are obtained by adding glucose to the solution.

CHAPTER II.

THE CHOICE OF THE ANAESTHETIC.

ANAESTHETICS may be divided into two main classes, viz. **General** or respiratory, and **Local**.

The general anaesthetics usually employed in dental surgery are nitrous oxide, ethyl chloride and ether; either by themselves or in various combinations.

Chloroform and its mixtures with ether are indicated in certain cases.

Nitrous oxide is the most suitable anaesthetic for the majority of such short operations as those of extraction of teeth, being almost entirely free from danger and allowing of a return to consciousness with but little discomfort and few after-effects. If either air or oxygen be administered with the nitrous oxide, a slight increase in the available anaesthesia is procured, amounting in the case of oxygen to about fifteen seconds.

The absence of after-effects is not entirely dependent upon the brevity of the inhalation, since when anaesthesia is maintained for five minutes or more, and three or four times the usual amount of nitrous oxide is inhaled, unpleasant after-effects are not usually experienced.

The reason for this is probably due to the fact that nitrous oxide forms an unstable combination with the haemoglobin of the blood, and stimulates the circulation.

A safe and rapidly acting anaesthetic is the desideratum for brief dental operations, and these properties are possessed by nitrous oxide.

The choice of the anaesthetic for dental operations depends chiefly upon two factors, viz.:

1. **The patient.**
2. **The operation.**

1. The Patient.

The anaesthetist should make a mental note of the patient's condition, with reference to whether the patient appears active, healthy and robust; or pale, weak and anaemic, before undertaking the administration. Preferably in all cases, this must be followed up by an examination of the heart and lungs. The pulse should be felt, and its frequency, strength and regularity noted, as well as the condition of the artery itself. The gait of the patient, his breathing, voice and colour will convey to a trained observer the physical and mental condition of the patient; besides which, there are certain diseases easily recognisable by the physiognomy they produce, *e.g.* anaemia, exophthalmic goitre, neurasthenia, cardiac and lung lesions.

If the patient be subject to shortness of breath, cough, palpitation, fainting fits, or there be any doubt otherwise as to his health, his usual medical attendant should, if possible, be previously seen or communicated with, and advice obtained as to the desirability of the patient undergoing an operation or receiving an anaesthetic. The administrator of the anaesthetic is frequently the patient's own medical attendant, and is already familiar with his health, vigour and temperament.

As far as the *age* of the patient is concerned, there are but few contra-indications to the use of nitrous oxide. In children only a brief anaesthesia can be obtained, but sufficient, as a rule, for the removal of one or more temporary teeth.

Ether is not a suitable anaesthetic during childhood, it is very irritating to the delicate epithelial lining of their air-passages and causes a profuse secretion of saliva and mucus; besides which the duration of anaesthesia obtained is not very prolonged. Ethyl chloride is a useful anaesthetic in childhood, when a longer and quieter anaesthesia than that obtained by nitrous oxide is required, but this advantage must be carefully weighed against its far greater lethal properties.

At the other extreme of life patients usually take nitrous oxide well, if administered with oxygen or air; although, the health and vigour of the individual are more important factors than the actual number of his years.

Young adults and middle-aged people are usually good subjects for nitrous oxide anaesthesia.

The *sex* of the patient plays a part in so far as muscular development is concerned.

Female patients, if anaesthetised during a menstrual period, are prone to excessive bleeding from the operation wound, and during the induction of anaesthesia are liable to exhibit excitement and hysterical phenomena.

Nitrous oxide may be administered during pregnancy even in its later months, provided sufficient air or oxygen is administered with it to eliminate all signs of asphyxiation. The cyanosis and jactitation which characterise deep anaesthesia produced by nitrous oxide alone may involve also the uterine muscle, with the consequent risk of miscarriage, particularly in patients prone to abort. Local anaesthesia is better suited to these circumstances.

Ether, owing to its liability to produce coughing and straining, and to be followed by vomiting, is unsuitable in the later months of pregnancy.

It is undesirable to administer general anaesthetics during lactation, lest the secretion of milk be injuriously affected. Local anaesthetics will be less likely to have any harmful effect in this respect.

Patients suffering from *chronic bronchitis*, *asthma*, *emphysema*, or *advanced phthisis* are bad subjects for anaesthetics, and need careful watching to prevent further embarrassment to their respiration and consequent increased strain on their heart and arteries. Nitrous oxide and oxygen may be administered to these people for short dental operations. Their condition, however, is apt to be aggravated after the administration, so that whenever possible local anaesthesia should be resorted to in these cases.

Patients suffering from *valvular disease* of the heart are liable to early and marked cyanosis under nitrous oxide, and grave risks may be incurred unless all asphyxial phenomena are eliminated and the pulse kept under strict observation. In the absence of an expert, these cases are better relegated to local anaesthesia. The colour of the patient's face, the character of his pulse and respiration and the presence of signs of back blood-pressure are the chief factors in determining how far compensation is maintained. Back blood-pressure is indicated by swelling of the legs and abdomen, oedema of the bases of the lungs and general anasarca.

The presence of *aortic disease* or of a *fatty heart* are the most important cardiac lesions to consider when the administration of a general anaesthetic is contemplated. All general anaesthetics are dangerous under these conditions, more especially those that throw much strain on the heart. Nitrous oxide is admissible only if given with oxygen by an expert. The patient should be anaesthetised in the recumbent posture, unless orthopnoea exists, in which case local anaesthesia alone is permissible. Unless struggling can be prevented and cyanosis avoided throughout the administration, the patient would be better advised to have whatever dental operation was contemplated performed under local anaesthesia, or should this be impracticable, a general anaesthetic should only be administered on consideration that the necessary operation would cause more shock if anaesthesia were withheld.

Frequent attacks of *syncope* associated with aortic disease or with a heart that has undergone degenerative changes are conditions that should prohibit the use of a general anaesthetic for dental purposes.

In congenital lesions of the heart or malformations of the chest and air-passages, there is considerable risk in administering a general anaesthetic, and local anaesthesia should be selected in preference wherever possible.

Elderly patients, the subjects of arterial degeneration (*atheroma*) and its sequences, require great care, and the administration may give rise to much anxiety. In advanced cases of atheroma, local anaesthesia had better be substituted for general anaesthesia, on account of the danger of apoplexy, arising from the increased blood pressure brought about by the latter or by the patient's struggles. Ether and undiluted nitrous oxide are in this respect injurious.

Aneurysm, not infrequently a sequela of atheroma, requires the same care in its management. Anaesthetics which do not raise the blood pressure, *e.g.* local anaesthetics, are best suited in these cases, but nitrous oxide and oxygen may be given, provided anaesthesia is induced slowly and cyanosis and struggling avoided.

Alcoholics and excessive smokers are " bad " subjects for the inhalation of any anaesthetic. Patients addicted to cocaine and morphia habits are likewise unsuitable subjects. In some cases of chronic alcoholism, nitrous oxide is almost impotent for the purpose of producing anaesthesia. These patients merely become intoxicated by nitrous oxide, unless this be pushed to a degree involving dangerous asphyxial symptoms; they are prone to become noisy and to struggle violently. If anaesthesia be obtained, it is very brief and is almost invariably accompanied by great muscular rigidity. Ethyl chloride by itself, or followed by ether, is the most satisfactory anaesthetic for these patients. Full doses of bromide of ammonium given for a few days preceding the administration will have a marked effect in quieting the patient. Recovery in these cases is often characterised by hallucinations, not infrequently of a pugilistic nature, and considerable tact is necessary in their management.

Very stout people are unfavourable subjects for the administration of any anaesthetic involving the delimitation of oxygen. Nitrous oxide should never be given without air or oxygen, as these patients rapidly become cyanosed, and frequently suffer from shortness of breath owing to a " fatty heart." Local anaesthetics are more suitable than inhalation anaesthetics for these people, as the former do not further embarrass the already impeded respiration.

Great care must be taken in anaesthetising patients suffering from inflammatory *swellings in the neck, e.g.* cellulitis (angina Ludovici), as the danger of respiration becoming seriously embarrassed in these conditions is often far greater than might be anticipated from the clinical signs of the swelling. The use of nitrous oxide and ether is contra-indicated in these acute inflammatory conditions, as the glottis participates in the concomitant swelling and oedema, and should the obstruction be further increased by the congestion induced by these anaesthetics, the serious embarrassment of respiration may endanger the patient's life. Moreover, the general toxaemia occurring in this condition involves the cardiac muscle and ganglia, thus lowering their vitality and rendering them less competent to withstand strain.

Thyroid tumour (goître), lymphatic hyperplasia and other forms of fluid and solid tumours, unless of small size and producing no obstruction to breathing, contra-indicate the use of nitrous oxide or ether, and if a general anaesthetic is deemed advisable, the chloroform and ether mixture ($C.E._2$), by causing less congestion, will be the safest to employ. All forms of bag-inhaler are undesirable in these cases, and wherever possible, local anaesthesia should be resorted to.

A good deal of attention has recently been ascribed to an obscure condition known as *lymphatism*, the *status* *lymphaticus* or *thymicus*, owing to the fact that patients suffering from this affection are prone to sudden death from quite trivial causes. In this condition or disease there is a general hyperplasia of the lymphoid tissue throughout the body, more especially of the tonsils, the lymphatic glands, the adenoid tissue of the naso-pharynx, the base of the tongue, the spleen and thymus glands. The thyroid gland is said to be enlarged in about half of the cases and the condition not infrequently coexists with symptoms of Graves' disease (Professor John Berg), and has been noticed in association with cretinism, epilepsy, rachitis and infantilism. The enlarged thymus may form a conspicuous object in the neck, and has been noted as a pulsating tumour above the episternal notch.

The condition usually occurs in infants, children or young adults, and those affected are said to possess certain characteristic features: thus, they are tall with fair and clear skins, intelligent but self-conscious and unduly influenced by physical and mental stimulation. Brachycardia is occasionally present, and this is indicated by a slow radial pulse. The blood is deficient in haemoglobin, and lympho-cytosis is frequently present (Paltauf). Attacks of dyspnoea (thymic asthma) and syncope may be prominent symptoms, and when the thymus is much enlarged, the former is associated with a peculiar brassy cough.

The above features, together with the presence of enlarged tonsils and lymphatic tissue in general and a pale complexion due to anaemia, are almost the only signs and symptoms of the disease.

Scarcely more than a tentative diagnosis can be made, but sufficient evidence may be present to warrant the anaesthetist in employing every precaution both in the choice of the anaesthetic and in its administration. The slightest interference with respiration must be avoided, and a complete, although not deep, and uniform anaesthesia maintained throughout.

Ether and nitrous oxide are contra-indicated if obstructive conditions are present, and if employed under less critical circumstances must be administered with free supplies of air and oxygen respectively.

Dr. Dudley Buxton regards chloroform as undesirable in these cases, and places ethyl chloride much in the same category. Ether administered by an open inhaler is the least dangerous method of anaesthesia to employ.

In some cases death has occurred suddenly and independently of anaesthesia, the respiration and pulse have ceased abruptly without any apparent obstructive asphyxial phenomena. In other cases death has been preceded by attacks of dyspnoea increasing in their severity. An enlarged thymus may produce dyspnoea through pressure on the trachea, and considering the hyperplasia that this organ is capable of undergoing in early childhood and the short distance from the manubrium sterni to the front of the vertebrae for its accommodation, such a contingency might well be expected.

The causation of death has been ascribed to an internal secretion produced by the thymus gland (Professor August Hammar) or by the hyperplastic lymphoid tissue (Blumer), which under certain conditions may originate a toxaemia that acts upon the heart or central nervous system.

Fatalities have most frequently occurred under the influence of chloroform (see page 227), no doubt on account of the age of the patient and the nature of the operation and quite apart from an overdose of the drug itself; although in most of the fatal cases, the chloroform was not administered by a regulating inhaler (*i.e.* by dosimetric methods).

The pathology of the disease appears to be that of a toxaemia. Besides a general hyperplasia of the lymphoid tissue throughout the body, the thyroid and thymus glands are commonly enlarged, the latter sometimes showing fatty and other degenerative changes. Dr. Spilsbury describes the growth of recent lymphoid tissue occurring in association with atrophied thymus tissue, and has noted the degeneration of Hassall's corpuscles in the central part of the gland and their entire absence in its peripheral part.

The heart has been found dilated, and its muscle undergoing fatty degeneration or brown atrophy, other cases have shown narrowing of the aorta.

Oedema of the skin has been noted by Gallatti and of the lungs by Ohlmacher.

Wiesel has drawn attention to the hypoplasia of the adrenal tissues, and believes this to be of much importance in the disease and a possible explanation of the abnormal blood pressure.

By consulting the following references, the reader will obtain a more detailed account of this condition ; from the first mentioned a large portion of this material has been obtained :

Dr. Dudley Buxton, *Lancet*, August 6, 1910.

H. Bellamy Gardner, *Section of Anaesthetists, Royal Society of Medicine*, Dec. 3, 1909.

Dr. W. J. M'Cardie, *Trans. Soc. of Anaesthetists*, Dec. 6, 1907.

Hildred B. Carlyll, *Guy's Hosp. Reports*, 1910, vol. lxiv.

2. The Operation.

The number and the condition of the teeth, their position, and the state of the mouth, must be taken into consideration in deciding what anaesthetic to employ.

One to four teeth, presenting no special difficulties, can usually be removed under a single administration of nitrous oxide.

The prolonged nasal administration of nitrous oxide will provide the most satisfactory anaesthesia in adults, when sufficient time is the only desideratum for the extraction of several teeth presenting no special difficulties. But when a similar operation has to be performed upon a child, the administration of a single dose of ethyl chloride is preferable. Children are not good subjects for the prolonged administration of nitrous oxide. They bear deprivation of oxygen badly, and under nitrous oxide become quickly cyanosed, exhibiting early jactitation, and unless only a light degree of anaesthesia be maintained they are prone to develop opisthotonus.

For a difficult extraction, for instance, an impacted lower wisdom tooth, more especially if this be on the right side of the mandible and accompanied with trismus, nitrous oxide combined with ether is usually the best anaesthetic to employ. The anaesthesia obtained by this means will allow the operator to have full control of the patient's head, the muscles become relaxed and thus the jaws can be more readily separated than under a nitrous oxide anaesthesia.

Should ether cause much salivation and secretion of mucus or fail to produce an available anaesthesia of sufficient duration for the operation, the administration may be continued by the alcohol, chloroform, and ether mixture (A.C.E.), or by chloroform administered by a Junker's apparatus and mouth tube, provided the patient be placed in the recumbent posture.

The anaesthetist should inquire of the dentist what duration of anaesthesia is likely to be necessary, and the anaesthetic to be employed must be selected accordingly.

When there is some doubt as to the difficulty of any given extraction, the operator should choose an anaesthetic which does not bind him to a limited duration of anaesthesia, but one that can be continued, if necessary, to meet the requirements of the case.

Luke[1] gives the following table of various anaesthetics used either by themselves or in sequence, and states broadly the available anaesthesia they provide:

Nitrous oxide, - - - -	35 secs.
,, ,, and ethyl chloride,	90–120 ,,
,, ,, (nasal method), -	1–5 mins.
,, ,, and ether, - -	1–10
Ethyl chloride, - - -	1–2 ,,
,, ,, and ether, -	1–10 ,,
,, ,, and C.E., -	2–5 ,,
C.E. and ether sequence, - -	3–10 ,, , or *ad lib.*
Local anaesthesia, - - -	as required.

[1] *Anaesthesia in Dental Surgery*, p. 24.

CHAPTER III.

PRELIMINARIES TO AN ADMINISTRATION.

Apparatus and Drugs.

BEFORE commencing to anaesthetise a patient, it is necessary to see that both the apparatus and drugs to be used are efficient, and that accessory requirements are at hand, *e.g.* a *mouth-gag*, *wooden mouth-opener*, *mouth-props*, *sponges and their holders*, *tongue-forceps*, *hypodermic syringe*, *strychnine*, *adrenalin* (0.1 per cent.) and ampoules containing *amyl nitrite* and *pituitary extract*; also, a *stethoscope*, a *tracheotomy case* containing a tracheotomy tube, scalpel, small retractors, dissecting and artery forceps, blunt hooks and a tracheotomy dilator (two-bladed). *Oxygen*, which will often be on the premises, forms a useful restorative in some cases of respiratory failure.

The anaesthetist should always have ready the means for administering one of the more powerful anaesthetics in the event of nitrous oxide proving inadequate.

For hospital work, the triple-union stand for three cylinders forms a useful equipment. Two of these cylinders should contain nitrous oxide and be connected by a Y-shaped union. The separate cylinder may contain nitrous oxide or oxygen according to the requirements of the administration, but in either case a reserve cylinder, fully charged with nitrous oxide, should always be at hand.

The anaesthetist should make sure that the screws and nuts connected with the bottles and their unions are secure, and that there is no leakage of gas.

The face-piece should be made of stiffened leather covered with rubber, and be fitted with an air-cushion where it comes into contact with the face.

The bag should be capable of containing at least three gallons of nitrous oxide gas. The various forms of stop-cock employed will be mentioned when describing the administration of nitrous oxide. Their valves should be in good working order.

It is hardly possible to discuss fully the merits of the various kinds of instruments and appliances mentioned, but a few points may with advantage be stated.

Efficiency and simplicity are the attributes of good surgical instruments, accompanied, as this usually is, with ease in cleanliness. Two mouth-gags (see fig. 1) are a convenience and preferably one of these should be Ackland's pattern with the jaws closing side by side; thereby forming a wedge of only half the thickness of the older style of gag[1] and facilitating its introduction when the jaws are clenched, whether from trismus or

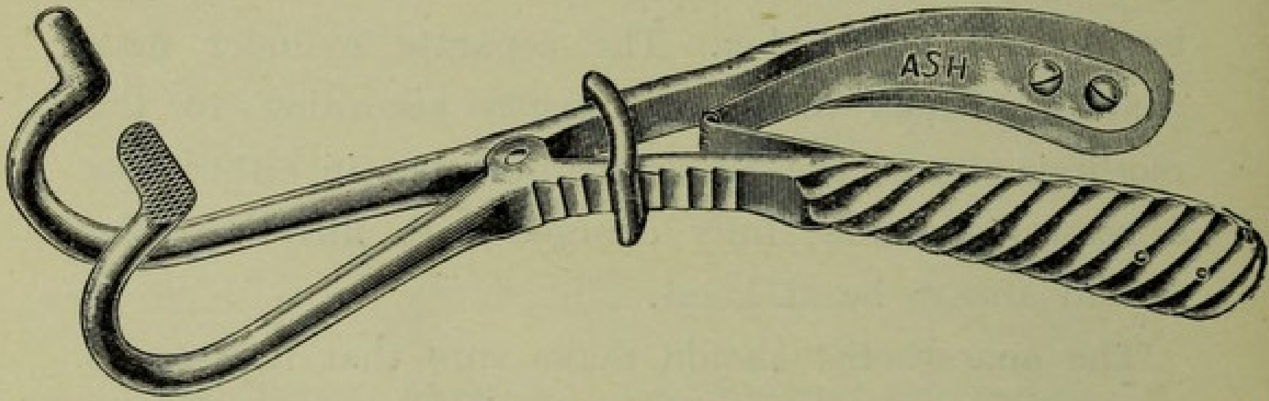


FIG. 1.—FERGUSSON'S GAG.

the slipping of a prop. Lead pads have recently been substituted for rubber coverings on the blades of mouth-gags, as by this means the instrument is rendered more

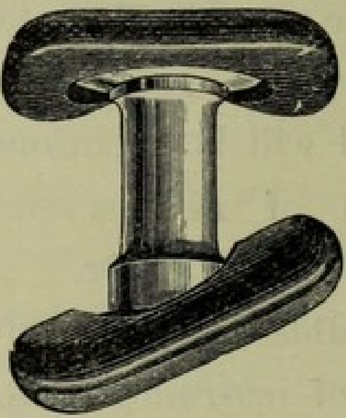


FIG. 2.—HEWITT'S MOUTH-PROP—SHOWN FITTED WITH INDIA-RUBBER PADS.

cleanly, and it does not preclude the employment of rubber pads if so desired.

Hewitt's mouth-props with lead pads are quite serviceable, and with the smaller sizes now made will be

[1] *Medical Times and Gazette*, 1861, vol. i. p. 105. A. Coleman. *Lancet*, Oct. 12, 1907. "The Gag," by G. H. Colt.

found convenient for patients of all ages (see fig. 2). Those with rubber pads are somewhat troublesome to clean between consecutive administrations, as in hospital work. A strong boxwood wedge (see fig. 3) is

FIG. 3.—WOODEN MOUTH-OPENER.

useful in opening the mouth for emergencies, but will not often be required if an Ackland's gag is at hand.

Sponge-holders should possess serrated blades and strong ratchet handles. Tongue forceps (fig. 4) should

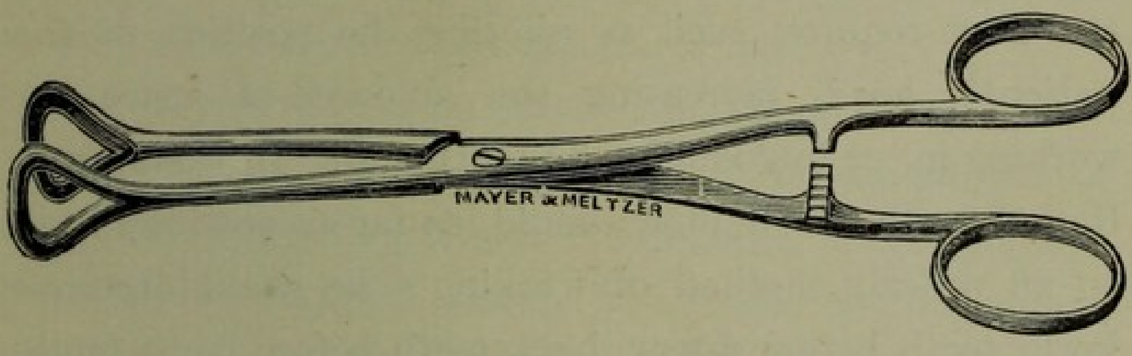


FIG. 4.—TONGUE FORCEPS.

have grooved blades and ratchet handles. The hypodermic syringe may be of glass or metal, but a well-fitting piston is an essential quality.

As an emergency, a mouth-prop can be contrived out of a cork notched in a V-shaped manner at each end, or from an empty cotton-reel. In all cases mouth-props must be secured by a strong ligature to some similarsized object to prevent the possibility of their being swallowed.

All instruments should be boiled before being used. Face-pieces, oral and nasal inhalers, should be washed with soap and water, then soaked in carbolic lotion (1–20), and finally dried. Rubber inhalation bags should be treated in a similar way at the end of an administration.

Procedure of Operation.

The anaesthetist should make himself acquainted with the procedure of the operation, so that he will know when and where a gag is likely to be wanted. He should also anticipate any assistance that the dentist may require, such as altering the position of the patient's head, increasing the amount of space for working in, or introducing a mouth-gag. In the extraction of teeth, the dentist should, as far as possible, keep to an orderly method of working; he should remove lower teeth before upper, back teeth before front teeth, and confine his attention to one side of the mouth before proceeding to the other side.

Preparation of Patient.

Attention should next be directed to the patient's comfort, adapting this as far as possible to the needs of the operator and the anaesthetist. It is assumed that the patient is already aware that an anaesthetic is to be administered, and that at least two hours have elapsed since his last meal. In this respect, we are in favour of following Mr. Braine's advice in choosing the operation time, as far as possible when the stomach would be empty in the natural course of events; not allowing the patient to omit a meal, or interfere with old habits of food-taking, such omission or interference produces an unaccustomed condition of want not at all desirable. Mr. R. W. Collum [1] favours a more rational preparation of patients for operations than that usually prescribed, and considers that more attention should be paid to their ordinary habits. He advises that meals should, as far as possible, be taken at their accustomed times, but that the quality and quantity of the food may require careful supervision.

The bowels should be emptied on the morning of the anaesthetic or on the previous day, if the patient is irregular in this function and requires a purgative, and the bladder emptied shortly before the administration commences.

For anaesthetics other than nitrous oxide, the régime should commence a day or two previous to the operation (see chapter on ethyl chloride, ether, and chloroform).

A wine-glass of port wine, or a small quantity of brandy and water may be allowed, if the patient be in delicate health or accustomed to a stimulant between

[1] *British Medical Journal*, Oct. 29, 1910.

meals. This should preferably be taken at the patient's habitual time, or half an hour previous to the administration. The effect of this in weakly patients is undoubtedly to temporarily invigorate their constitution, and a nervous patient will become more resigned to, and feel less agitated by, any impending operation.

All tight clothing, such as corsets, belts, and collars, should be loosened, so that the chest, abdomen, and throat may be in no way impeded during respiratory, or possibly struggling, movements. Tight corsets and bands round the waist prevent the full descent of the diaphragm, and consequently the interchange of gases in the lungs.

Posture of Patient.

This will depend upon the kind of anaesthetic that is to be administered. For a nitrous oxide or ethyl chloride administration, or a short inhalation of ether the patient should sit well back in the chair, with the spine erect and the head and neck in a line with the body. The floor of the mouth should assume a nearly horizontal plane, which can be raised or lowered by movements conveyed to the chair (see plate I.).

The posture should be one of muscular relaxation, and free from restraint. There should be no foot-piece or other obstacle about the operating chair, which may cramp the body and allow of leverage with the feet and legs should struggling movements ensue.

The objectionable foot-rest may be rendered serviceable if it be utilised for raising the patient's feet in a line with his pelvis, the heels alone resting on the rail of the foot-rest. In this position it is almost impossible for a patient to slip down into the chair during the anaesthesia, and his feet are well out of the operator's way.

The position of the patient must be that which favours a satisfactory anaesthesia, and such as can, if necessary, be altered during unconsciousness to meet the requirements of the operator.

For chloroform and its mixtures, the patient should assume the recumbent, or semi-recumbent position, with the shoulders slightly raised, so that the head may be turned to one side (see plate VI.). This position is also desirable for prolonged administrations of ether.

An apron or towel should be fastened round the patient's neck to prevent the clothing being soiled.

The room should be suitably heated and appropriately ventilated.

The best results are only obtained by due observance of the details incidental to anaesthetisation—the object aimed at is not merely to render the patient insensitive to the pain of any operative procedure, but to do this without causing him any discomfort either before, during, or after the administration of the anaesthetic.

Nitrous oxide should be administered by experienced and competent persons, and never single-handed unless there be overruling conditions; this maxim applies even more forcibly to the administration of the more powerful anaesthetics.

CHAPTER IV.

NITROUS OXIDE.

The Apparatus.

THE apparatus required for a nitrous oxide administration consists of the following parts: the cylinders for containing the nitrous oxide in a liquid form, the rubber bag for containing the nitrous oxide in a gaseous form, the stop-cock for admitting or omitting the nitrous oxide to the face-piece, and the face-piece for conveying the nitrous oxide to the patient.

Either the author's stopcock (see figs. 8 and 9), or Hewitt's stopcock (see figs. 5, 10, 11 and 12) may be employed. The former is described under Nitrous Oxide and Air (see page 64).

Hewitt's stopcock consists of an angular piece of metal tubing containing four apertures; two of these, formed by the open extremities of the tubing, are connected with the face-piece and gas-bag respectively, the remaining two are represented by slots in the periphery of the tubing.

Inside the stopcock is a rubber valve (inspiratory)

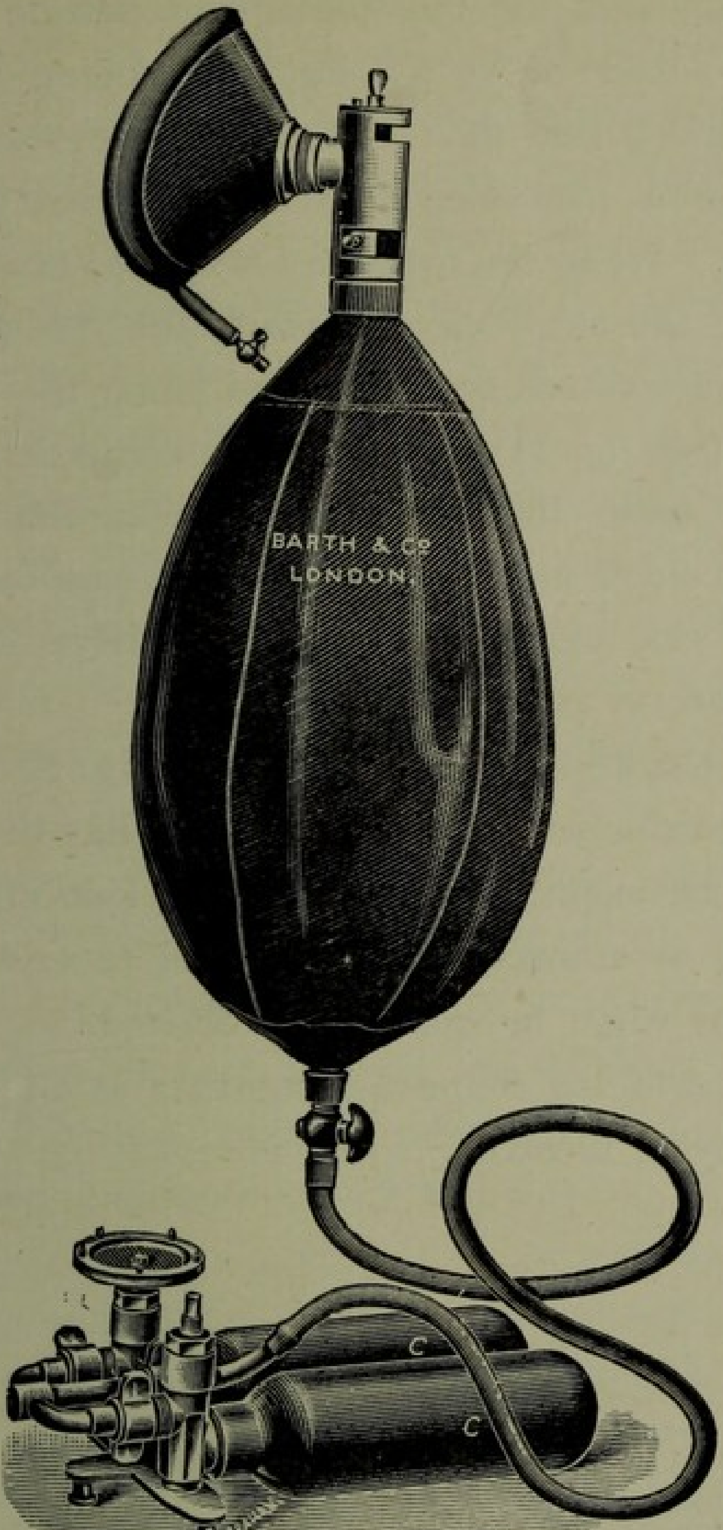


FIG. 5.—APPARATUS FOR THE ADMINISTRATION OF NITROUS OXIDE—SHOWING A HEWITT'S STOPCOCK.

The bag is partly filled with nitrous oxide and the stopcock open to air, as at the commencement of an administration.

opening towards the face-piece, and outside the stopcock is a rubber valve (expiratory) opening away from the face-piece (see fig. 11). The latter valve is protected by a movable metal cap (Hewitt) or cowl (Hilliard). When the lower slot is opened (see fig. 5), air can enter the stopcock and reach the face-piece after raising the inspiratory valve, and when the lower slot is closed (see fig. 11), nitrous oxide can enter the stopcock and reach the face-piece after raising the same valve ; in either case the expired gases pass out through the upper slot, closing the inspiratory valve, and raising the expiratory valve in so doing.

Should the upper slot be closed (see fig. 12) by means of the movable cap or cowl, this also has the effect of rotating the inspiratory valve to one side of the stopcock, and so allowing a free channel to and from the gas-bag, as when re-breathing is desired.

These parts are connected together as shown in the accompanying illustration (fig. 5).

The Administration.

Everything being in readiness, the administrator usually stands to the left and somewhat behind the dental chair. This position allows good command of the patient's head during the anaesthesia.

The cylinders of nitrous oxide should be in a position easily controlled by the anaesthetist's foot and well out of the way of the operator. The same bottle should be used until exhausted, so as to avoid the risk of commencing an administration with insufficient nitrous oxide, and it is a good plan to mark the bottle after its employment.

A small quantity of nitrous oxide is passed through the apparatus to free it from air, or the remains of a previous administration.

The stopcock is now shut off from the gas-bag (see fig. 8, I., fig. 10), and the latter is quietly filled to a half or two-thirds of its capacity with nitrous oxide gas. The screw valve is lightly turned off with the foot and all is now in readiness for the commencement of the administration.

The posture of the patient has already been described (Chapter III., p. 34), and the accompanying photograph (see plate I.) illustrates the points mentioned.

The patient is told that he has nothing to do and that all will be done for him. We feel convinced that the complicated instructions sometimes given to a patient about breathing are a mistake, and only tend to nervousness and confusion. There is no advantage in the deep inspirations which the patient is so frequently impressed to take ; these will be taken involuntarily in a more agreeable manner as consciousness is gradually lost. We find the best plan is to avoid instructions as to breathing, until observations can be made as to the type of respiration the patient presents.

With most patients there is a tendency to hurried breathing, and if this be carefully checked at the outset, there is rarely need for any further instruction ; shallow breathing, as already mentioned, remedies itself as the administration progresses. Children perhaps require managing a little differently from adults, but in their case it is even more important not to burden them with unnecessary instruction and to err rather in encouraging them than giving what is often unnecessary advice.

The mouth should be opened and a glance taken in it to ascertain its contents. Any denture should be removed and the presence of artificial crowns, loose teeth, loose roots or other impediments to the insertion of a prop or gag should be noted.

The prop should always be fixed to a chain or cord which hangs out of the mouth, and its free end attached to another prop or cork. Whenever possible the prop should be placed on the side of the mouth opposite to that on which the operation is to take place, and preferably behind the premolar region, or no further forward than the canine teeth. If the teeth to be removed are in the front of the mouth, the prop is less in the way of the operator if placed on the patient's left side. The mouth should be well opened, but at the same time not stretched to the utmost, or this will make the masseters taut and render the cheek rigid. If the prop can be so placed as to obviate the use of a mouth-gag, this is desirable, as time is economised during the anaesthesia, and the anaesthetist's hands are free for steadying the patient's head. The patient is now requested to bite

PLATE I.

Position of Patient for an Administration of Nitrous Oxide.

To face page 40.]

on the prop and close his lips; this renders the prop more secure and allows the adaptation of the face-piece to be more accurate.

If the patient has difficulty in opening his mouth on account of inflammatory oedema of the masseteric and pterygoid regions (trismus), either a gag must be inserted from the beginning and the face-piece adapted as well as possible over it, or the teeth must be separated by a small prop which will allow sufficient space for the subsequent introduction of the gag during anaesthesia.

The mouth can almost invariably be opened sufficiently wide to allow a small prop or a closed gag to be inserted, and only failing this is it permissible to commence the administration with the teeth clenched.

If it is found necessary to open the mouth during the anaesthesia, the teeth may be slightly separated by means of a wooden wedge forced between firm back teeth so as to allow space for a gag to be inserted. The wedge should be employed, when possible, on the opposite side to which the gag is required.

The patient's friends should be requested to wait in an adjoining room, and only by expressed desire should they be allowed to remain in the same room. When this permission is granted, they should be previously warned that the patient while under the influence of nitrous oxide may present an unpleasant appearance, or perhaps struggle and become noisy.

The face-piece, which fits better if its air-cushion be but little distended, is carefully adapted over the bridge of the patient's nose and then gradually closed in over his mouth (see plate II.). If the face-piece is applied in this manner there is no sudden obstruction to breathing, and if the respiratory channels of the inhaler be of a large bore, as they should be, respiration is easy and free from discomfort.

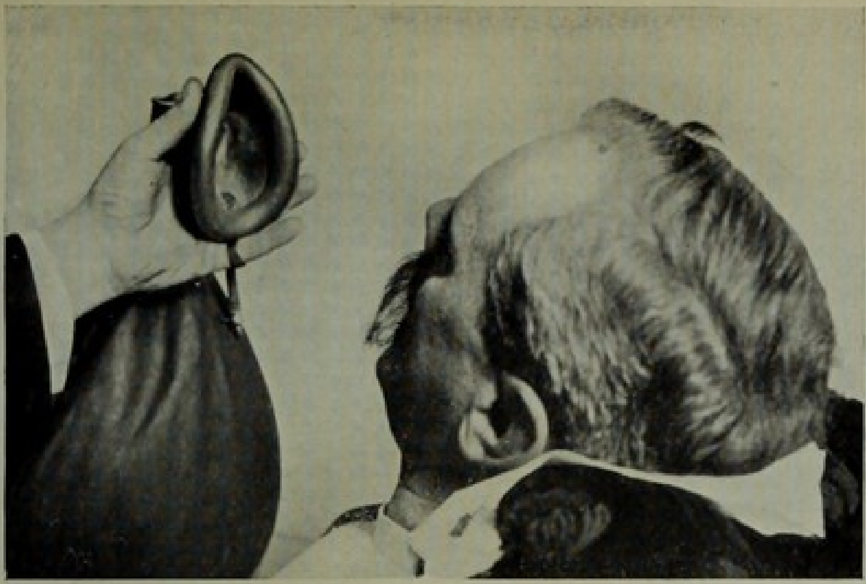
There is a tendency among beginners to use face-pieces that are too large, rendering their adaptation around the bridge of the nose difficult, and frequently necessitating the use of a second hand for this purpose. After the face-piece has been carefully adapted, it is retained in position with only sufficient pressure to prevent the escape of nitrous oxide or the entrance of air around the rubber pad.

A thick growth of hair about the face or an edentulous condition of the jaws may prevent the close adaptation of the face-piece. The moistening of a moustache or beard will allow better adaptation of the face-piece.

The face-piece should be held in such a way that the little finger supports the jaw below, while the remaining fingers are spread over the face-piece, holding it evenly and closely against the face (see plate II.).

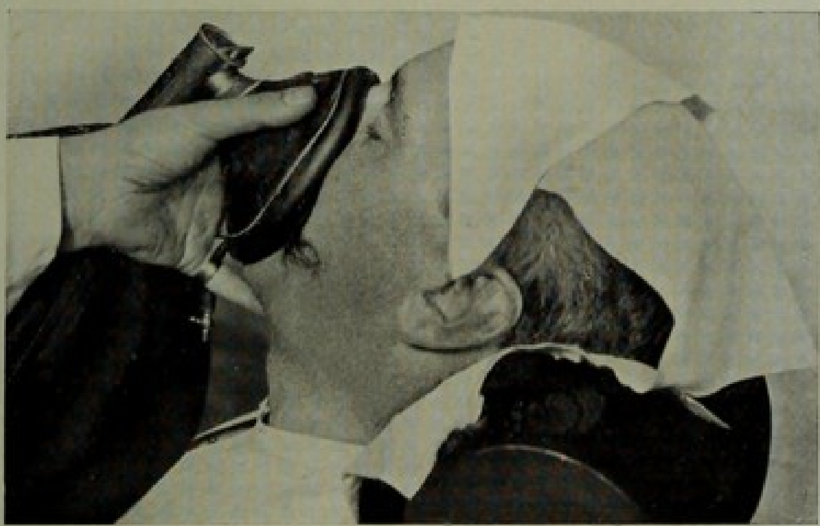
By supporting the jaw, the structures forming the front wall of the larynx are brought forward and the air passages thus kept patent.

Either hand may be used for holding the face-piece, according to individual preference. The right hand gives the anaesthetist better control of the patient's



A.

B



C.

PLATE II.—THE APPLICATION OF THE FACE-PIECE.

FIG. A.—Showing method of holding face-piece. FIG. B.—Showing method of applying face-piece over nose. FIG. C.—Showing method of applying face-piece over mouth and retaining the same in position.

(Patient's head is reclined too far over head-rest, especially in Figs. A and C.)

To face page 42].

head in the event of struggling, but is more irksome to the patient. The gas-bag should lie over the patient's chest when the face-piece is in position (see plate II.)

In dealing with timid children, the face-piece may be held at some little distance from the face for the

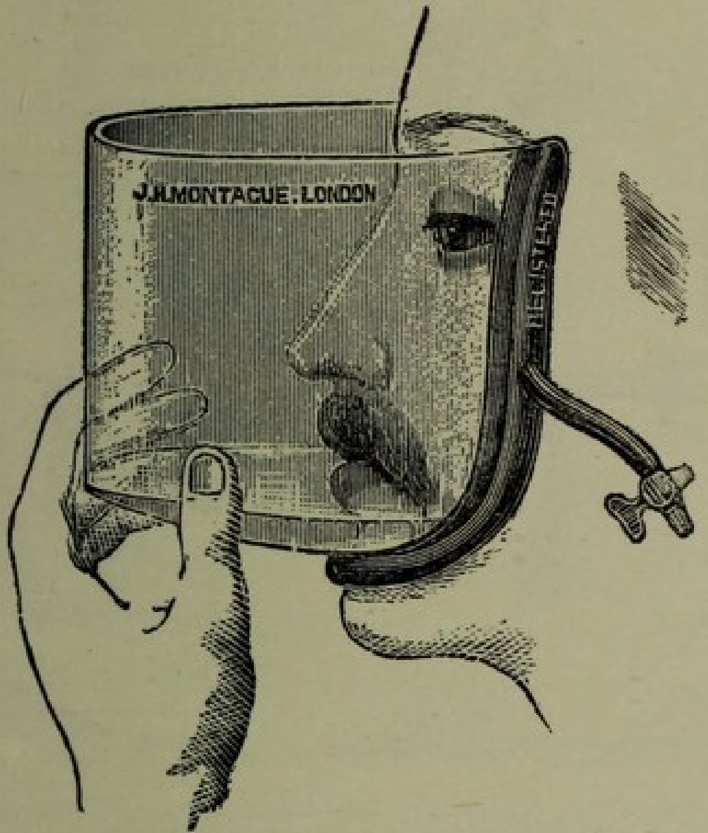


FIG. 6.—FLUX'S OPEN FACE-PIECE.

Patient in sitting posture.

first few breaths and after the patient's confidence has been gained, the mask may be gradually brought over the face, the mouth being the last part to be closed in.

This mode of procedure carried a little further brings us to a method of administering nitrous oxide through an open face-piece.

Dr. Flux,[1] relying on the fact that the specific gravity of nitrous oxide is greater than that of air, devised an open face-piece into which nitrous oxide could be poured from a stopcock connected up in the usual way with

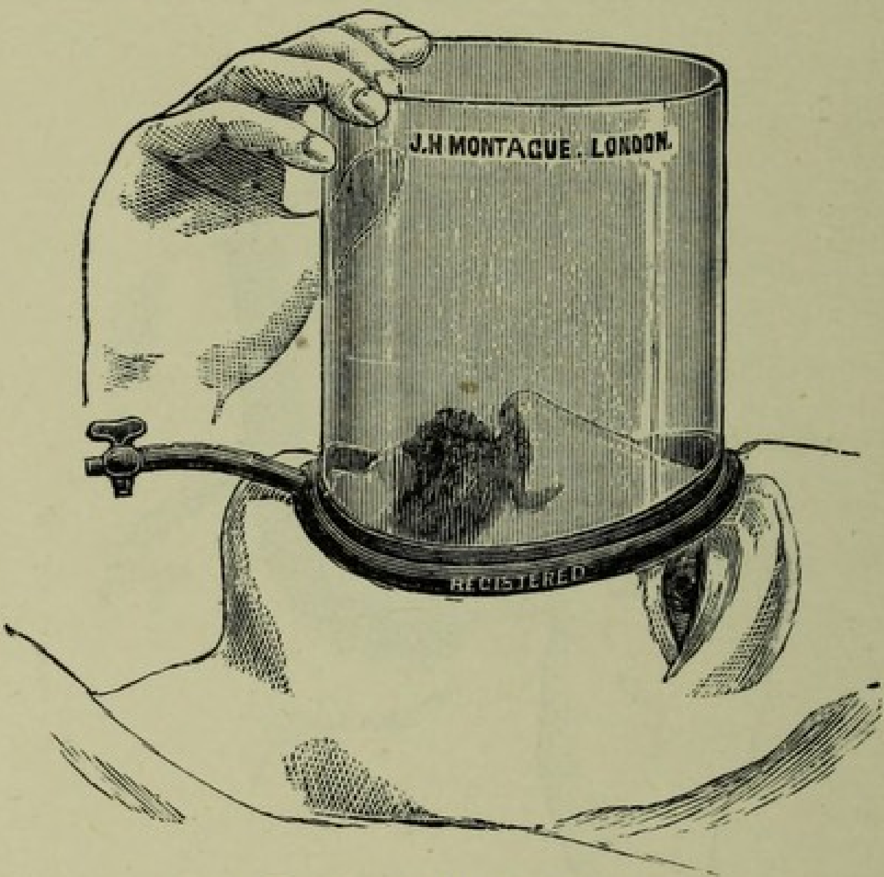


FIG. 7.—FLUX'S OPEN FACE-PIECE.

Patient in recumbent posture.

the gas-bag and cylinders. A separate face-piece is required for the upright and lying-down positions, in order that the open part of the face-piece, which receives the gas, may be uppermost. These face-pieces have been made in celluloid and fitted with removable rubber-pads (see figs. 6 and 7).

For timid children this method is often of great value,

[1] *Trans. of the Society of Anaesthetists*, vol. ii. p. 140

as they are not alarmed at the appearance of the apparatus, and that slight feeling of suffocation when a mask is first placed over the face is almost entirely avoided.

Dr. Flux's earlier experiments were carried out by means of a folded towel or serviette brought under and around the mouth in the shape of a cup into which the nitrous oxide was poured from an ordinary fitted-up gas apparatus without its face-piece.

The anaesthesia obtained by this means is light and transient and, therefore, only suitable if one or at the most two or three teeth, easy of removal, require extraction.

The nitrous oxide should be allowed to flow into the face-piece only during inspiration, relying on the force of expiration and the lighter expired air to empty the inhaler of the expired gases.

The method is useful in young children as a preliminary to the ordinary form of administration, the closed mask being substituted as soon as consciousness is lost.

The Inhalation Period.

The patient is first allowed a few breaths of air in and out of the inhaler through the opened air slot. This allows the patient to become accustomed to his surroundings before commencing the nitrous oxide administration. The air slot or aperture is now gradually closed and the patient informed that he is going to breathe gas. The manner in which the valves are working forms a good guide as to the fit of the face-piece. Should air enter around the face-piece, the administrator must use the fingers of his second hand for remedying the defect.

The face-piece can be best closed in around the root of the nose, should its fit here be inaccurate, by the pressure of a finger on either side, and adapted in other places by applying extra pressure with the free hand. The presence of a full beard and moustache may necessitate the use of a second hand for adjusting the face-piece. If a mouth-gag is inserted at the commencement of the administration, the face-piece must be adapted over it in the way indicated.

By working throughout in an orderly way, the patient is not at any time taken unawares, and consequently gains confidence and becomes more manageable.

The bag will require to be replenished from time to time with fresh supplies of nitrous oxide by turning on the foot-key, and to be kept as far as possible at a constant pressure of a half to two-thirds of its capacity. We are not in favour of keeping the gas-bag much beyond half-filled, but prefer the patient to exhaust the bag after each inspiration to below half its capacity, and to make up for this deficiency during expiration, by allowing more gas to flow into the bag.

Forcing the gas into the respiratory passages should be avoided. The pressure at which the gas is supplied should be as near as possible to that of the atmosphere. This principle has sometimes to be superseded in nasal

FIG. 8.—COLEMAN'S "GAS AND AIR" STOPCOCK.

F.P. Face-piece. **G.I.** Gas Inlet.
A.A. Air Aperture. **E.V.** Expiratory Valve.
I.V. Inspiratory Valve.
H. Handle (in position for admitting gas alone to inhaler).
I. Shows handle in position for admitting air alone to inhaler.
2. ,, ,, ,, rebreathing into gas-bag.

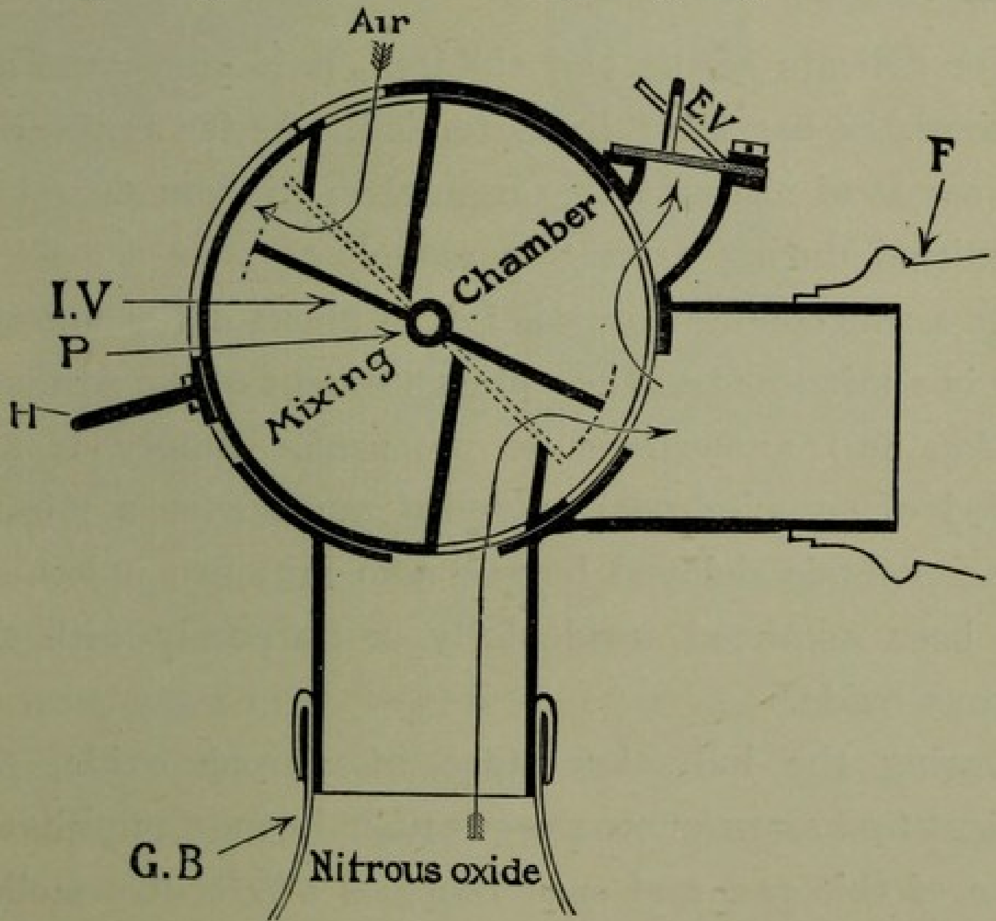


FIG. 9.—SECTION OF COLEMAN'S "GAS AND AIR" STOPCOCK.

F. Face-piece. **G.B.** Gas-bag.
E.V. Expiratory Valve (rubber). **I.V.** Inspiratory Valve (aluminium).
P. Pivot on which Inspiratory Valve turns.
H. Handle (in position for admitting both gas and air to inhaler).

administration of nitrous oxide or the patient would inhale air too freely through the mouth.

It must be clearly understood that respiration is not a mechanical process, and that any forcing of the nitrous oxide into the respiratory passages will be resisted and will tend rather towards inducing expiratory efforts than increasing the inspiratory ones. The inspired gases ultimately reach the smallest bronchial tubes and their alveoli by a process of diffusion, and it is not until the anaesthetic gases or vapours reach the pulmonary alveoli and come into contact with the circulating blood that any gaseous interchange in the tissues takes place.

For delicate adults and children, it is important not to have the bag too fully distended. As far as possible the egress of nitrous oxide from the cylinders should be permitted during expiration alone.

As a rule consciousness is lost in about half a minute, and in a minute from the commencement of the administration full anaesthesia is procured. Rarely is the period of consciousness extended much over a minute or anaesthesia delayed beyond two minutes, unless air has been admitted accidentally or purposely with the nitrous oxide.

During the induction stage of nitrous oxide, the patient first experiences the sweetish, but not unpleasant taste of this gas, and soon becomes aware of a feeling of dizziness and drowsiness, accompanied with pulsatile throbbing, chiefly in the head. Voices or noises heard assume a peculiar staccato and monotonous rhythm and often apparently last throughout the anaesthesia. Respiration becomes deep, quick, and regular

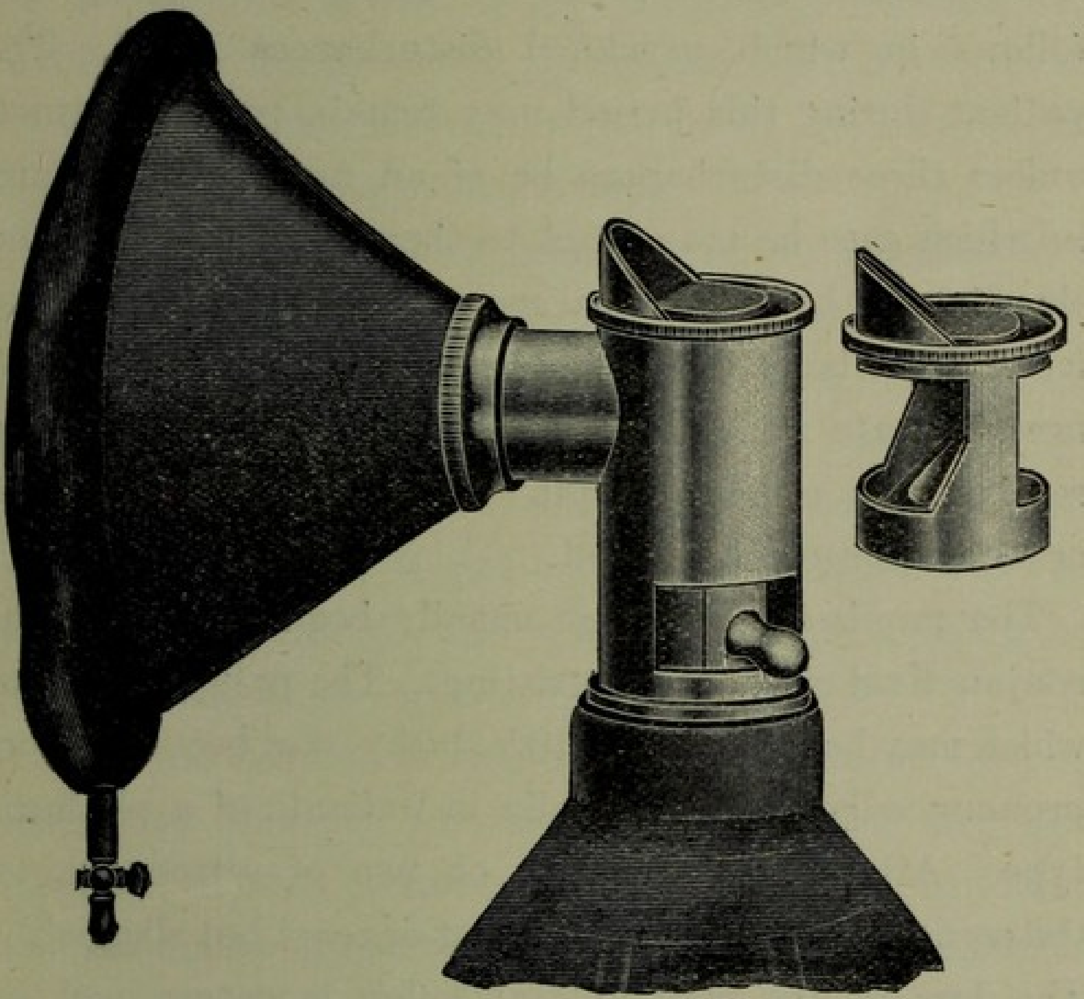


FIG. 10.—HILLIARD'S MODIFICATION OF HEWITT'S NITROUS OXIDE APPARATUS.

Showing valve-seat removable for cleansing purposes and adjustments to valves.

as consciousness is gradually lost, and the pulse, if previously quickened through excitement, becomes now slower and fuller, although slightly more accelerated than normal.

In less than half a minute impressions conveyed from the special sense organs become altered in their character; thus, numbness is frequently felt in the limbs, tinnitus in the ears; hearing being the last of the senses to persist, and the earliest to return during recovery from anaesthesia. After consciousness is lost, a period follows in which psychical disturbances ensue. The patient during this period may remain perfectly quiet, unless these disturbances be of an unpleasant nature, in which case he may react to them, by struggling and shouting, or by rhythmical movements of his hands and feet. In a large number of cases struggling and noisiness indicate faulty administration, the patient having received too much air from a badly fitting apparatus, or one improperly applied.

The pupils at this stage usually begin to dilate, the conjunctival reflex still persisting. The patient's colour, which may have become a little dusky, now becomes more pronouncedly livid, especially in patients of a plethoric type. After another breath or two of nitrous oxide, the conjunctival reflex will be lost or react but sluggishly. The loss of the conjunctival reflex is determined by lightly touching the ocular conjunctiva, which will be followed by closure of the lids if the reflex persists. A faintly audible inspiratory roughness, followed by a short and forcible expiration, which produces a "catch" in the breathing, accompanied perhaps with fine twitching movements of the eyelids and jactitation, now takes the place of the previously quiet rhythm, or the breathing may assume a soft regular snoring character.

The corneal reflex is not abolished. According to

Snow, this reflex may be absent in hysterical subjects even before anaesthesia is obtained.

The harsh " snorting " sound known as stertor is due to obstruction in the upper respiratory passage, probably from irregular and spasmodic contraction of the elevators of the larynx, which raise it towards the epiglottis and base of the tongue.

During the inhalation period it is often desirable to admit air through the stopcock, more especially in the case of children and delicate and anaemic subjects. For this purpose two methods are made use of: in one method air is admitted continuously throughout the administration, or if not at its commencement, very soon afterwards; in the second method, intermittent administration of air is employed.

The first method is that generally employed for children, the quantity of air given varying as the signs indicate, tending rather to decrease the amount of air as the inhalation proceeds. The indication for increasing or diminishing the amount of air is gauged chiefly by the patient's colour and the depth and rapidity of respiration.

In the second method air is only admitted towards the end of the inhalation period, when signs of oxygen deprivation are becoming manifested.

A useful plan in the case of excitable people, who breathe hurriedly, and rapidly lose consciousness, and in whom the signs of stertor and jactitation are early phenomena, is to give three or four breaths of air and allow the patient to nearly regain consciousness; by

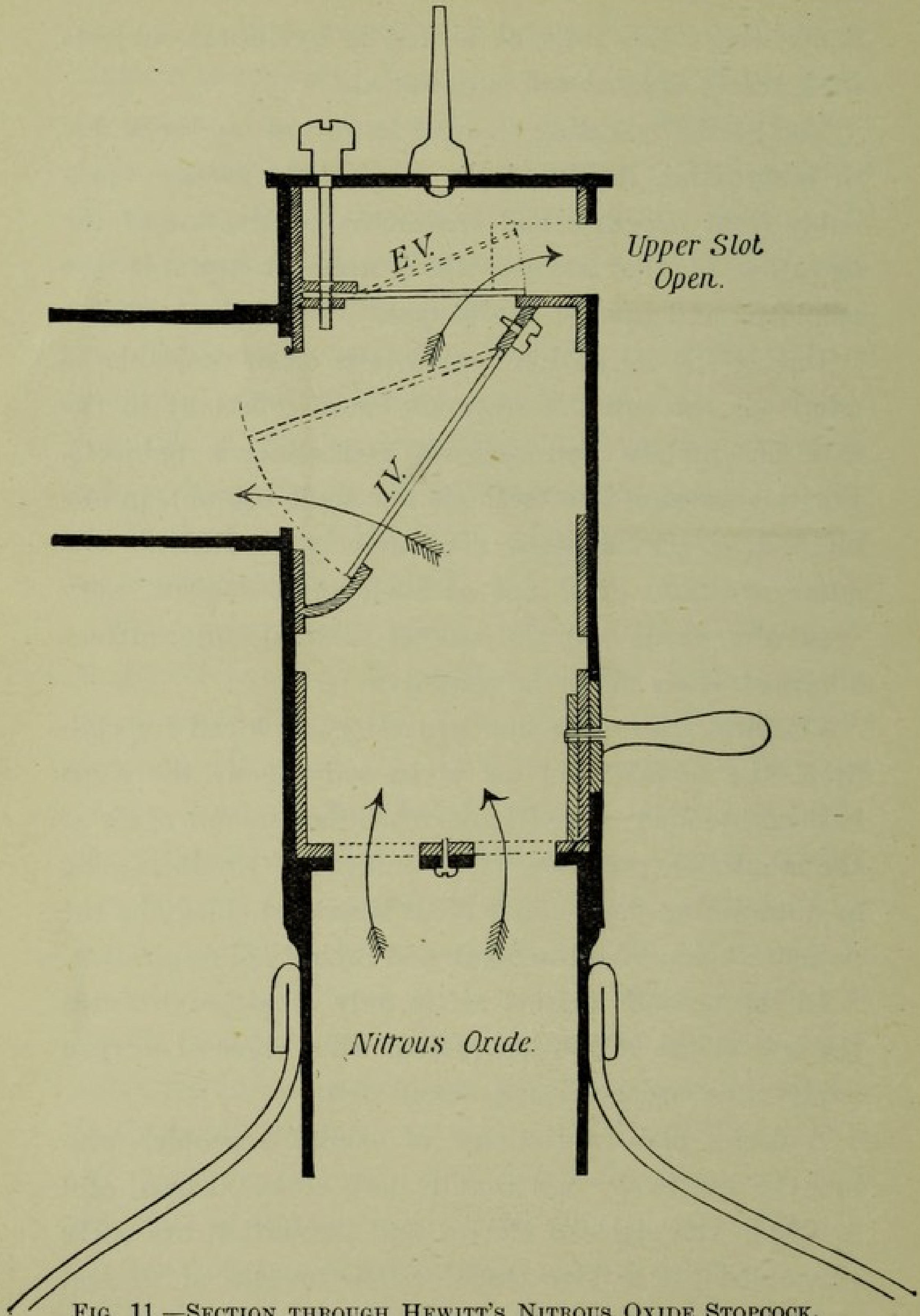


FIG 11.—SECTION THROUGH HEWITT'S NITROUS OXIDE STOPCOCK.
Showing the Inspiratory Valve (I.V.) and the Expiratory Valve (E.V.) in action as when Nitrous Oxide is being administered. Figure shows lower slot closed (from Probyn-Williams).

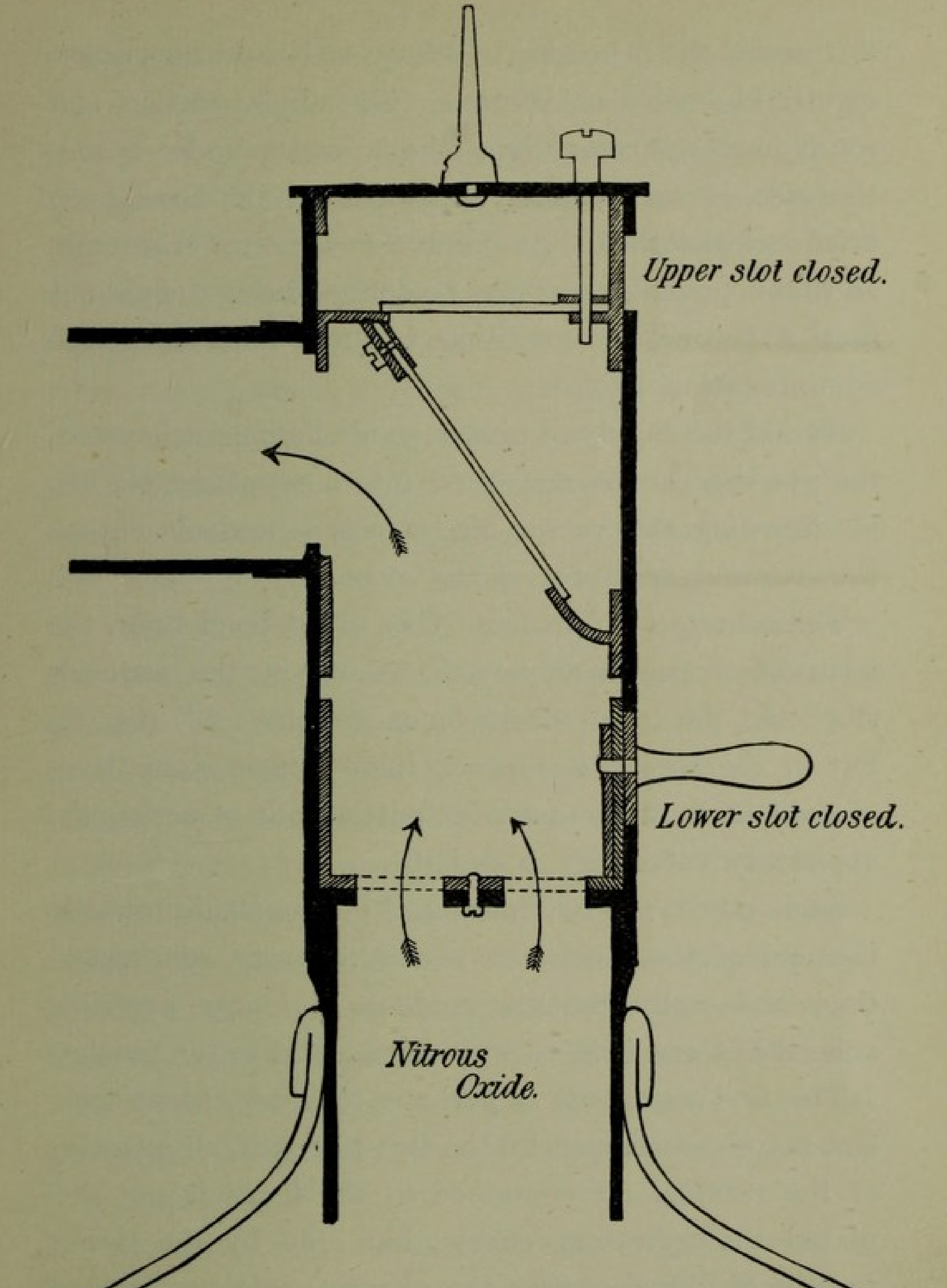


FIG. 12.—SECTION THROUGH HEWITT'S NITROUS OXIDE STOPCOCK.
Showing the Inspiratory and Expiratory Valves out of action, as when rebreathing into the gas-bag is permitted (from Probyn-Williams).

this means the breathing will frequently take on a quiet, regular character on resuming the administration and result in a satisfactory anaesthesia, which under a continuance of the original conditions would have been brief and disturbed. As prevention is better than cure, all that is possible must first be done to bring the patient into a favourable condition before commencing the administration.

Should the supply of nitrous oxide become exhausted, the gas-bag can be converted into a supplemental bag by throwing the valves out of action and closing all the external apertures of the stopcock.

The movements for doing this will depend upon the form of stopcock employed; thus, in the author's stopcock, the lever would be moved to "2" (fig. 8), but in the Hewitt's stopcock there is a separate lever or cowl at its upper part for putting out of action the expiratory valve (figs. 5 and 10).

Some advise the rebreathing of nitrous oxide towards the end of the inhalation period in every administration, and claim that it produces a longer available anaesthesia and is in no way detrimental to the patient.

The first argument is perhaps to some extent true, and may be explained by the fact that a small quantity of the residual air contained in the lungs is not displaced by expiratory efforts, but only by the slower process of diffusion after the nitrous oxide has reached the finer bronchi, so that the oxygen contained in this residual air is exhaled together with the "spent" nitrous oxide and carbon dioxide from the lungs into the supplemental bag, and it is this small percentage of oxygen in the to-and-fro current that delays anaesthesia and subsequently prolongs its maintenance. Obviously, where pure nitrous oxide is inhaled and the exhalations are allowed to escape externally, this interchange between the nitrous oxide and the residual air takes place more readily and completely.

The second claim is certainly open to criticism from the hygienic point of view. Nitrous oxide bags are not easily cleansed, and expired air contains besides carbonic acid, which progressively increases with the duration of the administration, a small quantity of organic matter and débris from the patient's air-passages ; besides the presence of pyogenic and other organisms found in diseased conditions, *e.g.* the tubercle bacillus.

Recovery after this method of rebreathing is slightly delayed and patients are more apt to suffer from headache and giddiness. The small saving of gas cannot seriously be entertained as a reason for its employment, but the method may be most usefully employed in cases where the supply of nitrous oxide unexpectedly fails.

In a recent communication to the *Lancet*[1] on blood pressure in anaesthesia, the following points of interest were elucidated :

" Nitrous oxide caused a constant rise of systolic pressure, but this was more marked when the exhaled

[1] Edinburgh Medico-Chirurgical Society, *Lancet*, February 12th, 1910.

air was passed out through valves. When the patient was allowed to rebreathe his expired air, there was no practical difference in the available anaesthesia, but the systolic pressure did not rise so high. This was explained by the lessened element of asphyxia. The inhalation of one gallon of oxygen before the administration of gas by the rebreathing method altogether eliminated asphyxia, and the blood-pressure hardly rose at all. At the same time the period of anaesthesia available was only slightly curtailed."

Signs of Anaesthesia.

To recapitulate—the usual signs of nitrous oxide anaesthesia are the following:

1. Colour slightly dusky.
2. Pupils dilated.
3. Loss or impairment of conjunctival reflex.
4. Stertor, or deep regular breathing accompanied by soft snoring.
5. Jactitation—muscular twitching of orbicularis palpebrarum.

The Operation Period.

The operator should be warned when the patient is fully anaesthetised, or preferably given some indication of the approach of this period.

A useful method is that of counting one, two and three, commencing the count synchronously with the patient's first stertor and removing the face-piece at the end of the third stertorous inspiration.

By removing the face-piece at the end of an inspiration, there is a gain of time, amounting to that occupied by the ensuing expiration.

In operations on the lower jaw, the face-piece may be removed at the end of the second stertor, as anaesthesia will deepen a little, owing to the unavoidable presence of the operator's fingers in the mouth obstructing the air-way. Respiration will be further embarrassed if the tongue be pushed back, or the patient's jaw depressed.

By forcing back the tongue the glottis becomes occluded and respiration prevented, so that the patient suffers from asphyxia and becomes cyanosed. The operator must be told that the patient is not receiving enough air and the operation must temporarily cease, while the anaesthetist pushes forward the jaw to restore the air-way.

Anaesthesia may be intentionally prolonged by compressing the patient's nostrils and so hindering the interchange of gases in the lungs.

In young children it is advisable not to retain the face-piece after the first stertor, and sometimes it is desirable to anticipate this sign, or the child may sink into the chair and the already short anaesthetic period is rendered less available to the operator.

Previous to removing the face-piece, the anaesthetist shuts off the gas-bag from the cylinders. The face-piece is quickly hooked over some convenient part of the back of the chair, and the administrator has his hands free for steadying the patient's head.

The manner in which the patient's head requires to be steadied will depend upon the tooth to be extracted. If it be a firm tooth in the upper jaw, the anaesthetist should resist the operator's upward thrust by firmly grasping the upper and back part of the patient's head and steadying it on the head-rest. In the lower jaw, the operator prefers to have sole command when standing behind the patient and operating on the right side; in other cases, the anaesthetist's fingers should be kept behind the angle of the jaw and his attention confined chiefly to steadying the patient's head. Some anaesthetists, with good intentions, support the lower jaw while the operator is working on the same; this is a hindrance to most operators, who prefer to apply their own counter-pressure, as by this means they can better gauge the amount of force they are using, besides being able to raise or slightly depress the jaw to their own benefit.

During the removal of upper teeth the patient's head may be allowed to slightly recline over the back of the head-rest, but for lower teeth an almost vertical position is more advantageous.

The duration of anaesthesia in adults may be said to approximately reach 40 seconds, varying from 30 to 50 seconds with the type of patient and the amount of nitrous oxide inhaled.

The mouth-prop should never be removed until the patient is fully conscious, and, indeed, this part of the operation may well be left to the patient, as after an otherwise successful anaesthesia, he may complain that he felt the last part of the operation, which in reality was the removal of the mouth-prop. This precaution will remove all ground for such a complaint.

Should the patient show signs of returning to consciousness before the completion of the operation, the face-piece may be reapplied, provided there is but little blood in the mouth. The patient's head should be kept in a vertical position to allow any blood to accumulate in the floor of the mouth, and the operator should sponge this away before continuing the operation.

When the face-piece is reapplied in this manner, the patient is quickly rendered unconscious, but the resulting anaesthesia is usually somewhat shorter and less tranquil than on the first occasion.

If there is much blood in the mouth, it is generally better to allow the patient to regain consciousness and to let him wash out his mouth; this procedure also gives the operator an opportunity of defining any tooth or teeth that remain, and carefully localising their position.

The reapplication of the face-piece is not to be recommended, and must be regarded as serving an emergency rather then as a definite procedure to employ.

The first method of repeating the dose of the anaesthetic before the patient regains consciousness is open to certain disadvantages. It is not always easy to reapply the face-piece and commence a second administration without the patient being aware that something untoward has happened ; and although actual pain may be prevented, some confused sensation or distinctly unpleasant dream may be experienced, and this may cause annoyance to the patient at the time, or be a source of anxiety when an administration is required on some future occasion.

In the second method the patient is often reluctant to undergo another administration, and may be feeling unwell from the effects of the previous anaesthesia.

Both these methods allow but a short additional time, and the operator is often hampered by the presence of blood in the mouth. Recovery is likewise unsatisfactory, and a sensation of giddiness, headache, nausea or even vomiting is more common than after a single administration.

The Recovery Period.

The return of consciousness is indicated by the colour of the patient's face, the presence of voluntary and purposeful movements of the eyes and limbs and reaction of the pupil to light.

On completion of the operation perfect silence should be enjoined while the patient is returning to consciousness. There is absolutely no need to arouse the patient hastily, and he will better appreciate coming to his senses without any assistance. An exception may be made in hysterical patients, more often females, who frequently show great reluctance to being disturbed, and may again and again fall into a lethargic condition after being aroused, or may become excitable and noisy. These patients require firm but kind treatment, and with some perseverance can usually be made manageable.

In a few cases there may be actual inability for the patient to arouse himself, but it is more frequently a case of disinclination and perverseness.

Any form of noise is distracting to a patient undergoing nitrous oxide anaesthesia, and no doubt in many cases what would have been a satisfactory result, both from the anaesthetist and the operator's point of view, has been defeated on this account alone. Patients usually become very sensitive to sound just as unconsciousness is approaching, and talking or the moving of instruments may lead them to believe that the operation is about to begin. Patients should be assured beforehand that no operative procedure will be commenced until they are fully unconscious, so that any movement on the part of the operator during the administration will not be misinterpreted.

Restraint of any kind should be avoided. If the patient is at first a little restless, this will usually pass off as anaesthesia approaches. Noisiness and struggling during the inhalation period usually indicate faulty administration, except in nervous and hysterical patients, when much can be done by gaining their confidence and using a certain amount of firmness. Again, during the recovery, even if the patient struggles and becomes noisy, it is better to avoid all restraint apart from preventing patients from injuring themselves. During the period of anaesthesia, however, restraint may be necessary to allow the operator to accomplish his work.

The manner in which a patient undergoes anaesthesia with nitrous oxide serves as a good test of the anaesthetist's skill and capability.

An experienced anaesthetist quickly observes the temperament of his patient, and recognising that no two patients are alike, treats each accordingly. His methods, although quick, are carried out in a quiet and orderly manner, and there is an absence of that mechanical and unfeeling method of administration witnessed in a beginner.

The Administration of Nitrous Oxide with Definite Quantities of Air.

So far an inhaler has not been designed by means of which nitrous oxide and air can be given in definite quantities, and the mixture varied at will, although for many years oxygen has been given in this way with nitrous oxide and the method found to be a very valuable one.

To attain this end, Mr. Carter Braine [1] devised a face-piece bearing a perforated aperture surmounted by a

[1] *British Dental Association Journal*, April, 1895.

movable metal cap. The perforations served for admitting air into the face-piece, and could be opened or closed to the desired extent by revolving the metal cap ; however, it was found that when the gas-bag was distended, little, if any, air entered these perforations owing to the existing pressure of nitrous oxide in the inhaler.

By working with gasometers a definite mixture of nitrous oxide and air can be administered,[1] but the mixture remains constant for the administration in question, and on account of the cumbrous apparatus required, this method is only applicable for institutional work.

All present forms of stopcock fail, for the reason that while nitrous oxide is passing from the bag to the inhaler across the stopcock, the pressure in the latter must necessarily be greater than that of the atmosphere, so that the partial opening of the air-slot, while allowing but little air to enter, permits the escape of the contained nitrous oxide, and it is only when the nitrous oxide is entirely shut off that air can be constantly admitted to the inhaler.

During inspiration there is a negative pressure in the stopcock, but this is almost immediately compensated for by the nitrous oxide rushing from the bag into the inhaler, so preventing any further entry of air, and even if the aperture, admitting the latter, be fairly widely open, it will serve more readily as an exit for nitrous

[1] Dr. Hewitt, *Medico-Chirurgical Transactions*, vol. 82.

oxide than as an inlet for air. An indefinite quantity of air may enter the inhaler along with the nitrous oxide during this negative phase, but this fact does not modify the contention that at present we possess no form of stopcock by which definite quantities of nitrous oxide and air can be administered.

This difficulty the author partly overcame by employing a single rubber valve for controlling the nitrous oxide and air entry to the stopcock.[1] A later development of this principle is embodied in the stopcock already mentioned which presents the following features (see figs. 8 and 9). The apertures which admit respectively the nitrous oxide and the air are equal in size, and guarded by a valve made of aluminium, working on a central pivot. By such an arrangement the entry of nitrous oxide into the stopcock raises the common inspiratory valve from both apertures, and so allows the simultaneous entry of air, when the air aperture is set for this purpose. Thus, the entrance of air into the mixing chamber is insured whenever the inspiratory valve is lifted, and can be regulated in amount by opening or closing the air inlet. Under these circumstances the flow of nitrous oxide through the stopcock aids rather than hinders the admission of air into the inhaler.

The inspiratory valve, although made of aluminium and larger than the ordinary rubber valves employed, is as sensitive as these to air currents, owing to the manner in which the valve is balanced at its centre, and

[1] Anaesthetic Section, Royal Society of Medicine, Feb. 3, 1911.

the slight clicking sound produced on its closure is a guide to the patient's breathing.

This principle of valve-seat comprises the two advantages present in the Hewitt's stopcock, viz. the common inspiratory valve is put into action and tested while the patient is breathing air alone and before nitrous oxide is inhaled; and the patient in respiring through valves throughout the administration experiences but little discomfort when nitrous oxide is substituted for air.

Care of Apparatus.

India-rubber bags and tubing should be kept in a dry, warm room and preferably hung up. If not in frequent use, the gas-bag should be distended once every week or so to keep it supple and in readiness for an emergency.

Rubber face-pieces and valves require similar supervision, the latter, unless made of the thick red rubber, require fairly frequent renewal.

Some forms of gas-bags can be turned inside out; this is a useful precaution to take, where rebreathing has been permitted.

Nitrous oxide in passing from a liquid to a gaseous state absorbs heat, cooling both the cylinder and its connections, and should the temperature fall below freezing-point, the moisture in the surrounding air condenses and freezes in the form of a fine powdery snow, which is deposited as a white layer on the gas-cylinder and its metal attachments. Probably this is the cause of the valve, checking the egress of nitrous oxide from the cylinder, occasionally becoming blocked.

A 50-gallon cylinder of nitrous oxide will usually serve for seven or eight ordinary administrations, but the amount of nitrous oxide inhaled to produce a full anaesthesia may vary from 2 to 15 gallons or more, according to the age and physique of the patient.

A 50-gallon cylinder or bottle, although less portable than a smaller one, has the advantage in being more stable and less liable to rotate while turning the foot-key. A 25-gallon bottle may barely suffice for a prolonged nasal administration, although the latter method uses up less nitrous oxide than might be anticipated.

The contents of a bottle can be determined by its weight, and to some extent by the sound emitted when tapped with a spanner; the simplest and most reliable means, however, is to turn on slowly the gas-cylinder with a key, the forcible or gradual escape of the gas indicating the fulness of the cylinder.

Difficulties and Dangers arising from Nitrous Oxide Administration.

The difficulties and dangers arising from a nitrous oxide administration may occur during the period of induction of anaesthesia, during the period in which the operation is in progress, or during recovery from the anaesthetic.

This forms a useful classification, as the complications arising are to some extent dependent upon the governing factors that are in progress during these three stages. At the outset, let it be stated that the difficulties and dangers of nitrous oxide administration are to a large extent preventable, and that the after-effects of this anaesthetic are conspicuous by their absence.

A. During or preceding the Induction Period.

Irritability of the throat. Some patients have very irritable throats, and are unable to tolerate the presence of a mouth-prop. This condition may be often remedied by allowing the patient to gargle his throat or rinse out his mouth with carbolic acid lotion (1 %), or by spraying the palate and fauces with a solution of cocaine (5 %). Sometimes the patient can tolerate a mouth-prop when this is self-inserted.

If a small prop placed towards the front of the mouth still causes retching, the anaesthetist must rely on opening the mouth after anaesthesia has been induced. The operator may give useful assistance by prising the teeth apart on the side opposite to which a gag is required. For this purpose the operator uses a wooden wedge (see fig. 3) on strong back teeth, whilst the anaesthetist attempts to introduce his mouth-gag. Less strain is put on individual teeth when the jaw is forced open on both sides in this manner.

Struggling and *noisiness,* occurring especially in hysterical and neurotic subjects, are not usually due directly to the anaesthetic, but to its faulty administration.

Nausea and *vomiting* during the induction of nitrous oxide are not often met with, apart from obvious indiscretions in diet previous to the administration.

Vomiting occurs rather more frequently when air or oxygen is administered with nitrous oxide. Should there be premonitory signs of vomiting, such as retching, the induction period should be curtailed, as far as possible, by increasing the pressure of nitrous oxide ; in this way the onset of vomiting may be prevented. As a rule, the vomiting is not accompanied with much retching, the vomited matter appearing to well up from the floor of the mouth on but little provocation. The administration must at once cease under these circumstances, and the patient's head be bent forward to prevent the vomited matter from trickling down into the air-passages. It is not advisable in these cases for the anaesthetist to reapply the face-piece, even after thoroughly swabbing out the mouth and fauces. The patient should be advised to come prepared for an anaesthetic on some future occasion, avoiding any factor, *e.g.* a long railway journey, that may have played a part in the unfortunate occurrence.

On the subsequent visit, the operation should preferably take place late in the morning, so that three hours or more have elapsed since the patient's habitual breakfast hour.

Pallor and *faintness* are often premonitory symptoms of vomiting, and sometimes occur in patients apparently in good health, and in the absence of indiscretions in diet or other disturbing factors ; apart from this a feeling of faintness associated with cold sweating not infrequently occurs in patients who have worried over an impending operation.

The patient's colour and strength are quickly restored on lowering the head, and may be further maintained by the application of smelling salts, briskly chafing the hands or giving the patient a small quantity of stimulant. The latter is better avoided, if it is intended to proceed with the administration, the stimulating effect of the nitrous oxide will often immediately improve the patient's condition.

Coughing is induced in some patients on the administration of nitrous oxide ; probably this is caused by the restrained feeling produced on application of the inhaler, rather than directly to the effect of the nitrous oxide. If the attacks of coughing do not rapidly pass off, the inhaler should be removed and the patient allowed to clear his throat. The employment of wide-bore inhalers with free channels has already been insisted upon.

Early cyanosis and stertor, occurring in apparently healthy persons during the induction stage of nitrous oxide, if not due to faulty posture or tight clothing, can usually be remedied by admitting three or four breaths of air at the stopcock, allowing the patient to nearly regain consciousness, and only continuing the administration after the colour has been restored and the breathing become regular. The administration may then be continued until full anaesthesia is procured.

To obtain the best result in these patients, it is advisable not to have the bag distended and to counteract early cyanosis by admitting air through the stopcock.

Hurried breathing, especially when deep, will rapidly produce cyanosis ; this should be checked early in the administration by telling the patient to breathe slowly and quietly.

Most patients have a tendency towards hurried breathing when inhaling nitrous oxide, and unless this be checked at the outset an unfavourable anaesthesia results. The opposite condition of slow, shallow breathing can usually be disregarded, as this type of respiration remedies itself with the progress of the administration.

Apnoea, or sudden suspension of breathing, is more often associated with nitrous oxide and oxygen than with other forms of anaesthesia, and usually follows rapid and deep breathing. According to Haldane and Priestley,[1] apnoea is due to a temporary fall of carbon dioxide, so that the circulatory blood fails to stimulate the respiratory centre in the medulla ; whilst the oxygen pressure is insufficiently pronounced to excite respiratory efforts.

A condition simulating apnoea is not uncommonly produced in patients whose breathing is rapid and shallow, during this " apnoeic " period the breathing may

[1] *Journ. Phys.* vol. xxxii. p. 225.

appear to be suspended for several seconds, the patient in the meanwhile retains a good colour, and presents a good pulse. This phenomenon remedies itself, or may be curtailed by increasing the pressure of nitrous oxide and thus produce positive ventilation of the lungs to initiate an expiration. The administrator should make sure that the inhaler is closely fitting around the patient's face, as the entrance of air around the face-piece is the usual cause of this condition. This false apnoea, which is nothing more than light, undetected atmospheric breathing, must be distinguished from physiological apnoea following rapid and deep breathing under anaesthesia.

Cessation of respiration may result from an adminis tration that has been unwisely pushed beyond the limits of full anaesthesia, or, in other words, from an overdose of nitrous oxide. The signs and symptoms resulting from this undue deprivation of oxygen are manifested by an exaggeration of those of complete anaesthesia. Thus, the patient's colour darkens or becomes livid, the breathing, if not entirely suspended, is stertorous, spasmodic, and irregular, the pupils are widely dilated, the lids separated and fixed. Little or no change, as a rule, is detected in the pulse.

The failure of respiration in these cases is due to obstructive muscular spasm and not to the far more serious condition of paralysis of the respiratory centre in the medulla oblongata. This muscular spasm likewise manifests itself in the muscles of the back (opisthotonus), and in those of the glottis, jaw (trismus), thorax, and abdomen, aggravating the respiratory embarrassment already present in the upper air-passages.

The operation if commenced should immediately cease, and the patient be given every opportunity for aerating his blood. There is no need to rush at any particular method of restoration, provided the patient's pulse is good and his air-passages are, as far as possible, kept free. An assistant should get in readiness any appliances or drugs that may be required for an emergency.

Compression of the chest, while the patient is in the chair, will in many cases suffice to restore respiration, timing each compression to follow any inspiratory efforts on the part of the patient.

If an assistant is present, his duty should be to see that the patient's mouth is kept well open and the tongue drawn forwards.

Rhythmic tongue traction is a useful means of relaxing laryngeal spasm and inciting inspiratory efforts.

Briskly rubbing the lips with a towel will sometimes restore the breathing.

If respiration fails to resume after a minute or two some efficient form of artificial respiration must be performed, and of these Sylvester's method is the most satisfactory (see plate III.).

To carry out this the back of the dental chair is lowered to a horizontal position, and the arm-rests removed, or the patient is carefully lifted off the chair and placed on the floor with a firm cushion beneath his shoulders; his arms are grasped between the elbow and shoulder by the anaesthetist, who stands or kneels behind the patient's head for carrying out the necessary movements.

These movements consist in bringing the patient's arms firmly down on to his chest and thereby compressing its contained viscera, after which the arms are slowly drawn out and upwards above the patient's head, to be again brought down over his chest. These manipulations should be performed slowly and deliberately at the rate of normal respiration (*i.e.* about fifteen times a minute), and continued until normal breathing is resumed.

The effect of these movements is to alternately compress and relax the thorax, the latter recoiling through its own elasticity, and so to empty and fill the lungs with air. As a rule these movements are performed far too rapidly and perfunctorily. In raising the arms, the patient should be stretched out and, unless a heavy person, almost drawn towards the manipulator, whilst in bringing the arms down as large a surface as possible should be brought to bear on the chest walls.

A hypodermic injection of strychnine, ether, or brandy may be administered by an assistant, while the artificial respiration is continued.

Breathing has been restored after artificial respiration has been maintained for over two hours, so that hope of recovery should never be lightly despaired of.

There are many other methods of performing artificial respiration, but the method detailed above carries out efficiently the principles of most of the other methods.

In the absence of an assistant a gag should be inserted in the mouth with the blades opened and fixed, the front part of the tongue should be seized with forceps and allowed to hang out on the dependent side of the mouth. The mere pulling forward of the tongue opens the orifice of the larynx and allows gaseous diffusion, the nitrous oxide in the lungs interchanging with the external air.

In the vast majority of cases normal breathing will be resumed within a few minutes, but should these measures fail laryngotomy must be performed.

Pallor, apart from indicating a temporary circulatory depression, as occurs previous to fainting or vomiting, may have a far more significant meaning, when associated with *respiratory failure*. This is fortunately a complication which rarely occurs with nitrous oxide, unless the latter has been pushed to such an extent as to cause grave interference with the pulmonary circulation.

The treatment of pallor, faintness, or the slighter degrees of syncope that are likely to occur in dental practice consists in keeping the patient warm, lowering his head, raising his extremities and applying stimulants to the nostrils, such as smelling salts or nitrite of amyl. If the patient be in the dental chair, this may be tilted so that the patient's head is the lowest part

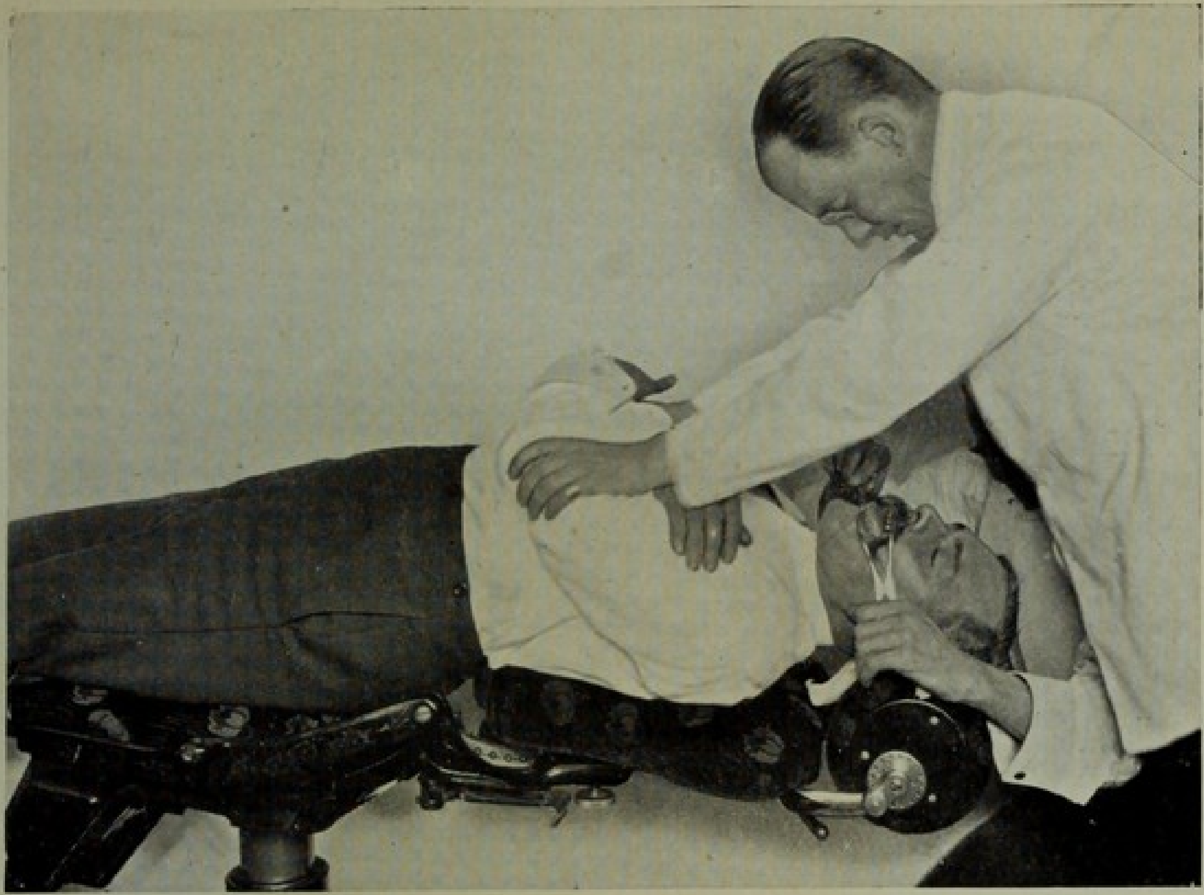


PLATE III.—SYLVESTER'S METHOD OF ARTIFICIAL RESPIRATION.

Patient in horizontal position with head lowered and extended. Mouth kept open and tongue drawn forward by an assistant. For movements, see text on page 72.

UPPER FIGURE.—Expiration. LOWER FIGURE.—Inspiration.

To face page 74.]

of his body.; or the patient may be placed in a supine position on the floor.

Other methods of stimulation consist in flicking the skin with cloths wrung out in cold water; the application of a galvanic battery, placing the electrodes on the phenic nerve and diaphragm; and the subcutaneous injection of ether or strychnine. Dr. Buxton recommends partial or total inversion of the patient. As pallor in these cases is almost invariably a sequel of respiratory failure, the treatment for the latter condition must be carried out in conjunction with that for syncope.

There is some doubt as to whether primary syncope occurs under nitrous oxide, or even whether respiratory and circulatory failure are ever simultaneous. That this is so is fortunate, as the administrator is forewarned by the cessation of respiration of any serious circulatory failure; the warning, however, should be quickly seized upon, especially in debilitated patients or those known to suffer from cardiac lesions.

The experiments made by a Committee appointed to investigate the merits of nitrous oxide[1] showed that in the case of healthy animals the following order of symptoms took place prior to death: The inhalation having been continued about two minutes after complete unconsciousness was attained, the respiration became slower and slower with an increasing interval

[1] *Trans. Odont. Soc.* vol. i. (New Series), p. 31. *Ibid.*, vol. v. (New Series), p. 11.

between every succeeding one, until they gradually ceased; during the same time the pulse became gradually weaker, but the heart's action could be felt for some time, generally about thirty seconds or rather longer, after respiration had terminated. In these experiments the Committee invariably found that, if they discontinued the administration before respiration had ended, the animal recovered without assistance; when respiration had ceased, but the heart's action had not done so, artificial respiration resuscitated the animal, but not otherwise; whilst, after cessation of the heart's action, no means that are known to us could restore animation.

Mr. H. J. Paterson [1] believes that the asphyxial element is due not to deficiency of oxygen, but rather to an excess of carbon dioxide in the blood, and gives evidence supporting this view.

Apoplectic fits and *hemiplegia* have been recorded during nitrous oxide administration; these conditions are too rare to need discussion.

The following case, however, recently came under the author's notice.

A patient, who had undergone nitrous oxide anaesthesia in the morning for the removal of five teeth, was observed to be suffering from hemiplegia five hours later.

Attention was drawn to this condition by the patient dropping her cup while having tea, and subsequent

[1] *West London Medical Journal*, 1899, p. 202.

examination showed that her left arm and leg were flaccid and apparently useless. Her hand-grasp on the left side was diminished, while on the same side ankle-clonus was well-marked. Sensation of pain was absent in the left arm, left leg, and left side of the body. There was some paresis on the left side of the face.

The patient was in a hospital at the time of this occurrence, having been delivered a few weeks previously of a six months' foetus, labour being induced on account of placenta praevia. Owing to this fact, the patient was carried to and from the ward on a stretcher, so that weakness of the leg was not observed immediately after the operation, although she complained soon after of difficulty in moving in bed.

The facial paralysis passed off on the following day and sensation and movement of the limbs commenced to return within three days. The sensory and motor functions of the limbs gradually improved and two months later the patient had fully recovered, except for some slight weakness in the left leg.

The nitrous oxide was given by the ordinary method, and nothing unusual noticed during its administration.

B. During the Operation Period.

The difficulties and dangers arising during this period are associated both with the operation and with the anaesthesia. In carefully following out the ordinary rules for the extraction of teeth, and those for administering an anaesthetic, accidents of all kinds can to a large extent be avoided. A tooth may drop from the forceps on to the root of the patient's tongue ; should this occur, the head must be immediately bent forward, and the operation discontinued until the tooth is recovered. Any attempt made to dislodge the tooth from this position with the finger may induce a deep inspiratory effort, resulting in the tooth passing down the air-passages.

When, however, the tooth lodges on the floor of the mouth or sulcus of the cheek, the finger may be swept round behind the foreign body, and the latter brought to the front of the mouth and removed, the head being held forward during these manipulations.

Blades of forceps, props, and gags may break, and any of these may pass over the back of the tongue through the isthmus of the fauces, and partially or completely obstruct the air- and food-passages.

Foreign bodies of the above nature are not likely to cause complete obstruction as in the case of a bolus of food impacted at the entrance of the gullet ; although, if unrelieved, inflammation would rapidly ensue, causing oedema of the glottis with complete blockage.

Obstruction to the Food-Passages. If the foreign body remains impacted in the *pharynx*, the mouth must be widely gagged open, and the finger thrust to the back of the pharynx, the foreign body sought for and removed. If this fails, a further attempt should be made with suitably curved forceps, aided by a good light. In most of these cases the nature of the foreign body will be known.

When asphyxial symptoms are urgent and increasing the air-passages must be immediately opened, and after the patient has been given relief, further attempts made to remove the foreign body.

Inversion, together with vigorous shaking of the patient, has been effectual in dislodging a foreign body, and should be tried both before and after opening the air-passages.

A heavy, smooth body, such as those mentioned, would in most cases find its way into the *oesophagus* and become lodged in some part of its course, giving rise to a fixed pain, aggravated by swallowing or coughing. Some amount of dyspnoea would be present, varying with the position and size of the object. The foreign body may be spontaneously ejected into the mouth or pass into the *stomach*.

An emetic, such as the subcutaneous injection of apomorphine hydrochloride ($\frac{1}{6}$ grain) may be permitted when the foreign body is known to be small and smooth (Cheyne and Burghard). Previous to the injection the practitioner should allow the patient to drink a glass of water, otherwise an empty stomach may simply contract on the foreign body.

The most common situations for foreign bodies to become arrested in the oesophagus are at its two extremities and where it is crossed by the aorta, *i.e.* the narrow parts of the canal. Should they safely negotiate these places, the pyloric end of the stomach is the next position likely to offer resistance.

Provided no further symptoms arise, the foreign body may be allowed to pass naturally. The patient should be kept quiet for a few days, and take food of a pultaceous nature.

Obstruction to the Air-Passages. Teeth are the most likely of the above-mentioned foreign bodies to pass into the *larynx*, excluding blood, pus, and saliva. If causing total obstruction, death may result, unless treatment be very prompt.

Partial obstruction is evidenced by a sudden sense of suffocation, marked cyanosis and dyspnoea, violent spasmodic coughing, and alteration in the voice.

During one of these expiratory spasms the foreign body may be ejected into the mouth ; if not, immediate preparations must be at hand for performing laryngotomy. An attempt is then made to bring the foreign body out through the laryngotomy wound or to dislodge it into the buccal cavity. A small, light body, *e.g.* portion of a tooth, may become lodged in the ventricle of the larynx. This will be indicated by the shortness of the intermissions between the attacks of spasmodic coughing, and requires a high tracheotomy or laryngotracheotomy, followed by dislodgment of the foreign body from below.

If the foreign body becomes lodged in the *trachea* it may shift its position with respiratory movements, causing spasmodic and urgent attacks of coughing, associated with dyspnoea. An extensive low tracheotomy should be performed, and the edges of the wound kept well open, in the hope of the foreign body being expelled during an attack of coughing.

Should it have passed into one of the *bronchi*, it will give rise to a dull pain behind the sternum associated with shortness of breath, cough, and diminution of breath sounds; later, collapse of that portion of the lung supplied by the affected bronchus, producing dulness over a corresponding area.

The right bronchus being the larger, and the spur formed at its commencement deflected to the left of the middle line, is consequently more often the recipient of foreign bodies.

Irritation and inflammation follow the retention of a foreign body in a bronchus, and an abscess has been the means by which a foreign body has become loosened and expelled during a fit of coughing, or recovered externally by the empyema making its way towards the chest wall.

Within recent years a direct method of diagnosing and removing foreign bodies from the air- and food-passages by bronchoscopy and oesophagoscopy respectively has been advocated, and many successful cases have been reported.[1] For these methods to be successful it is important to undertake the extraction at an early period.

[1] D. R. Paterson, *British Medical Journal*, Aug. 18, 1906, and Feb. 8, 1908.

For the technique of these operations and the treatment of foreign bodies impacted in the food- or air-passages, the reader is referred to some work on surgery, as only the emergency treatment for these conditions can here be referred to.

Loosening or dislodgment of a tooth. A tooth may be loosened or dislodged in introducing a gag. Unless the tooth was previously loose, this is generally an avoidable accident, and usually results from the gag not being inserted sufficiently carefully or having been placed in the front of the mouth. By inserting a gag in the front of the mouth one or more of the incisor teeth may be splayed out or entirely dislodged from their sockets and a similar accident may occur through the use of a central prop. The loosened or dislodged teeth must be immediately reinstated, in the latter case after previously cleansing.

The insertion of a gag may also be responsible for *bruising of the lips, gums, or other adjacent soft parts.* the first of these accidents usually occurs through the lower lip being insufficiently depressed before the introduction of the gag. The lip gets carried over the lower teeth, and crushed on these when the gag is opened.

Another accident attendant upon extraction of teeth, more especially under anaesthesia, is *dislocation of the mandible,* and in these cases it is almost invariably bilateral. The contributing factors to this accident are muscular relaxation and the presence of a prop or gag between the teeth forming a fulcrum. While the mouth is kept widely open by a prop or gag in the molar region, the condyle of the jaw is partly resting on the eminentia articularis. In this position it requires but little force if the condyle of the jaw be depressed and its capsule stretched, as in extracting a lower back tooth (*i.e.* posterior to the fulcrum), for the condyle to be further displaced on to this eminence, when a sudden contraction of the external pterygoids, or any forward movement conveyed to the jaw by the operator, might suffice to complete the dislocation.

Apart from anaesthesia, dislocation may occur when a lower tooth, generally a posterior one, is being removed, and occasionally occurs under quite trivial circumstances, *e.g.* on protruding the tongue, widely opening the mouth, yawning, etc. But under these conditions there is generally some pathological condition of the temporo-mandibular joint present, *e.g.* laxity of its capsule (subluxation).

A dislocation may not be apparent as long as the prop or gag remains in the mouth, and frequently it is not until the patient returns to consciousness and the prop or gag is removed that inability to close the mouth is noticed.

The condition is then easily diagnosed; the patient becomes greatly alarmed if it be the first time dislocation has occurred, and will ejaculate and point to his mouth, which remains partly open, the lower jaw projecting downwards and remaining fixed. The condyle can be detected in a false position, and a hollow can be both seen and felt in front of the tragus. The angle of the jaw passes backwards from the condyle, due to the obliquity of the ascending ramus. The coronoid process can be detected below the anterior part of the zygoma on bimanual examination. Later, saliva may be noticed dribbling over the lower lip, owing to difficulty and pain on swallowing.

As the capsule is not torn in this form of dislocation, the jaw is generally easily reduced by depressing the condyle to below the level of the eminentia articularis, the attachment of the temporal muscle to the coronoid process acting as a fulcrum, after which the internal pterygoid, masseter and posterior fibres of the temporal muscles will immediately draw the jaw into its proper position.

This manipulation is best carried out by standing in front of the patient, who should be seated. The thumbs are well wrapped round with thick napkins, or the corner of a towel to a point beyond that enclosed by the lips. Pressure is now exerted with the thumbs in a downward and slightly backward direction, as far back in the molar region as possible ; at the same time the fingers should be spread out under the chin, and exert pressure in an upward direction, as soon as the condyle is felt to be disengaged. As a rule, however, as soon as this stage is reached, the jaw is violently retracted into its normal position by its muscular attachments ; and it is in this part of the process that the thumbs are liable to be crushed if not protected.

Other methods have been suggested, *e.g.* the placing of corks or wooden blocks between the molar teeth and forcibly elevating the chin. Under these conditions the fulcrum is formed by the artificial wedge used, and for this reason the method is not to be recommended. The attached temporal muscle forms a better fulcrum, it is not absolutely rigid, and is thus capable of conveying to the fingers the amount of force that is being applied, and how much it is desirable to employ.

In cases of unilateral dislocation, the lower jaw is directed towards the side opposite to that on which the displacement exists, and there is a hollow present in front of the tragus on the injured side, which becomes noticeable on comparing the two sides. The jaw is not so widely opened, and allows of a little movement by means of which the position of the dislocated condyle can be detected. Most of the other signs are present as before, their modification depending upon the unilateral condition present.

The reduction of a unilateral dislocation is carried out on precisely similar lines as when complete, except that the force exerted by the thumbs is applied to the injured side only.

The further treatment of such cases consists in giving support to the jaw and preventing its full range of movement, and this may be temporarily accomplished by means of a four-tailed bandage.

Obstruction of the air-passages by the operator. Should the operator depress the jaw, force back the tongue or unwittingly obstruct the air-passages in other ways while extracting teeth, the patient will become cyanosed; especially if the obstruction occurs directly after the removal of the face-piece or during a continuous administration of nitrous oxide.

This temporary cyanosis will usually pass off on allowing the patient one or more full breaths of air, and the operation may then be resumed. Apart from these, to some extent avoidable causes of obstruction, the patient may suffer from impediment to free breathing owing to enlarged tonsils, adenoid growths, or tumours and swellings pressing externally on the air-passages or growing from their lining membranes. All these conditions introduce a risk of asphyxia, which can be greatly minimised if the anaesthetist is cognisant of their presence.

C. During the Recovery Period.

Some of the difficulties and dangers occurring during this period have already been stated in the preceding pages, and only those occurring later, and known as "**after-effects,**" need now be mentioned.

Recovery from nitrous oxide in the sense of a return to consciousness, commences as soon as the inhaler is removed and air is permitted to enter the air-passages, but its effects do not always pass off quite so readily.

Some patients express a feeling of *exhilaration* after nitrous oxide, while others complain of *lassitude* and *depression*. In a few recorded cases, *melancholia* and *mania* have followed the administration of nitrous oxide, but in most cases these have been patients of weak intellect or neurasthenic. *Headache* and *giddiness* may be complained of and last throughout the day, the former is occasionally very severe and accompanied by general malaise.

Transient *loss of taste and smell* have been notified in a few instances, also a temporary *albuminuria* and *glycosuria*. These conditions have so directly followed the administration of nitrous oxide that there appears to be without doubt some causal relation.

Luke records the occurrence of a "*cataleptic condition*" following a gas administration, and we have likewise seen this condition ensue towards the end of an anaesthesia in men and more frequently in women. We believe this to be an hysterical manifestation, and, although alarming when first met with, the phenomena become well recognised on subsequent occasions. Most of these patients have perfectly recovered in ten to fifteen minutes after the administration is concluded and are unaware that anything untoward has happened.

If the patient should feel *faint*, smelling salts may be held to the nose, or the patient may be given an ether draught or a little brandy. The room should be warm and appropriately ventilated, according to the weather, and the patient allowed to remain in the chair or on a sofa until he has sufficiently recovered to get up without assistance. For the rest of the day the patient should remain quietly at home and avoid exertion.

Syncope is more common in children, and in its slighter degrees seldom requires any other treatment beyond allowing the child to lie down for a few minutes.

As regards food, patients can usually be safely left to their own desires, provided that food is not taken directly after the administration. Liquid or soft food will usually be preferred by the patient whilst the gums remain tender, and an adult will avoid all but the plainest food, as long as there is any tendency to *nausea* or *vomiting*. A cup of weak tea is often acceptable to the patient, and may be taken about half an hour or so after the operation.

The " after-effects " of nitrous oxide anaesthesia have been fully considered here, so as to save a large amount of repetition in the subsequent chapters.

Nitrous Oxide and Oxygen.

The Apparatus.

The apparatus employed for this combination of gases is necessarily more complicated than that for nitrous oxide alone (see fig. 13).

A double india-rubber bag is required for containing the two gases, each bag communicating by means of rubber tubing with its respective cylinder; for compactness these tubes are frequently placed one inside the other, and in some forms of apparatus the rubber

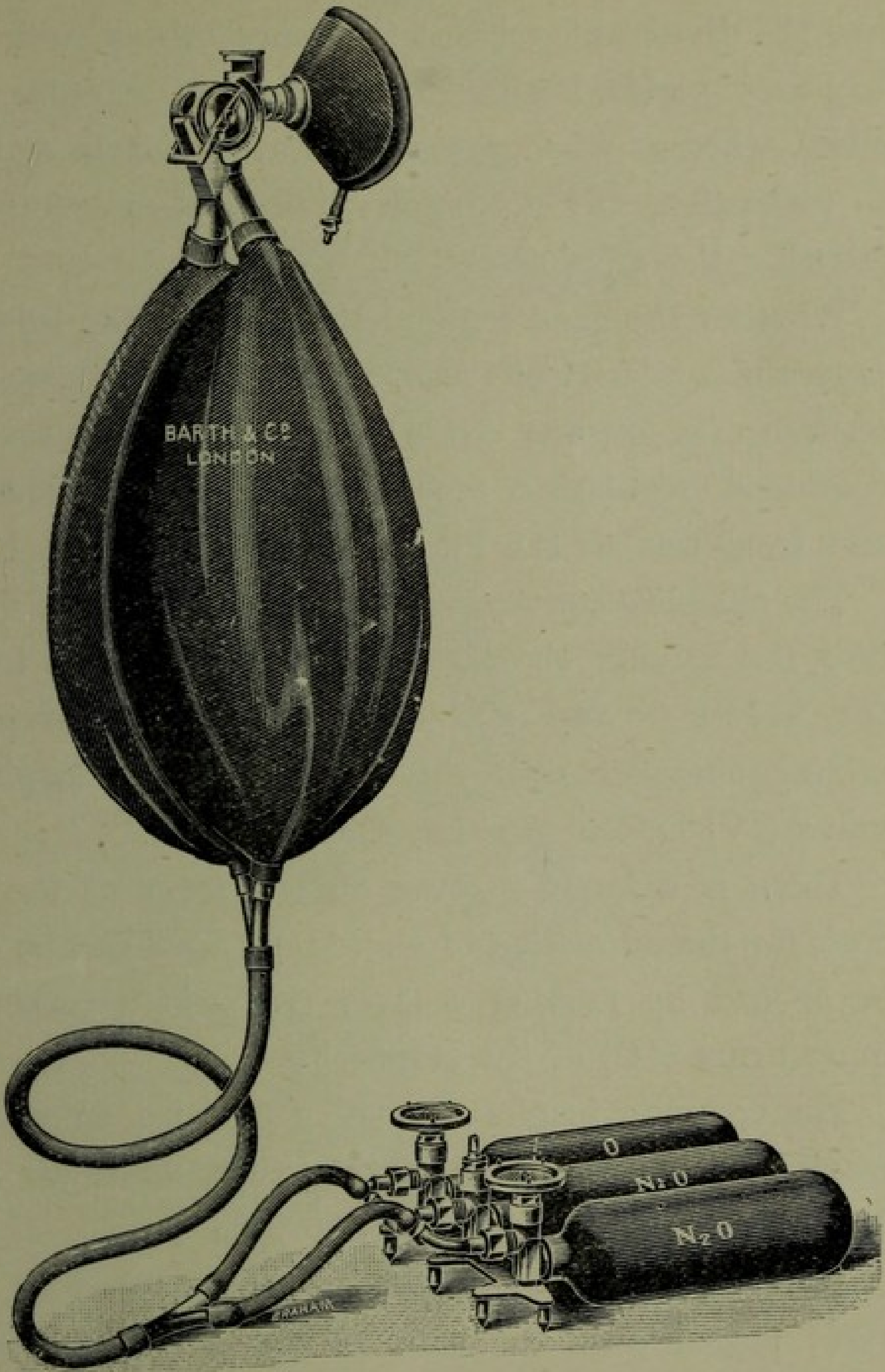


Fig. 13.—Hewitt's Apparatus for Administering Nitrous Oxide and Oxygen.

bags are similarly adapted; but such an arrangement has the disadvantage that the inner rubber tubing and bag may perish, leading to leakage and mixture of the gases, whereas when these parts are separate and open to inspection, any defect can be remedied before commencing the administration.

Whether the gas-bags and their connecting tubing be separate or placed one inside the other, the gases they contain, *i.e.* nitrous oxide and oxygen, are led to a combined regulating stopcock and mixing chamber, and from this to the inhaler (see figs. 14 and 15).

The channels conveying the nitrous oxide and oxygen into the mixing chamber are protected with inspiratory valves (*iv* and *iv'*), and the gases after leaving the mixing chamber pass through a common inspiratory valve (IV) before reaching the face-piece.

There is a large opening on the front of the stopcock for the admission of air (AH). This can be closed or opened by moving a lever (H), which rotates the inner drum (ID) of the stopcock.

The common inspiratory valve likewise serves as an inspiratory valve to the air aperture, when air is admitted through the stopcock.

The stopcock is completed by an expiratory valve (EV) placed over the channel connecting the mixing chamber with the face-piece.

No arrangement exists in any of the present forms of gas and oxygen apparatus for re-breathing into the gas-bag, so that the anaesthetist must take due

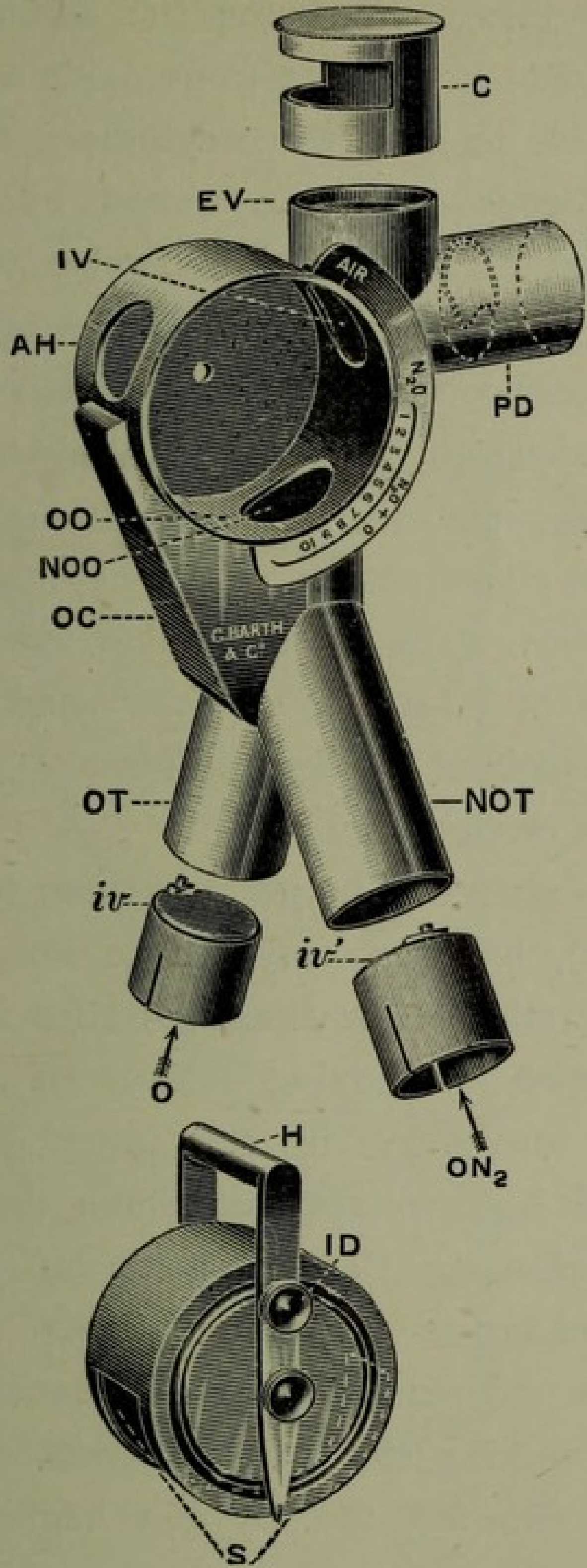


FIG. 14.—THE REGULATING STOPCOCK AND MIXING CHAMBER SHOWN IN DETAIL.

For full description see *Anaesthetics and their Administration*, by Sir F. W. Hewitt, 1907, pages 307, 308, 309 and 310.

precautions before commencing the administration to have a sufficient supply of nitrous oxide at hand.

It is desirable to have three cylinders, two of which containing nitrous oxide are united by a Y-shaped union, and led off by means of rubber tubing to the nitrous oxide bag, the third cylinder containing oxygen is similarly connected with its respective bag. The separate cylinder may be placed above or on a line with the other two cylinders, according to individual preference, but in either case the three cylinders should be of a similar size. The nitrous oxide cylinders should preferably be of 50-gallon capacity, and the oxygen cylinder, although of the same dimension, will contain but 15 gallons of that gas.

The oxygen after leaving its bag passes to the oxygen chamber (OC), but can only escape into the mixing chamber when the perforations (OO) for its admission are thrown open by moving a lever (H). This lever controls the movement of the inner drum of the stopcock, and by revolving the inner drum, the ten perforations allowing the admission of oxygen into the mixing chamber are consecutively opened; by reversing this movement these perforations are shut off from the mixing chamber. Nitrous oxide is prevented from entering the oxygen bag, and oxygen from entering the nitrous oxide bag by the interposition of valves between the respective bags and the mixing chamber.

By means of a supplementary stopcock, the last of

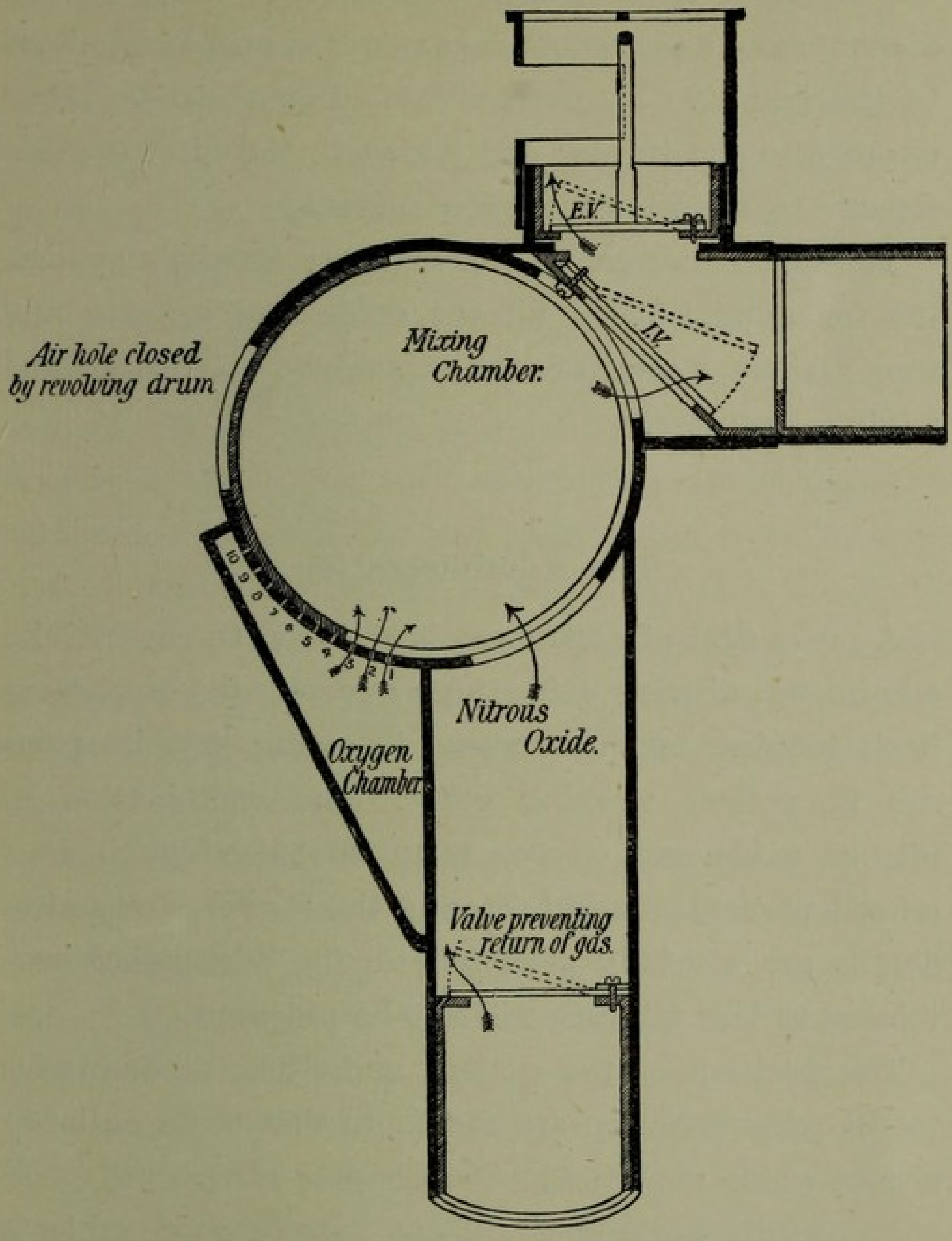


FIG. 15.—SECTION THROUGH STOPCOCK OF HEWITT'S NITROUS OXIDE AND OXYGEN APPARATUS.

Showing nitrous oxide and "3 °/₀" of oxygen (*i.e.* through 3 holes) being admitted to the mixing chamber.

the series of holes can be increased to a far greater diameter and a corresponding amount of oxygen admitted to the inhaler. By such means oxygen can be introduced into the inhaler and added to the nitrous oxide stream to almost any desired extent.

The figure reproduced above shows Hewitt's apparatus for administering nitrous oxide and oxygen, and the various parts of the combined stopcock and mixing chamber.

The Administration.

A great deal of experience is required to successfully administer nitrous oxide and oxygen, the apparatus itself requires much attention in seeing that its parts are in perfect working order. The combination of nitrous oxide and oxygen must be looked upon as a refined method of administering the former, and unless details are carefully attended to, the advantages pertaining to this mixture will not be procured.

The position of the patient and other preliminaries to the administration are similar to that of an ordinary nitrous oxide anaesthesia (see Chapter III.).

Powerfully built men are not usually good subjects for this form of anaesthesia ; whereas for children and delicate people or those advanced in years it is a most satisfactory anaesthetic.

A thick growth of hair about the face or an edentulous condition of the jaws may prevent the close adaptation of the face-piece, and give rise to difficulty, owing to the entrance of air during the administration.

The indications for nitrous oxide and oxygen have already been considered in Chapter II. Speaking generally, the type of subject requiring a free supply of air during an ordinary nitrous oxide administration is a good subject for nitrous oxide and oxygen.

The relative proportions of nitrous oxide and oxygen can only be learned by experience; suffice it to say here that 6, 7, and 8 per cent. of oxygen may be regarded as the maximum of this gas required for men, women, and children respectively. Very rarely is it necessary to administer over 10 per cent. of oxygen for a dental case; although the apparatus is capable, by means of the supplementary stopcock, of administering three times that amount.

The perforations do not strictly correspond to percentages, as the precise amount of oxygen entering the inhaler depends upon other factors besides the actual size of these holes. The distension of the bags and their relative position to one another are factors which will modify the amount of oxygen entering the inhaler. Each apparatus will be found to vary slightly in the amount of oxygen let through by the perforations; but these variations will remain constant for the apparatus in use, and designating the amount of oxygen employed in terms of percentages is merely a convenience.

Those suffering from the various forms of anaemia or whose oxygen deprivation depends upon the impairment of their respiratory mechanism, *e.g.* bronchitis, pleurisy, phthisis, asthma or emphysema require a free supply of oxygen.

Induction of Anaesthesia.

The induction of anaesthesia with nitrous oxide and oxygen is carried out as follows:

The bags are half-filled with their respective gases and the face-piece adjusted. The patient is first allowed two or three breaths of air, the inhalations escaping through the expiratory valve, as in an ordinary gas administration. The indicator is then turned to N_2O, the patient now inhaling pure nitrous oxide and exhaling through the expiratory valve as before. After a breath or two of pure nitrous oxide, the indicator is moved to '2' or '3' on the oxygen scale, the patient now inhaling this percentage of oxygen in addition to the nitrous oxide previously inhaled.

It is usually recommended to commence the administration with nitrous oxide and 2% of oxygen, but we are in favour of first allowing the patient two or more breaths of pure nitrous oxide, for the reason that the residual air in the lungs contains its own oxygen at this period and requires no further dilution.

After every three or four breaths the indicator may be moved on a point, until perhaps registering '5,' '6,' or '7' on the scale, when its onward or backward movement at this or an earlier period will be guided by the circumstances present. The indicator should be moved more rapidly in children, delicate and anaemic subjects, or those debilitated by age and disease, until the optimum point of oxygen is reached.

Phonation, struggling, or the presence of purposeful movements are indications that the patient is receiving too much oxygen; whereas cyanosis, stertor, and muscular twitchings are indications for increasing the amount of oxygen. Apart from these signs, the anaesthetist must be guided by the age, physique, and temperament of the patient, as in the administration of all anaesthetics.

The admission of oxygen is determined chiefly by the patient's colour and respiration, much in the same way as when administering air with nitrous oxide.

Children, anaemic and delicate subjects require a larger percentage of oxygen than those more advanced in years or in robust health; the reason for this being that the amount of oxygen already combined with the colouring matter of the blood in the form of oxyhaemoglobin is greater in the latter than in the former type of patient.

The necessity for suddenly increasing or diminishing the amount of oxygen is an indication that the administrator is not observing the varying phases of anaesthesia, or that he is unable to interpret their physiological meaning.

The indicator may be kept stationary when a percentage of oxygen has been determined favouring quiet, but audible and regular breathing, and the administration continued with this percentage until full anaesthesia has been attained.

During the administration the two bags must be kept as far as possible of an equal size, or else the amount of oxygen entering the inhaler cannot be gauged.

It is rarely necessary to replenish the oxygen bag during a dental administration, so that after filling it to the required extent the oxygen bottle may be firmly shut off. The inhalation period of nitrous oxide and oxygen is about one and a half to two minutes or roughly twice that of nitrous oxide by itself, and the resulting available anaesthesia may be said to be about fifteen seconds or more longer than that derived from nitrous oxide.

Signs of Anaesthesia.

The signs of anaesthesia are not so apparent as when nitrous oxide is administered by itself, the cyanosis and stertor of the latter being absent.

Regular breathing, of a soft snoring character, loss of the conjunctival reflex, fixation of the ocular globes and muscular relaxation are the guiding principles as to when anaesthesia is present.

The soft snoring breath-sounds are produced by a vibration of the soft palate owing to paresis, and are distinctly recognisable from the harsh "snorting" sound known as stertor.

The pupils usually remain of a moderate size, so that no reliance can be placed on them as a guide. Oscillatory movements of the eyeballs (nystagmus), usually in a vertical direction, is not uncommonly observed as anaesthesia approaches; later the eyes become fixed. The corneal reflex is but rarely lost in the short administration necessary for a dental operation.

The anaesthesia obtained by nitrous oxide and oxygen is slightly deeper than that obtained by the former gas alone, reflex struggling and screaming are therefore more in abeyance.

Return of consciousness usually first makes itself apparent by some voluntary movement on the part of the patient, and as hearing is the first of the senses to recover, the movement in generally is response to some afferent stimulus received through this channel.

The patient's eyelid should be raised, and the administrator should note any voluntary movement of the eyeball. A reflex dilatation of the pupil with the extraction of each tooth can often be observed; this occurs during both the conscious and unconscious state of the patient. The afferent impulse arises through stimulation of a pressor nerve, the fifth in the case in question, whilst the efferent channel through which is produced the dilated pupil, is the sympathetic; the centre for this reflex arc is probably in the medulla. Similarly, in the case of dyspnoea, the afferent channel is represented by the vagus, and the efferent path, or rather one of the efferent paths, is the sympathetic, producing the dilated pupil and prominent eyeball indicative of, among other signs, inefficient aeration of the blood. The prominence of the eyeballs is due to contraction of the unstriped muscle in the capsule of Ténon.

After-Effects of Nitrous Oxide and Oxygen.

The administration of nitrous oxide and oxygen, requiring a special apparatus and the skill of an expert to procure its advantages, has so far been left chiefly in the hands of the specialist, and has not been exploited by those unfamiliar with nitrous oxide anaesthesia.

The advantages to be obtained by the use of nitrous oxide and oxygen are the absence of cyanosis, stertor, and jactitation. The production of a quieter and slightly longer anaesthesia than that obtained by nitrous oxide alone. Disagreeable dreams are less frequent, and the operator is less likely to be embarrassed by tonic and clonic contraction of muscles, which in the case of the jaw greatly hinder his manipulations.

The disadvantage of this method is the more complicated apparatus required and the skill necessary to obtain the best results from its use. It is apt to alarm nervous patients, and is more liable to get out of order than an ordinary gas apparatus.

An anaesthesia closely approaching that of nitrous oxide and oxygen in its favourable properties can be obtained by substituting air for the latter. The anaesthesia derived from nitrous oxide and air is quiet and practically of the same duration, the asphyxial symptoms are reduced to a minimum, and the apparatus for carrying out the administration is far simpler.

The after-effects of nitrous oxide and oxygen are much the same as those of nitrous oxide and air when the inhalation periods are of similar duration.

Recovery from anaesthesia induced by nitrous oxide and oxygen is less satisfactory than from the former alone. Pallor and faintness are rather more common than with nitrous oxide. Nausea or actual vomiting are also more frequent complications, and headache is more severe and persistent. The slightly increased after-effects do not appear to be entirely due to the more prolonged period of induction, necessitating a larger intake of nitrous oxide, as with the continuous administration of nitrous oxide, the "after-effects" are certainly not increased proportionately to the amount of nitrous oxide inhaled.

Dr. Hewitt has noted three cases of transient maniacal excitement immediately after the administration in patients who were powerfully built men.

Mr. Edgar Willett records a case in which the patient remained practically asleep for four days after a short administration of nitrous oxide and oxygen.

On the other hand, it must be stated that this is the only anaesthetic in which no fatality has as yet occurred, although this combination has been in frequent use for a quarter of a century.

Continuous Administration of Nitrous Oxide.

This method has been prominently brought before the profession during the last thirteen years, and its limits of usefulness have by no means yet been reached. Various modifications, both in apparatus and in the methods of employment have evolved since its introduction, in 1898, by Alfred Coleman.[1]

The two main methods employed for maintaining nitrous oxide anaesthesia during operations on the mouth are effected by either conveying the gas through a nasal cap, or by a tube which is passed into the patient's nose or mouth ; the latter two methods are associated respectively with the names of Hilliard [2] and Coxon.[3]

Most of the modifications in the apparatus used for the continuous administration of nitrous oxide have been made in that form of inhaler which employs a nasal cap.

The nasal passages are physiologically adapted for warming the inspired air by their uneven surface and free blood supply and for testing its purity by the sense of smell. The effect of a stream of cold gas entering the mouth is to condense the moisture in the expired air, which, issuing like a cloud of steam, obscures the surgeon's view.

Mr. H. J. Paterson introduced lateral tubes to the nose-piece in place of the single central tube used by

[1] *Transactions of the Society of Anaesthetists*, March 17, 1898.

[2] *Ibid.* April 21, 1898. [3] *Ibid.* March 17, 1898.

Coleman, and made other improvements which brought the apparatus from an experimental into a practical form.

Other modifications may be said to consist in the shape of the nasal cap, and in the presence or absence of the following features:

An expiratory valve on the nasal inhaler;

An aperture for admitting air on the nasal inhaler;

A communication between the mouth-cover and the nitrous oxide supply, and

The presence or absence of rubber pads around the circumference of the nasal and oral inhalers.

The Apparatus.

The inhaler, devised by the author a few years ago, and which he has since modified (see fig. 16), consists of a nose-piece NC, bearing an expiratory valve EV, conveying tubes and adjusting clamp SC, and a two-way stopcock St-C, the remaining parts are those of an ordinary nitrous oxide apparatus, with the addition of a mouth-inhaler M, fitted with an expiratory valve EV, and a bag compressor C^2.

The Barth triple-union with stand for three cylinders forms a useful equipment for hospital work, two of the cylinders containing nitrous oxide being connected by a Y-shaped union with the nasal apparatus.

For a portable apparatus, two fifty-gallon cylinders united by a Y-shaped union will be found convenient.

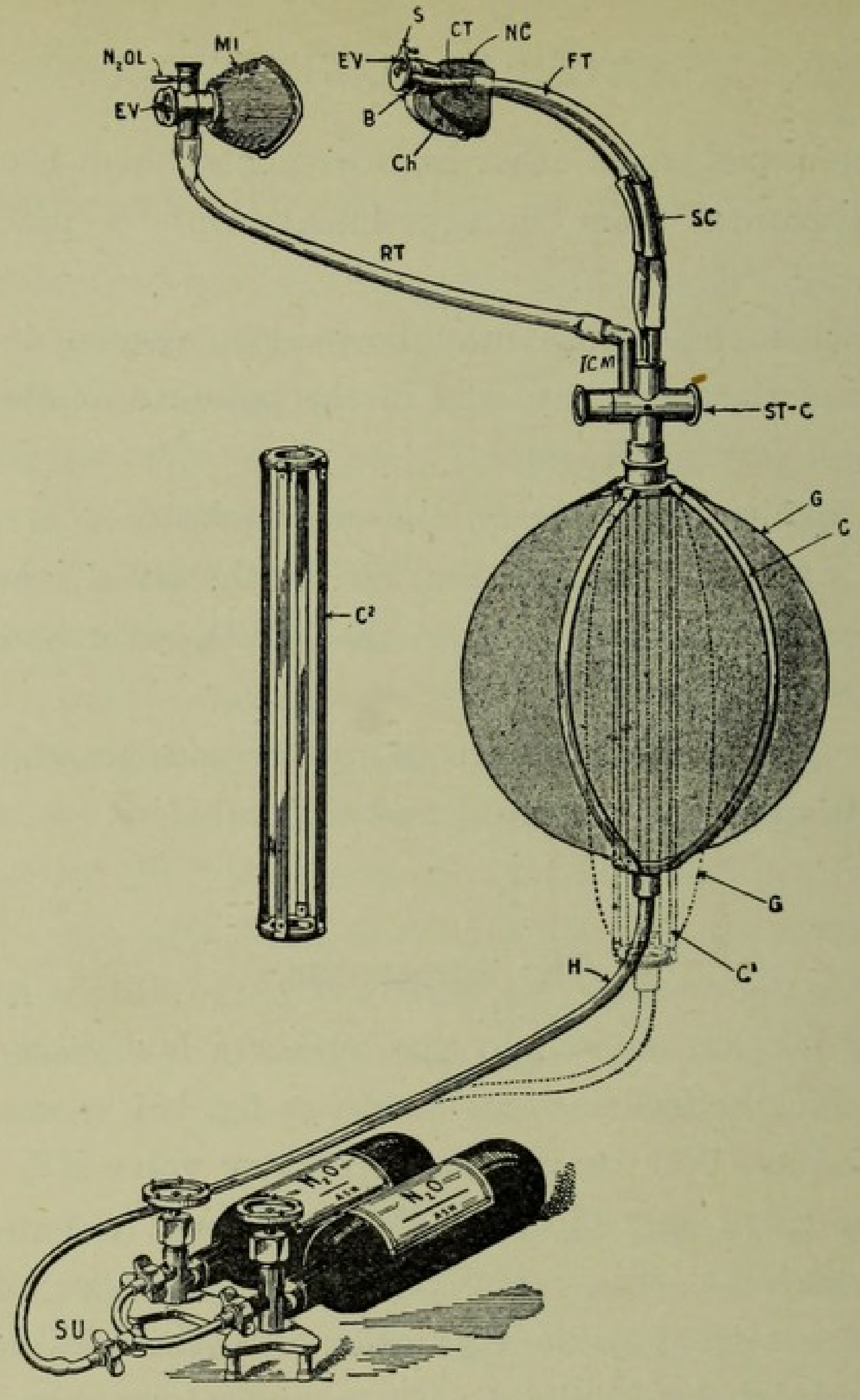


FIG. 16.—COLEMAN'S APPARATUS FOR NASAL ADMINISTRATION OF NITROUS OXIDE.

NASAL INHALER.

- **EV.** Expiratory Valve.
- **B.** Body.
- **Ch.** Channel.
- **S.** Shutter.
- **CT.** Conveying Tubes.
- **NC.** Nose-Cap.
- **FT.** Flexible Tubes.
- **SC.** Sliding Clamp.

ORAL INHALER.

- **MI.** Mouth Inhaler.
- **N_2OL.** Nitrous Oxide Lever.
- **EV.** Expiratory Valve.
- **RT.** Rubber Tubing.
- **ICM.** Inhaler Connection Mount.

- **ST-C.** Stopcock.
- **G and G^1.** Gas-Bag distended and empty.
- **C, C^1 and C^2.** Gas-Bag Compressor distended and at rest.
- **H.** Tubing to Gas Stand.
- **SU.** Single Union connected to Gas Stand.

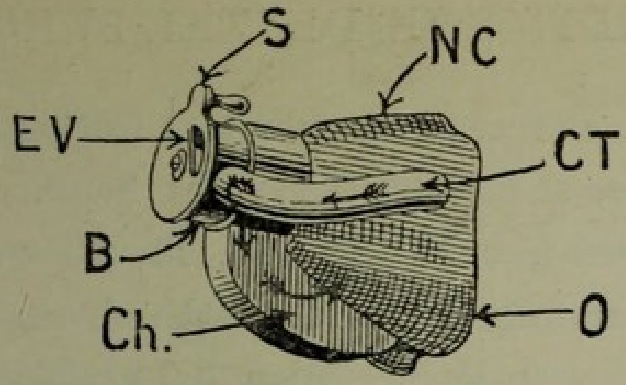


FIG. 17.—COLEMAN'S NASAL INHALER.

EV. Expiratory Valve. **B.** Body.
Ch. Channel. **S.** Shutter.
CT. Conveying Tubes. **NC.** Nose Cap.
O. Orifice through which Nitrous Oxide emerges.

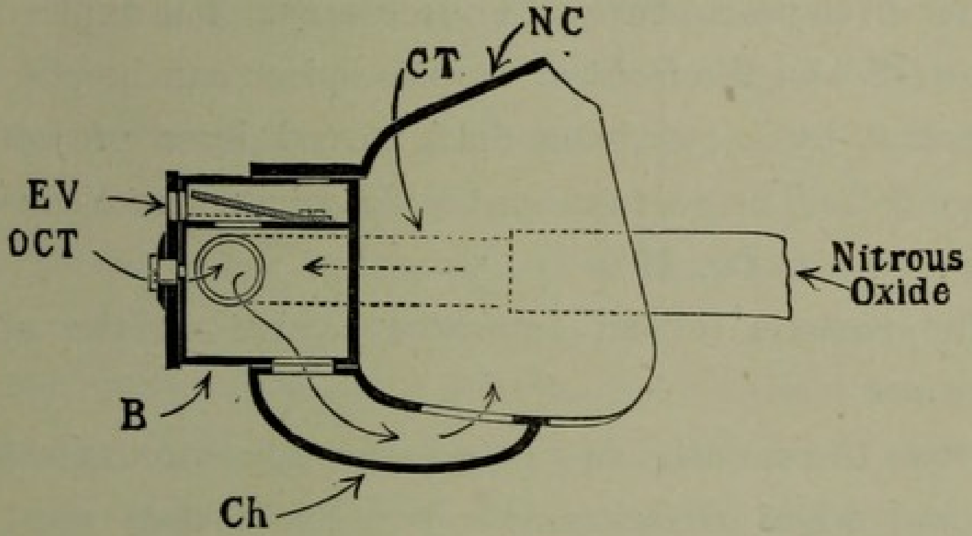


FIG. 18.—SECTION OF COLEMAN'S NASAL INHALER.

NC. Nose Cap. **EV.** Expiratory Valve.
Ch. Channel. **CT.** Conveying Tube.
OCT. Opening of Conveying Tube into Body or Main Chamber.
B. Body or Main Chamber.

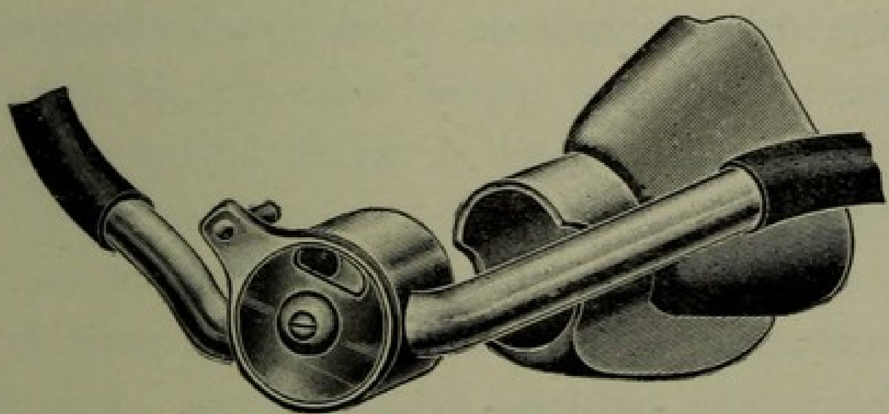


FIG. 19.—COLEMAN'S NASAL INHALER.

Showing Conveying Tubes with Expiratory Valve-mount detached from Nose Cap.

In either case, one reserve cylinder, fully charged with nitrous oxide, should always be at hand.

(1) The *nose-piece* (see NC figs. 16, 17, 18 and 19), which has been carefully adapted to the shape of the nose, is fitted with two lateral tubes (CT), which open into a chamber (Ch), under the nostrils, and thus convey the gas directly to the nose. The snug fit of the nose-piece and the position of its openings under the nostrils render an india-rubber pad unnecessary. The expiratory valve (EV) on the front of the nose-piece can be put out of action by a revolving disc, moved by a projecting flange (S). The valve-mount is detachable for cleansing purposes (see fig. 19).

The reasons for an expiratory valve on the nose-piece are:

First, the mouth only acts as an efficient expiratory channel while consciousness persists, for as soon as anaesthesia approaches the soft palate and tongue lose their muscular tone (paresis), and tend to meet partly or completely shutting off the buccal cavity from that of the pharynx. Under such circumstances expiration will take place around the nose-piece, or in any other direction where less resistance is encountered.

The shutting off of the oral from that of the nasal pharynx will be more complete in those patients with long soft palates and large flabby tongues. This change from "naso-oral" breathing to "to and fro" nasal breathing as anaesthesia approached had previously been observed,[1] but its anatomical explanation was pointed out by Mr. J. F. Trewby, who has made some very careful observations on the part played by the soft palate in nasal administration of nitrous oxide.

A second reason for the employment of an expiratory valve on the nose-piece is for the patient's comfort. Patients can expire more freely and comfortably when allowed to do so through the nose, as well as the mouth, than when only permitted the latter channel.

The employment of a "valved" nose-piece likewise avoids the necessity for instructing patients to expire through the mouth, as they can now choose either channel with almost equal advantage to the anaesthetist.

The addition of an expiratory valve necessitates a slightly more bulky nasal-inhaler, but this is somewhat compensated for by the less projecting lateral tubing.

(2) The *stopcock* (figs. 16, ST-C and 20) consists of an outer and inner cylinder. The inner cylinder (fig. 20, I), which is graduated and open at one end, can be projected beyond either end of the outer cylinder (fig. 20, O) and, according to the position in which it is set, air (fig. 20, A), nitrous oxide (fig. 20, B), or a mixture of the two (fig. 20, C), can be delivered to the inhaler. This is brought about by dividing the inner cylinder into two equal chambers, and according to which chamber faces the inspiratory valve, nitrous oxide, air, or a mixture of the two is delivered to the inhaler.

[1] See *Nasal Administration of Nitrous Oxide*, by F. Coleman (published by Claudius Ash), 1908.

The movement of the inner cylinder controls the size of the apertures which admit the nitrous oxide and air ; both apertures are similar in shape and protected with a common inspiratory valve (see fig. 20), which prevents rebreathing into the gas-bag and allows a definite mixture of nitrous oxide and air to enter the inhaler.

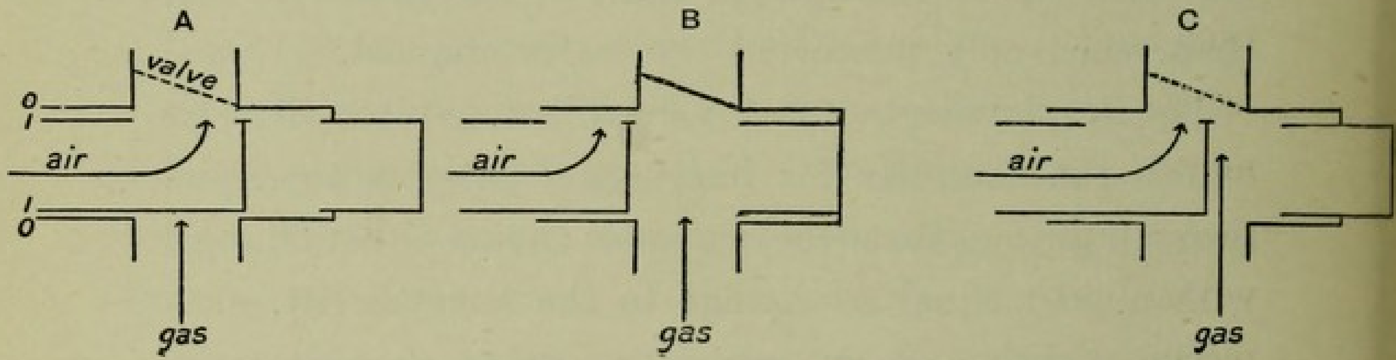


FIG. 20.—SECTION OF COLEMAN'S NASAL STOPCOCK.

Showing Inner Cylinder (I) in positions for admitting air (A), gas (B) and gas and air (C) to the inhaler.

This principle of employing a common inspiratory valve for controlling both the gas and air inlets to the stopcock has enabled the administration of fairly definite quantities of air with the nitrous oxide stream and under any pressure of nitrous oxide ; so that the inhalation of air by the mouth during the operation can be prevented by increasing the pressure of nitrous oxide from the bag with less liability of producing cyanosis.

The nitrous oxide in raising the inspiratory valve likewise permits the entrance of air, when the aperture for the latter is opened, as described in connection with the author's stopcock for an ordinary gas administration (see p. 28).

The stopcock is connected to the nose-piece by means of lateral rubber tubing, and to the gas-bag by a single rubber tube.

(3) The *conveying tubes* (fig. 16, FT) between the nose-piece and the stopcock are held in position, when they are adjusted on the head, by means of the sliding clamp (SC), and the clamp is kept where it is set by the weight of the gas-bag and tubing. A short curved piece of metal tube is interposed on each side between the nose-piece and the lateral rubber tubing, allowing the conveying tubes to exert their force in bringing the nose-piece evenly and firmly over the face.

(4) The *mouth-inhaler* (fig. 16, MI) is made entirely of metal except for the expiratory valve, which is removable. It is connected with the stopcock by means of a single rubber tube and by pressing or releasing a lever, nitrous oxide is admitted or shut off from the inhaler (see plate IV.). The inhaler has been carefully adapted to the shape that the mouth assumes when partly open, as with a mouth-prop *in situ*.

(5) The *bag-compressor* (fig. 16, C, C^1 and C^2) consists of two metal rings placed respectively above and below the gas-bag and serving to fix the extremities of the four narrow strips of metal, which encircle the bag. The empty bag is passed through the rings, and the stopcock adjusted to the neck of the bag in the usual way. As the bag becomes distended the metal

frame opens out over its surface, and, owing to the elasticity of the frame and its tendency to close in, a constant firm pressure is exerted on the contents of the bag.

The apparatus above described comprises some additional features, which were not possessed in the author's original form of apparatus, viz. an expiratory valve on the nose-piece, the special valve-seat in the stopcock, a bag-compressor, and the means of utilising the mouth-cover as an inhaler.

The advantages of this form of nasal inhaler are as follows:

(1) It is self-retaining and affords freedom to the anaesthetist, who is thus at liberty to insert a gag or to assist the operator in other ways.

(2) The metal nose-piece and mouth-inhaler are easily removed for cleansing, as the valve mounts are detachable and rubber-pads are avoided.

(3) The stopcock allows of the admission of fairly definite proportions of gas and air to the inhaler, and its movements are simpler than the ordinary tap-form of stopcock.

(4) The bag-compressor prevents over-distension of the gas-bag, and exerts a constant pressure on its contents. Under these conditions the mouth does not form such a ready channel for the inhalation of air during the administration.

(5) The induction of anaesthesia, when employing the mouth-inhaler, is similar to that of the ordinary

method of administration, except that separate inhalers are employed for the nose and mouth instead of a common one for this purpose. We are not in favour of the routine use of the mouth-inhaler for inducing anaesthesia, but it serves a useful purpose in dealing with refractory patients or those designated as "difficult" subjects for nasal administration of nitrous oxide.

Both these classes of patient diminish with the experience of the anaesthetist.

Some have found difficulty in manipulating the stopcock placed behind the patient and intervening between the nasal inhaler and the gas-bag, and prefer regulating the nitrous oxide at the nose-piece.

The objections to controlling the air entry at the nose-piece are: that it necessitates a more bulky inhaler, rendering its adaptation and stability less secure, a larger inhaler is necessarily more in the operator's way; and further, when the admission of air is controlled from the front of the patient, *i.e.* at the nose-piece, the operator is embarrassed by the anaesthetist's hands.

The advantages in being able to shut off the nitrous oxide and admit air at the nose-piece are: that the stopcock is in a more convenient position for the anaesthetist, although less so for the operator, and the effect of its manipulation can perhaps be better observed. A somewhat less important point is the fact that the patient receives air immediately the slot in the nose-piece is opened; whereas, when the air enters at a separate stopcock for this purpose, the intermediate tubing has first to be traversed.

Mr. Trewby's nasal inhaler carries out the principles of the author's apparatus and the administration is conducted much in the same way, except that certain modifications in the nasal and oral inhalers necessitate slightly different arrangements for inducing and maintaining anaesthesia.

The chief variations are:

The connection of the nasal and oral inhalers by means of a wide-bore flexible tube instead of connecting the latter directly to the gas-bag, and an aperture for admitting air on the nasal inhaler.

The mouth-cover or oral inhaler is capable of being swung to either side of the patient's face and this movement automatically cuts off its own supply of gas, as required when anaesthesia is obtained, and the patient is ready for operation.

During the maintenance of anaesthesia, air can be admitted at the top of the nose-piece, by depressing the angular metal mount, which serves the double purpose of carrying an expiratory valve and controlling the supply of nitrous oxide and air to the inhaler.

On opening the air-aperture in the nose-piece, that for admitting gas is closed; whereas, on closing the air-aperture gas is admitted to the inhaler. In intermediate positions the nasal inhaler is open to both air and nitrous oxide.

The mouth-cover takes its fit around the margins of the lips, and consequently is rather smaller than those forms which include these structures.

Mr. Trewby was the first to suggest and employ a bag-compressor, and the author has since made use of the same in a modified form, the modification allowing of more uniform compression.

Previous to the use of the bag-compressor, the pressure of gas was temporarily increased by squeezing the bag between one's knee and the chair, a crude and unsatisfactory means of obtaining the desired result.

Mr. Trewby has had the gas-bag brought forward, by means of an interposed hollow metal tube, suspended at its forward end to the arm of the chair and weighted at its posterior end to assist retention of the nasal cap, so that the bag can be better watched throughout the administration. Mr. Trewby has followed the author in the abandonment of rubber pads fitted to his inhalers.

The employment of a mouth-inhaler connected up to the nitrous oxide supply has obviated the occasional necessity of commencing the administration by the ordinary method, and, when anaesthesia is procured, of substituting the nasal inhaler for maintaining the same.

Mr. Trewby has drawn attention to two types of tongue and palate that may give rise to difficulty in the administration.

In one form the tongue is large and flabby, and this is associated with a long, pendulous, soft palate, so that the two structures are almost in contact with one another. During the inhalation of the nitrous oxide, the congestion of the tongue and soft palate may actually prevent expiration through the mouth, and unless there is an expiratory valve on the nose-piece or the apparatus permits of " to and fro " breathing into the gas-bag, the patient will become asphyxiated rather than anaesthetised.

In the second form, the tongue is firm and compact, and the soft palate short, so that there is a considerable space between these structures, allowing free inspiration of air when the mouth-cover is removed, so much so, that it may be difficult to supply an adequate amount of nitrous oxide through the nose-piece, even although the bag is fully distended.

To obviate this free inhalation of air through the mouth during the operative period, Mr. Trewby and Mr. Dinnis have designed a triangular shield, bearing an expiratory valve, and having a handle, bent out around the cheek so as to be out of the operator's way (see fig. 21).

The metal shield is introduced after anaesthesia has been procured, and is held against the anterior pillars of the fauces and rests on the base of the tongue.

Mr. Trewby has found this instrument especially useful in healthy adult men, and states that it likewise serves the purpose of preventing a foreign body from entering the larynx.

Dr. Kirkpatrick[1] had previously suggested introducing a sponge into the back of the mouth, so as to occlude, or limit, the air-way from it, and obtained some success by this means.

He now relies on increasing or diminishing the pressure of gas in the naso-pharynx for altering the position of

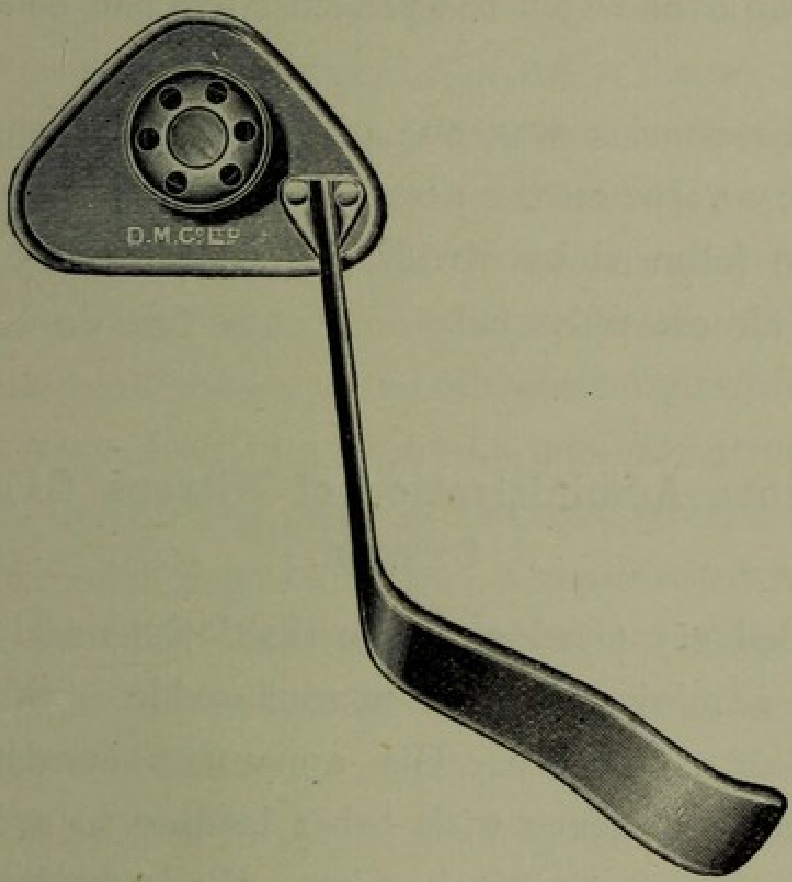


FIG. 21.—TREWBY-DINNIS ORAL SHIELD.

the soft palate, and so excluding or admitting air to the lungs. When positive pressure is required, the expiratory valve on the nose-piece is shut off, and the gas-bag is distended, whereas, when it is necessary to admit air by the mouth, the pressure in the bag is relaxed. Thus the soft palate is made to serve as an inspiratory

[1] *Medical Press*, July 16, 1902. T. P. C. Kirkpatrick, M.D.

valve in controlling the amount of air entering the lungs. Dr. Kirkpatrick advocates having the mouth closed during the induction period, so as to insure better nasal breathing, provided there is sufficient space between the teeth or gums for the subsequent introduction of a mouth-gag, otherwise he employs a small prop over which the patient's lips can be approximated.

Dr. Kirkpatrick was one of the first to employ an expiratory valve on the nose-piece, an advantage which was soon followed by Mr. Nash, of Ayr, and has since become almost universal.

Continuous Administration of Nitrous Oxide and Oxygen.

Mr. Bellamy Gardner has utilised the nasal method for the administration of nitrous oxide with definite quantities of oxygen. His apparatus consists of a Paterson's nose-piece with tubes leading to a Hewitt's gas and oxygen mixing chamber; the latter is fitted to a double rubber bag connected to the cylinders, and the apparatus is completed by a "valve-chimney" interposed between the nose-piece and the mixing chamber and a mouth-cover bearing an expiratory valve.

The rubber bag is a modification of that devised by Dr. Levy for employment with Hewitt's gas and oxygen apparatus, and consists of a smaller bag for containing the oxygen placed within a larger bag for the nitrous oxide, an arrangement which claims to render the pressure of the contained gases equal, provided that the oxygen bag be not distended. The valve-chimney is removable and reversible, and according to the position in which it is set, the apparatus may be used with a face-piece for an ordinary gas and oxygen administration or with a nose-piece for those cases in which it is desired to maintain anaesthesia for a longer period.

Mr. Gardner's apparatus is free from valves when the chimney is reversed, as employed for nasal administration, so that the method of re-breathing is permitted for inducing and maintaining anaesthesia.

The administration is commenced by allowing the patient 6 % of oxygen with the inhaled nitrous oxide, and this mixture of gases is re-breathed into the bag. The outer or nitrous oxide bag is replenished from time to time, the fresh gas from the cylinders taking the place of that absorbed or lost through the mouth, so that the outer bag remains fairly constant in size. Mr. Gardner advises that the nitrous oxide bag should be kept full, but not distended.

The percentage of oxygen is gradually increased up to about 15 %, during an inhalation lasting about a minute and a half, after which, as a rule, anaesthesia is complete.

At this stage the patient presents a normal colour with quiet nasal respiration, a sluggish corneal reflex and moderately contracted pupils, the frequency of the pulse is slightly raised, but its volume is good.

Anaesthesia is maintained much in the same way, as in the continuous administration of nitrous oxide and air, the oxygen taking the place of the air to obviate cyanosis and other asphyxial phenomena.

The special mouth-cover must be employed during the induction stage if the patient inspires too freely through the mouth, and in some cases additional pressure of nitrous oxide is required.

The oxygen bag is filled to the desired extent before the commencement of the administration, and rarely requires replenishing.

Should the cavity of the mouth become occluded from that of the pharynx, owing to the pressure of nitrous oxide forcing down the soft palate on to the tongue, or to a paresis of the soft palate during anaesthesia, " to and fro " nasal breathing will be assumed. The administrator should then diminish his supply of nitrous oxide and so reduce its pressure.

An apparatus that can be employed for two purposes has undoubtedly many advantages, and Mr. Bellamy Gardner's apparatus seems well suited for an ordinary gas and oxygen administration; but whether the full advantages derived from giving definite mixtures of gas and oxygen through the nose can be obtained, in the presence of the many adventitious factors associated with nasal administration, appears doubtful.

A discrepancy in the amount of oxygen which the patient is inhaling by the mouth must always remain a disturbing factor to any carefully regulated percentage of gases admitted through the stopcock, and such regulation must necessitate a rather complicated apparatus.

The objections to re-breathing the contents of the bag have been already mentioned under nitrous oxide (p. 54).

Mr. Trewby has recently contrived an arrangement by which oxygen can be admitted to the nasal inhaler. A small rubber bag (one gallon capacity) contains the oxygen, and this is connected to the inhaler by means of tubing, an inspiratory valve being interposed to prevent re-breathing into the oxygen bag. The oxygen bag, after being filled, is disconnected from its cylinder, and its contents are forced into the inhaler during anaesthesia, as the requirements demand. Pressing the bag opens the valve and allows the oxygen to enter the nose-piece.

Children slightly cyanosed under the continuous administration of nitrous oxide can be more readily restored to a better colour than when air alone is given.

Indications for the Nasal Administration of Nitrous Oxide.

The operations on the mouth, for which nasal administration is suitable, are chiefly those connected with the teeth and their surrounding parts, *e.g.* multiple or difficult extractions, the removal of pulps of teeth, the preparation of roots for crowns, the opening of antra or cysts, and the removal of small innocent growths.

For multiple extractions which present no special difficulties, but only require the element of time for their successful performance, this method has many advantages.

If the operator requires an anaesthesia probably longer than that procured from an ordinary nitrous oxide administration, he will be wiser in choosing an anaesthetic or a method of its employment capable of prolonging anaesthesia to the desired extent, rather than trusting to good fortune during the prescribed half minute or so of an ordinary administration or to the re-application of the inhaler with its disadvantages.

Young adults and middle-aged people, especially women, are usually good subjects for the nasal administration of nitrous oxide, and children of a placid and controllable temperament. We have anaesthetised many children of this type, requiring the removal of several temporary and permanent teeth with complete success.

Patients suffering from slight nasal obstruction or even with adenoids are often not unfavourable subjects for this form of anaesthetisation, for the reason that a stream of nitrous oxide under slight pressure will easily pass through the narrowed air-way. The expired air will less readily escape through the same channel, but owing to an associated high palate induced through habitual mouth breathing, the fauces become increased in height, so allowing in most cases a free expiratory channel through the mouth.

Deviated nasal septa, enlarged turbinate bones and nasal polypi are more likely to interfere with nasal breathing, especially when the overlying mucous membrane is inflamed, but these conditions do not necessarily contra-indicate the method. The patient's capability for nasal respiration can be tested in the way mentioned (see page 123) before deciding for or against this method of administration.

Contra-Indications for the Nasal Administration of Nitrous Oxide.

The contra-indications for the nasal administration of nitrous oxide are, generally speaking, those of nitrous oxide administered in the ordinary way (see chapter II.), and the general and local conditions that are unfavourable for this anaesthetic are in most cases still more unfavourable when the anaesthesia is prolonged.

It is often urged that the value of being able to maintain nitrous oxide anaesthesia during dental operations is likely to produce a deleterious effect on the operator, who, realising that he is no longer working under a strict time limit, is apt to lose the alertness in operating that it was formerly necessary to acquire, and that the student would be better taught to do as much as possible during a "single dose" anaesthesia, reserving the benefit of the longer anaesthesia for more advanced students or for special cases.

Alertness in operating is undoubtedly an advantage in restricting the period during which it is necessary to maintain the patient under anaesthesia, but on the other hand better extraction can be done if the operator is not strictly limited to time—the movements for loosening a tooth can be carried out more carefully with consequently less injury to the alveolus, less risk of fracturing the tooth and less after-pain.

The beginner must be taught to do a little, and to do it well, and this he can carry out to better advantage both to himself and to his patient, if the disturbing factor of time is as far as possible eliminated ; speed in operating will come with practice, but will be disastrous if attempted at too early a stage.

On the other hand, the author fully recognises that the type of anaesthesia maintained is frequently far from desirable, fluctuating between pronounced cyanosis and an anaesthesia so light that reflex movements are not in abeyance, although the patient may throughout be unconscious of pain.

The Administration.

Much the same applies with regard to the preparation of the patient as in an ordinary nitrous oxide administration. It is advisable that at least three hours should elapse between the patient's last meal and the operation; the meal in question may, within reason, be that which the patient is accustomed to take.

The same accessories must be again at hand, as in use for the ordinary method of nitrous oxide administration (see Chapter III.).

Before inserting a prop, it is desirable, except perhaps in the case of nervous patients, to briefly explain the advantages of the method about to be employed, and to let the patient see the apparatus. An intelligent patient will then grasp what is required of him, and be a help rather than a hindrance in the carrying out of the administration.

A patient's capability for nasal respiration may be tested by temporarily placing the mouth-cover in position and asking him to breathe, if under these circumstances respiration is free and unimpeded the anaesthetist may have every anticipation of a successful anaesthesia.

It has been suggested that the naso-pharynx should be gargled before commencing the administration ; this is a precaution that may be observed advantageously where much mucus is suspected. Condy's fluid and alum have been recommended for the purpose.

After cleansing the bag by passing a small quantity of nitrous oxide through the apparatus, the stopcock is shut off from the gas-bag, and the latter filled to a half or two-thirds of its capacity. The screw-valve of the cylinder is then lightly turned off.

The nose-piece is carefully placed in position, and the tubing is adjusted to the head by means of the sliding clamp, the clamp being kept where it is set by the weight of the rubber-tubing and gas-bag (see plate IV.).

The Induction of Anaesthesia.

After the patient has taken two or three inspirations of air through the nose-piece, and has become accustomed to his surroundings, the stopcock is opened to the bag and nitrous oxide is admitted to the inhaler. The patient now inhales nitrous oxide through the nose and exhales through the nose or mouth. As long as the patient continues to breathe in this manner there is no need to place the mouth-cover in position, and patients feel less burdened in its absence.

The mouth-cover is applied at the commencement of the administration only when it is desirable to rapidly produce unconsciousness, and in these cases it may also be advantageous to allow the nitrous oxide to flow into the mouth-cover, and so convert it into an additional inhaler. By pressing a lever on the mouth-cover, the latter is thrown into communication with the gas supply from the bag (see plate IV.). The method of inhalation is now similar to that of an ordinary administration, the only difference being that separate inhalers are used for the mouth and nose.

The bag requires to be replenished from time to time with fresh supplies of nitrous oxide by turning on the foot key, and to be kept as far as possible at a constant pressure of one-half to two-thirds of its capacity.

Evidence of excitement from oral breathing, or the entrance of air around the inhaler, must be overcome by increasing the pressure in the bag and placing the

PLATE IV.

Nasal Inhaler in Position for the Continuous Administration of Nitrous Oxide.

Fingers of right hand are shown manipulating the stopcock, and those of the left hand applying the mouth-cover with lever pressed down for admitting nitrous oxide. (Patient's head is too far reclined over head-rest.)

To face page 124.]

mouth-cover in position, and, if necessary, allowing nitrous oxide to flow into the mouth-cover.

The induction stage of nitrous oxide is but little prolonged by the use of the nasal method. Some patients appear to lose consciousness even more rapidly by the nasal than by the ordinary method of inhalation.

As a rule, consciousness is lost in from half a minute upwards, according to the mode of administration; thus, if the mouth-cover be applied throughout the induction, this period will be practically of the same duration as in an ordinary administration. The period of unconsciousness preceding anaesthesia is likewise similar to that of an ordinary administration, and the concurrent signs and symptoms need not be detailed again.

Luke gives the induction period as 35 to 40 seconds, and states that anaesthesia may be completely established in 40 to 50 seconds without the use of the mouth-piece in three-fourths of the cases.

There is, however, a change in the respiration which may take place as consciousness is lost, and that is, nasal expiration is substituted for oral expiration, the cause of this being, as previously mentioned, a paresis of the soft palate with consequent closure of the oral cavity from the naso-pharynx.

Anaesthesia, induced by the nasal method, need not be carried to the same depth as in an ordinary gas administration, where the result, to some extent, depends upon the initial dose. In this respect, the induction period, with almost entire absence of cyanosis and stertor, closely resembles that of nitrous oxide and oxygen.

In many cases the operation can commence when the breathing assumes a soft, regular, snoring character, and the colour of the patient is only just beginning to become livid. It is exceptional for stertor to be present at the stage at which the operation may be most advantageously commenced.

The operator should be warned when the patient is fully anaesthetised, and the mouth-cover, if employed, should be removed.

The Maintenance of Anaesthesia.

During the induction period it is rarely necessary to admit air through the stopcock, but when anaesthesia is reached it may be necessary, from to time, to allow its entrance; avoiding, on the one hand, any undue cyanosis, while, on the other hand, a sufficient degree of anaesthesia must be maintained to abolish all painful sensations.

The patient will require to be guided through a somewhat narrow channel, which is being constantly influenced by the operator's manœuvres, the varying position of the patient's head, and adventitious factors; such as the presence of blood, mucus, and saliva in the mouth.

The apparatus remaining in position of itself, leaves the anaesthetist free to steady the patient's head throughout the operation, and he can, at the same time, employ his right hand for regulating the stopcock, inserting a gag, or altering the position of the patient's head to suit the needs of the operator.

While the lower jaw is being operated on the patient may tend to become somewhat cyanosed, unless an occasional breath of air is admitted through the stopcock, or the latter set in such a position that both air and gas are admitted to the inhaler; but even this will not suffice if the operator is depressing the jaw, forcing back the root of the tongue, or unintentionally obstructing the air-passages in other ways. Under these circumstances, the operation must cease and the patient must be allowed one or more full breaths of air; only after cyanosis has passed off should the operation be continued.

When, however, upper teeth are being removed, it is generally necessary to close the air-aperture and to increase the pressure of nitrous oxide in the bag, and in addition to close the expiratory aperture on the nose-piece should the patient show signs of returning to consciousness.

If the patient returns to consciousness before the operation is completed, provided there be but little blood in the mouth, this may be sponged out, the mouth-cover reapplied, and anaesthesia again procured.

Since using the bag-compressor, the author has found it possible to restore anaesthesia by increasing the pressure of gas and without reapplying the mouth-cover. This has been a decided gain, as previously there was great difficulty in restoring full anaesthesia after the patient had once regained partial consciousness.

Blood may be removed during the operation by lightly mopping with throat sponges; unless this be done carefully, the throat is irritated, and the secretion of mucus increased, besides leaving the throat sore.

The nose-piece may require a little steadying while the operator is extracting upper front teeth, but it will tend to spring back into position as soon as the upper lip is released.

Dr. Hewitt's suggestion of firmly wedging a large sponge between the gums when the operation on one side is finished, and similarly plugging the other side of the mouth at its completion, may be usefully employed in multiple extractions. The sponges used must be secured to props or corks outside the mouth.

On completion of the operation the gas-bag is shut off from the stopcock, the sliding-clamp is released, and the nose-piece is removed.

The nose-piece and mouth-cover can be disconnected and sterilised by boiling. The valve-mounts can be placed in carbolic lotion.

After-Effects of Continuous Administration of Nitrous Oxide.

Although recovery, in the sense of a return to consciousness, is apparently slightly delayed as compared with an ordinary gas administration, this will be found to be the reverse of the case if the recovery period of an ordinary administration be judged from the time the face-piece is removed.

Screaming and crying during the administration are common in young children, although they may have felt nothing of the operation. Luke, in an analysis of a hundred cases, classes six as noisy.

Considering the large quantity of nitrous oxide inhaled, recovery is remarkably rapid, and provided that not much blood has been swallowed during the operation, and cyanosis has been carefully avoided, the recovery from this form of anaesthesia is satisfactory.

Increased discomfort is largely due to the more extensive operation usually undertaken. Headache, giddiness, faintness, nausea, and depression are undoubtedly more prominent than after a short administration of nitrous oxide. Sickness is unusual, and the symptoms above mentioned, even if less transient, are certainly not increased proportionately to the amount of nitrous oxide inhaled.

The patient may be sick soon after recovery from the anaesthetic, but the vomiting is rarely repeated, and seldom occurs later than ten to fifteen minutes after the operation.

If the administration has been attended with much cyanosis, the patient will suffer from headache, giddiness and depression. Palpitation and faintness sometimes lasting for many days have been noted, and haemoptysis, owing to the induced congestion of the lungs, has also been observed.

Nitrous oxide being such an evanescent drug and forming but an unstable combination with the haemoglobin of the blood, there is less danger of an accumulative effect resulting from its prolonged administration than with other drugs, so that its effects are usually temporary and fleeting.

Nasal administration of nitrous oxide has been maintained for over half an hour on more than one occasion.[1] The authors are not in favour of this method of administration, when an anaesthesia of such duration is required, but unforeseen circumstances may necessitate prolonging an anaesthesia to this extent.

It has been stated that the right side of the heart may become overloaded owing to the pulmonary resistance, and that this may result in a dilatation of the right ventricle and subsequently of the right auricle, should the tricuspid valve be rendered incompetent. We must admit that if cyanosis and respiratory embarrassment are permitted throughout an anaesthesia lasting some minutes, there is a liability for the right side of the heart to become dilated in accommodating itself to these altered conditions, and that this dilation in a weakly acting or fatty heart may lead to serious incompetence of its valvular mechanism.

[1] Mr. MacCormac records a case lasting 35 minutes and Mr. Loosely one of 37 minutes' duration.

CHAPTER V.

ETHYL CHLORIDE.

Characters of the Drug.

ETHYL chloride (C_2H_5CL) is a very valuable anaesthetic, but has a limited field of usefulness in dental surgery. To the earnest student of anaesthetics the history of ethyl chloride is interesting, but is not within the scope of this chapter; neither is it possible within the limits of these pages to mention all the various methods or the numerous though excellent apparatus which have been devised for its administration. Only that apparatus and method of use will be described, therefore, which the experience of the author leads him to believe to be the best, for in multiplicity of detail only confusion arises. Ethyl chloride has passed through phases of popularity and ill-repute, is still highly valued by some and equally feared by others. It is relatively a safe drug if intelligently used, but is potentially one of the most lethal anaesthetics we possess, and greater experience for its successful administration is required than is necessary with most of the other anaesthetics employed by dentists. Its great popularity has been earned by its capability of producing deep sleep-like anaesthesia unaccompanied by venous engorgement, cyanosis or jactitation and other signs of asphyxiation; by its portability and comparative ease of administration and by its relative freedom from after-effects. Its ill-repute has resulted from its liability to kill certain types of patients, or to produce dangerous symptoms suddenly and unexpectedly. Chloride of ethyl has therefore been said to be unreliable in its action. This, we believe, is an unjust criticism, for when its action is thoroughly understood, and sufficient experience of its use has been gained, it can be relied upon to give a longer and quieter anaesthesia than is procurable with nitrous oxide.

Ethyl chloride is a colourless, mobile liquid, prepared by the action of hydrochloric acid on a boiling solution of chloride of zinc in ethyl alcohol; the vapour given off being condensed in an inverted flask from which it is collected. It is very volatile and boils at 35° F., its vapour being heavier than air. It has an agreeable etherial smell; a few inhalations of its vapour produce a pleasant feeling of exhilaration, and if the inhalation be continued consciousness is suddenly and rapidly lost. In its pure state it evaporates without leaving any greasy residue, and there should be absolute freedom from any garlic-like odour.

Chloride of ethyl is usually sold in phials fitted with a spring tap, and large enough to contain 60 c.c.; this quantity should be sufficient to anaesthetise twelve patients. It is also dispensed in glass ampoules containing 3 c.c. or 5 c.c., a quantity sufficient for a single administration. These ampoules are to be preferred when the drug is only occasionally required; for unless it be kept securely closed and in a cool place and not exposed to light it does not keep well.

Dose.

The appropriate dose depends upon the age, weight, health, vigour, and temperament of the patient and the depth of anaesthesia required. Small people as a rule need less than large people to produce the same degree of anaesthesia. The only exception to this rule is, that persons with a hyper-sensitive or over-excited nervous system will need a relatively larger dose than those of calm and placid disposition. Persons addicted to the use of alcohol and tobacco in excess will also require larger doses of the anaesthetic to produce deep and quiet anaesthesia. Anaemic patients require much smaller doses; they become narcotised by ethyl chloride with extraordinary rapidity. The dose also depends upon the method of administration employed—more of the drug being required with an open than with a closed inhaler. The average dose necessary to anaesthetise an average adult patient with a closed inhaler is 4 or 5 c.c. Children rarely require more than 3 c.c.

Indications for the administration of Ethyl Chloride.

Ethyl chloride is a very suitable agent for anaesthetising children, persons up to middle age, alcoholics, excessive smokers, anaemic or hyper-sensitive patients. In these patients the anaesthesia produced by a single administration of nitrous oxide is fleeting; they are not good subjects for the continuous administration of nitrous oxide, owing to their hyper-sensitive reflexes and their tendency to struggling and excitement under its influence. If the employment of chloride of ethyl be restricted to these types of patients, and it be given with due regard to the various points dealt with in this chapter, we believe that unpleasant after-effects will not commonly be met with, and that in skilled hands it will be found a highly satisfactory anaesthetic.

Contra-indications to the Administration of Ethyl Chloride.

We stated at the beginning of this chapter that chloride of ethyl had a limited field of usefulness, but at the same time we believe that much of the discredit into which it has fallen has been due to its having been administered to unsuitable patients.

Ethyl chloride should not be administered for surgical operations in the following conditions:

Old age; Chronic bronchitis; Asthma; Emphysema; Kidney disease; Great obesity; Advanced pregnancy;

Abdominal distension, due to tumour or to ascites; *Atheroma; Exophthalmic goitre; Tumour or abscess encroaching upon the respiratory passages.*

In *old age* the chest walls are inelastic or rigid, and the heart and respiration easily depressed. In the event of respiratory failure owing to rigidity of the chest, it is extremely difficult to restore this function by artificial respiration. Elderly patients are more susceptible to the influence of the drug; they are therefore more easily overdosed, and they do not eliminate the poison or recover from its effects so readily as do persons in middle life.

Patients suffering from *chronic bronchitis, asthma,* or *emphysema* are more prone to respiratory failure, and in them it is more difficult to perform artificial respiration. They bear delimitation of oxygen badly, and they should never be anaesthetised with a closed inhaler.

In *great obesity* ethyl chloride should be administered with the greatest caution. A closed inhaler should never be used, but the open method may be adopted, when a slightly longer anaesthesia is desired than that obtainable by nitrous oxide and oxygen. These patients bear deprivation of oxygen badly, their air-ways are narrowed by excessive fat and a large tongue; they salivate readily, are prone to excessive secretion of mucus; the action of the diaphragm is impaired; the action of the heart is embarrassed by fat, and in them artificial respiration is difficult. It is therefore wiser not to run the risk of respiratory or cardiac failure by administering ethyl chloride to them.

In *advanced pregnancy* and *abdominal distension,* due to tumour or fluid, the action of the diaphragm is greatly impeded, and respiration is effected principally by the thoracic muscles ; but since these muscles cease to act when a comparatively light degree of anaesthesia is reached, respiratory failure is to be expected if full doses of ethyl chloride be administered to patients in this condition.

If the distension be due to fluid it is probably due to disease of the liver, kidneys, or heart, so that it is unwise to risk further damage to these organs by exhibiting a poison which may impair their action or excite inflammation. Albuminuria has been noted after the administration of chloride of ethyl.

Atheroma, if advanced, is an unsuitable condition in which to administer ethyl chloride, since its action raises the blood pressure in the earlier stages of anaesthesia, and may cause the inelastic arteries to give way.

Exophthalmic goitre. These patients bear deprivation of oxygen badly ; they are prone to serious attacks of palpitation and heart failure, and to sudden engorgement of the thyroid gland, with consequent risk of respiratory obstruction or failure. Other *tumours about the respiratory passages* may also produce respiratory embarrassment if congested by the action of ethyl chloride.

Patients with *abscesses in the mouth or pharynx* are unsuitable subjects, since under ethyl chloride the coughing reflex is rapidly abolished, and there is a risk of the contents of the abscess being inhaled while the patient is under the influence of the anaesthetic.

In all these cases the merits and suitability of local anaesthesia, of nitrous oxide and oxygen or of the alcohol, chloroform and ether mixture (A.C.E.) should be considered in preference to chloride of ethyl.

Preparation of the Patient.

As a more profound anaesthesia is produced by ethyl chloride than by nitrous oxide, the previous preparation of the patient is a question of more importance when the former drug is to be administered. The stomach should be empty, but to obtain this it is not desirable to starve the patient or to depress him by an unduly long interval without food. If his digestion be sound, the best plan is to allow him to take the meals to which he is accustomed, and to fix the time of operation about half an hour before the usual meal-time, when in healthy subjects the stomach may reasonably be expected to be empty. If he be dyspeptic, a light meal only at the usual time should be recommended. He should be advised to take a smart purgative two nights before the day of the operation. In this way the bowels will be empty and at rest; whereas, if the purgative be taken on the night immediately preceding the operation, its action may not have been complete by the time the patient reaches the dental chair, and an accident may happen under the influence of the anaesthetic. The bladder should always be emptied immediately before the administration is begun, more particularly in the case of children, who should be definitely sent to the lavatory for this purpose.

Tight clothing about the neck, chest, and abdomen should be loosened. It is important to remember that under deep anaesthesia all the muscles of respiration, except the diaphragm, cease to act, that the diaphragm acts more forcibly than usual to compensate for the inactivity of the other respiratory muscles, and that effective respiration depends upon its unhampered movements. If, then, the lower part of a tight corset be not undone as well as the upper part, the patient runs considerable risk of asphyxiation, resulting from the impaired diaphragmatic action.

Ethyl chloride should never be administered without a prop being previously placed between the teeth in order to ensure a free air-way and a ready means of opening the mouth in the event of an emergency arising. Ethyl chloride acts so rapidly that a cessation of respiration for a few minutes will be sufficient to overdose the patient, owing to the drug not being eliminated and producing its cumulative effect.

Dentures must be removed and the mouth examined for loose teeth, crowns, or bridges before the administration is begun, since serious risk of respiratory obstruction might be incurred by their dislodgment when a Mason's gag is used upon them.

Methods of Administration.

Two methods of administration may be adopted :

(1) **The "closed" method**, that is to say, with a limited supply of air in an inhaler fitted with a bag, by means of which re-breathing is enforced. This form of administration is not infrequently preceded by nitrous oxide.

(2) **The "open" method**, that is, with an unlimited supply of air by means of an inhaler without a bag ; with this latter method there is no re-breathing, and the patient inspires fresh air at every inspiration.

The *advantages of the "closed" method* over the open method are that it is more rapid and more certain, the signs of anaesthesia are more clearly defined, and a greater depth of anaesthesia is more easily and quietly induced.

A closed inhaler is to be preferred for anaesthetising powerful men and hysterical women ; patients addicted to the excessive use of alcohol, tobacco, or drugs, and in those cases where muscular relaxation and a profound depth of anaesthesia are required.

The *disadvantages of the "closed" method* are that it is less unlikely to be followed by unpleasant after-effects than is experienced when the "open" method is adopted ; and that on general hygienic principles it is undesirable to make a patient re-breathe his own expired air, containing, as it does, organic excrementitious matter and micro-organisms; it is these poisonous excrementitious gases which on being re-breathed cause the subsequent headache and faintness often experienced after this method of administration has been adopted.

The *advantages of the "open" method* over the "closed" are that there is no delimitation of oxygen; it is this delimitation of oxygen which is partly responsible for the faintness or collapse sometimes met with after an administration by the "closed" method. It is more cleanly. The risks of overdose or the onset of dangerous symptoms are reduced to a minimum. Children and nervous patients greatly prefer an inhaler without a bag.

The "open" method should be adopted when any but the shortest operation is to be undertaken upon a child; and in those other patients who bear deprivation of oxygen badly, for instance, the obese, the anaemic, and the "lymphatic," pregnant women and those suffering from swellings in the abdomen or about the respiratory passages.

The *disadvantages of the "open" method* are that the induction of anaesthesia is protracted, it is more likely to be characterised by excitement and struggling; larger doses of the anaesthetic are required; a less profound anaesthesia is produced, and one in which complete muscular flaccidity is not usually obtained.

The Apparatus.

In the selection of an inhaler for either method certain essential features should be kept in view ; these are :

(1) It must have a *wide bore*, and absolutely no sense of obstruction must be experienced in breathing through it.

(2) It must be *simple in design* and capable of being easily cleansed.

These features are embodied in the author's open inhaler (see fig. 24), and in Carter-Braine's modification of Ormsby's ether inhaler (see fig. 22), which the author considers to be the best for administering ethyl chloride.

If either of these inhalers be adopted there is the additional advantage of having an instrument which can be used not only for ethyl chloride, but also for ether or the chloroform and ether mixture (CE_2) should occasion arise. The author's inhaler is described under Ether (see p. 175).

The Administration of Ethyl Chloride by the "Closed Method."

The Apparatus.

Carter-Braine's inhaler (see fig. 22), which the author recommends for this method, consists of a metal face-piece containing an adjustable air slot. It is furnished with a detachable rubber cushion, so that when applied it may fit the patient's face more accurately and with greater comfort. To its opposite extremity is fixed a metal cage containing a sponge. This cage is covered by a rubber bag of sufficient capacity to hold at least one

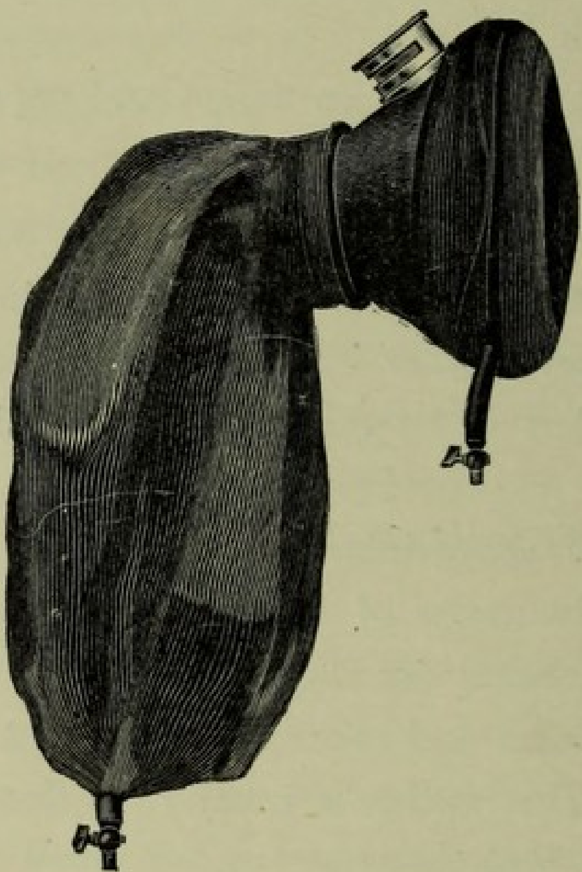


FIG. 22.—CARTER-BRAINE'S MODIFICATION OF ORMSBY'S ETHER INHALER.

full expiration of a well-developed man. The bottom of the bag is pierced by a short length of rubber tubing carrying at its end a vulcanite tap. A phial containing the dose of the chloride of ethyl it is intended to give may be fitted to this tap by means of a collar of rubber tubing, or the anaesthetic may be sprayed into the bag *before the sponge is placed in position.* In this way none is wasted, and the drug does not freeze, as invariably happens when it is sprayed upon the surface of the sponge. In using the phial the drug can be administered very gradually after the face-piece is accurately applied. In the latter method the sponge acts as a screen, and prevents the patient inhaling the vapour too suddenly; this is further prevented if the face-piece is correctly applied.

A successful administration with this apparatus greatly depends upon the character of the sponge and the manner in which it is placed in the inhaler. The following points should be noted:

(1) It should be a *honeycomb* and not a Turkey sponge; this should be cut so that the channels run parallel with the long axis of the inhaler, in order that there may be no obstruction to respiration.

(2) It should be *unbleached*, as it will then keep its form, even if wet. A bleached sponge is softened in the process of bleaching and will collapse when wet, and thus become difficult to breathe through.

(3) It should *not fit the inhaler tightly* lest its channels be compressed and obliterated.

(4) It should be well *wrung out of warm water* before use, in order that it may be fully expanded.

The sponge after use should be cleansed and kept in a one per cent. solution of formalin. In this way it is rendered perfectly sterile, and the formalin makes it more durable.

A suitable quantity of plain sterile gauze may be used instead of the sponge if preferred, and this may be renewed at each administration.

The apparatus being ready, the patient having been placed in a suitable posture in the chair, and the mouth prop fixed in position (see Nitrous Oxide, pp. 39 and 40) the face-piece is gradually applied. Great care should be taken in no way to alarm the patient; the sudden application of an inhaler charged with the somewhat pungent vapour of ethyl chloride will cause involuntary holding of the breath or even spasm of the glottis. The best method is to open the air slot holding the inhaler between the finger and thumb of the left hand, to rest the face-piece upon the bony bridge of the nose at an angle away from the face, giving it the slightest pull in a downward direction, so that the air cushion grips the nose and fits accurately. If placed too low the nostrils are compressed and occluded, and in a normal nose-breather an unpleasant sense of obstruction or even suffocation is experienced. Now by degrees gradually shorten the angle between the inhaler and face until the whole face-piece is in close contact with the face (see plate II.). The fit of the inhaler around the mouth is ensured by supporting it with the little finger of the left hand placed beneath the patient's chin; by this means the correct position is maintained, and the prop is prevented from slipping. In this way the occurrence of the first sign of anaesthesia, viz. "laryngeal stertor," is more easily detected by the supporting finger which rests upon the thyroid cartilage of the larynx.

Experience will soon teach how rapidly these manipulations may be carried out. It is wiser not to hasten them at the risk of causing discomfort to the patient. The inhaler should not be applied rapidly for the sake of avoiding loss of the drug by evaporation, as this loss may be allowed for by placing in the inhaler at the outset a larger quantity of the anaesthetic than may be actually required. It is better to charge the inhaler with more than sufficient ethyl chloride than to have too little and make up for deficiency of dose by protracted re-breathing, remembering that the after-effects are directly proportionate to the degree of delimitation of oxygen, and to the duration of the administration. During the application of the face-piece the patient is instructed to breathe quietly and naturally just as if he were breathing air. It is important not to interfere with the patient's normal way of breathing—it is more comfortable for him, and is an aid to the anaesthetist, since the alteration in the type of respiration produced by the anaesthetic is a valuable guide as to the progress of the anaesthesia.

Induction of Anaesthesia.

As soon as the inhaler is accurately fitted the air slot should be gradually closed. This may generally be accomplished in three or four breaths, the behaviour of the patient being closely watched meanwhile. If holding the breath, swallowing movements, or other signs of discomfort be observed, the strength of the vapour should be diluted by admitting more air for a few breaths, to enable the patient to become accustomed to the anaesthetic. A few words of encouragement and assurance are most helpful—nervous patients particularly much appreciate being told during the administration that they are "taking the anaesthetic very nicely"; this gives them confidence, and calms them, and the resulting anaesthesia is less likely to be characterised by hyper-excitability. After respiration through the inhaler has continued for eight or ten breaths with the air slot closed, the patient's normal, quiet, and rather shallow respiration becomes deeper and more rapid. This is due partly to the delimitation of oxygen and the consequent stimulation of the respiratory centre by "venous" blood circulating through it. Thus urgent impulses to make greater efforts to take in more oxygen are sent out to the respiratory muscles. At the same time the higher centres of the brain become narcotised and the higher consciousness lost. In this condition the patient is not responsible for his actions; his self-control has been abolished by the action of the narcotic; he may suffer from an intoxication characterised by excitement or delusions. Very nervous children and women are particularly interesting in this stage of anaesthesia, often giving way to emotion or fear, as soon as the control of the higher consciousness is abolished, which they were able to disguise and suppress only as long as they maintained full mastery over themselves. Since patients pass through the same stages of mental activity while returning to consciousness after an anaesthetic, as they do while passing under its influence, but in reverse order—crying, etc., occurring during the earlier stages of the administration, will almost certainly be followed by crying during recovery, in spite of the fact that the patient may have experienced no pain or even consciousness of the operation. It is well, therefore, to warn the friends, if they be present during the operation, that this may occur. If this precaution be not taken, it may be hard to convince a nervous mother that her child was quite insensible to pain. In this condition of disordered consciousness the sense of hearing may be temporarily exaggerated ; it is therefore imperative that all persons in the room maintain a discreet silence until at least a deeper plane of anaesthesia be reached.

The heart and respiration during the first stage of anaesthesia are stimulated, the pulse increases in frequency and fulness, and the blood pressure shows a temporary rise. The next stage—that of absolute unconsciousness—is characterised still by deep and rapid breathing, but by a less full pulse, since the vasomotor centre has participated in the general stimulation. The arterioles dilate, the face becomes flushed, and the blood pressure begins to fall. This may cause excessive bleeding from the operation wounds, and is accompanied in some cases by profuse sweating. The breathing now, instead of remaining deep, full, and free, is modified by the appearance of a faint though characteristic laryngeal stertor. This is first felt, by the little finger of the left hand supporting the jaw, as a coarse vibration, and is not immediately audible. This stertor is produced by paresis of the soft palate and aryteno-epiglottidean folds or false vocal chords, and is the first indication of commencing muscular flaccidity. This true and diagnostic laryngeal stertor must be differentiated from the obstructive or "false" stertor sometimes observed. This may be due to faulty position of the patient's head, causing inspiratory obstruction, either from pressure of the chin upon the larynx and trachea owing to the head being tilted too far downwards, or more commonly from its being thrown too far back, as for an operation upon an upper molar tooth. In this latter position the neck muscles are stretched, and the trachea is in consequence compressed and obstructed. There is the additional danger in this position of the tongue falling backwards and being "inhaled" or "swallowed," causing complete obstruction and risk of asphyxia or overdose from uneliminated ethyl chloride. Obstructive stertor may also be caused by adenoid growths and enlarged tonsils or abscess in connection with the lower molar teeth. It is therefore of the utmost importance that the patient be properly placed in the dental chair, not only to prevent respiratory obstruction, but also to prevent the signs of anaesthesia being misinterpreted; and, furthermore, to obviate blood, saliva, or pus gravitating backwards, with the consequent risk of spasm of the glottis. The globes of the eyes, after having shown in the previous stage considerable mobility from excitement, now become fixed, usually in a position of convergent squint downwards; but they may both turn to one or other side. Almost immediately afterwards the superficial ocular reflexes disappear, the pupils begin to dilate, and the patient is sufficiently anaesthetised for operation.

Superficial Ocular Reflexes.

Some confusion is often experienced in the minds of students as to what is meant by the superficial ocular reflexes; a few words of explanation, therefore, may help to prevent misunderstanding. These reflexes are two in number, (1) the "*tonicity*" *of the eyelid*, and (2) the *conjunctival reflex*. By the "tonicity" of the lid is meant the sense of resistance which is felt by the examining finger when an attempt is made to raise the lid in a partially anaesthetised patient. When this is tried the lid immediately closes more tightly; the same also occurs when even the lashes only are lightly brushed with the finger. So long as this latter reflex is present no further examination of the eye should be made, since the conjunctival reflex is never lost so long as the "tonicity" of the lid persists. The degree of tonicity of the lid is an accurate gauge of the activity of the conjunctival reflex. Furthermore, no attempt to ascertain the degree of tonicity of the lid should be made until the other definite signs of loss of consciousness have manifested themselves, viz. laryngeal stertor and fixity of the globes of the eyes. If the anaesthetist has not waited for the appearance of these signs and touches the patient's eye before consciousness is completely lost, he subjects his patient to much unnecessary alarm, and shows the patient that the administrator does not know whether anaesthesia has supervened or not; the patient therefore loses all confidence in him, and is haunted by the fear that the operation may be begun before he is completely unconscious. Even if full anaesthesia be finally reached, it will very probably be characterised by reflex movements, struggling or excitement.

By the "conjunctival reflex" is meant the active and forcible closure of the lid when the examining finger is placed upon the sclerotic coat of the eye. The proper method of ascertaining whether the conjunctival reflex persists, is to lightly raise the lid with the tip of the index finger of the right hand, which is only possible if the tonicity of the lid be lost, then lightly to touch the conjunctiva covering the sclerotic coat with the tip of the second finger—care being taken to avoid the cornea—and at the same moment to release the raised lid. If now the lid remains inactive and flaccid the reflex is absent, but if the lid actively closes directly the conjunctiva is touched, this closure is the manifestation of the activity of the reflex arc. The persistence of the reflex indicates that anaesthesia is not fully established, and it is well to continue the administration for a few breaths longer. There are several degrees of activity of this reflex which indicate the " excitability " of the patient's sensory nerves generally, and that of the dental branches of the fifth cranial nerve in particular. Unless, therefore, this reflex be abolished during an administration of ethyl chloride, there is no certainty that the patient will not exhibit other reflex signs during the progress of the operation. Both eyes should be observed in testing the ocular reflexes, and frequent tests should be avoided, as the eye reflexes rapidly become unresponsive if too frequently examined.

Corneal Reflex.

The conjunctival reflex must be differentiated from the corneal reflex, which remains active until a very much deeper plane of anaesthesia is reached, a stage which it is rarely necessary or desirable to produce in dental surgery, and one which is within the danger zone. The corneal reflex is elicited by raising the lid with the index finger of the right hand, and lightly touching the cornea or clear portion or " sight " of the eye with the tip of the second finger, at the same time releasing the raised lid. If the lid now actively closes to protect the " sight " from injury, this closure indicates the persistence of the reflex ; but if there be no " twitching " of the lid as the finger tip touches the cornea, the reflex is said to be absent. Great care must be taken to release the lid as the examining finger touches the cornea, otherwise if the lid be held during the manipulation its closure is prevented, the test is of no value, and the patient's condition may be misjudged.

The signs enumerated above follow one another so rapidly, usually in 40 to 60 seconds from the beginning of the administration, that as soon as laryngeal stertor manifests itself the anaesthetist must warn the operator that the patient is nearly ready, and be prepared to discontinue the administration within a few breaths. If the operation to be performed is but a brief one, it is not desirable to push the administration beyond the occurrence of audible laryngeal stertor.

If the administration be continued after the abolition of the conjunctival reflex, the pupils dilate more widely, the corneal reflex disappears, and finally the pupils become insensitive to light. This indicates a dangerously profound anaesthesia, and one that should never be induced except in special cases. The abolition of the corneal reflex by ethyl chloride is specially dangerous in dental surgery, since the coughing reflex in this stage of anaesthesia is also abolished; whereas if the conjunctival reflex persists, we know that the coughing reflex is also active. The coughing reflex disappears after the conjunctival but before the corneal reflex, and its activity is the patient's only safeguard against inhaling saliva, blood, or other foreign matter. These, if once allowed to pass the sentinel of the larynx, may be inhaled deeply into the lungs and set up septic pneumonia, pulmonary abscess, or gangrene of the lung. It is therefore most important to maintain the sensibility of the laryngeal mucous membrane in order that any foreign body may excite coughing and be thus expelled. If, on the other hand, the sensibility of the larynx be impaired, spasm of the glottis may supervene on the entry of inhaled saliva, blood, or other foreign matter, and if it be entirely abolished, this matter may be inhaled more and more deeply into the lungs with every succeeding breath.

Signs of Anaesthesia.

To sum up—in the vast majority of subjects the signs of anaesthesia are, in the order of their appearance :

1. *Laryngeal stertor.*
2. *Fixity of the eyes.*
3. *Dilatation of the pupils.*
4. *Loss of the ocular reflexes.*

It must, however, be remembered that these signs are not invariably present, and therefore the anaesthetist must keep a strict watch over his patient, and be ready to interpret unusual symptoms.

The Administration of Ethyl Chloride preceded by Nitrous Oxide.

Advantages.

For certain dental operations upon certain types of patients it is often advantageous to combine small doses of ethyl chloride with nitrous oxide gas. For operations that require a longer anaesthesia than may ordinarily be expected from a single administration of nitrous oxide upon persons who are not good subjects for gas, the addition of 2 to 5 c.c. of ethyl chloride to the gas will be found satisfactory. The resulting anaesthesia should be free from the signs of asphyxiation which characterise pure nitrous oxide anaesthesia, and anaesthetists have observed that when the two drugs are combined, in the method about to be described, there is greater freedom from after-effects than is found after the administration of ethyl chloride alone. This method of producing anaesthesia is well suited to patients of the "neurotic" type, who would object to the smell and taste of ethyl chloride, who would be more likely to suffer from its effects, and who would be likely to struggle or be noisy under gas alone; to anaemic persons, to excessive smokers, to alcoholics, and indeed to all those in whom ethyl chloride is indicated (see page 134).

The Apparatus.

Dr. Hewitt's method of administering these drugs in combination is considered by the author to be the best, and this method only will be described. No special apparatus is necessary, but the author's modification of Hewitt's apparatus will be found the most convenient (fig. 23). In this the gas-bag is fitted with two vulcanite taps from its most dependent part. To one of these is attached the rubber tubing leading from the gas cylinders, and to the other the graduated glass tube containing the required dose of ethyl chloride.

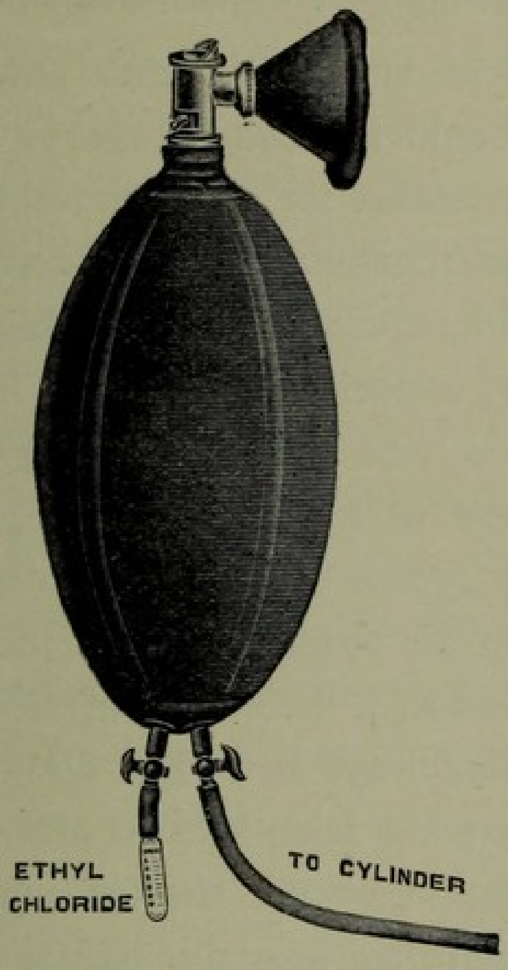


FIG. 23.—HILLIARD'S MODIFICATION OF HEWITT'S NITROUS OXIDE APPARATUS FOR THE CONCURRENT ADMINISTRATION OF ETHYL CHLORIDE.

The addition of this second tap obviates the inconvenient necessity of disconnecting the gas-bag from the cylinders in order to fit on the ethyl chloride tube, and thus enables the administrator to give any additional quantity of gas that may be required. The top of the stopcock is modified to facilitate removal and cleaning of the valve carrying collar, expedites adjustments to the expiratory valve that may become necessary, and renders the action of this valve more apparent. (See fig. 10.)

Induction of Anaesthesia.

The administration to a healthy patient of normal temperament should proceed as follows: Turn off the vulcanite tap intended for the ethyl chloride; fill the bag about three-quarters of its capacity with nitrous oxide, less will be required for an anaemic person or one with small chest capacity; now place from 2 to 5 c.c. of ethyl chloride (the dose depending upon the age, weight, and type of patient) in the glass tube, and connect this, by means of the rubber collar with which it is provided, to the vulcanite tap at the bottom of the gas-bag. Proceed with the administration of the nitrous oxide in the usual way, but when about two-thirds of the contained gas has been inhaled and expired, rotate the valves so that they are thrown out of action and re-breathing to and fro into the bag is enforced. The tap of the ethyl chloride tube may now be opened. When four or five respirations have continued in this way, by which time the patient will have lost consciousness, and be insensible to its pungent vapour, the ethyl chloride may be gently tilted from the glass tube into the bag; it will almost immediately volatilise, owing to the warmth of the patient's expirations, but it is desirable to thoroughly mix the ethyl chloride vapour with the gas and "air" in the bag by manipulating and inverting it. If the patient show some duskiness of colour on account of too much gas having been inhaled, this should be remedied by giving one or two full breaths of air, and then proceeding until complete anaesthesia is established. This is indicated by the laryngeal stertor, fixity of the eyes, dilated pupils, and loss of conjunctival reflex, as described above (see page 153). If the administration be properly conducted there should be no evidence of cyanosis or jactitation. If the initial dose of ethyl chloride prove insufficient, more may be sprayed in through the stopcock.

By this method an anaesthesia of a minute and a half to three minutes may be relied upon. The induction of anaesthesia is more pleasant than the inhalation of pure ethyl chloride, and some observers[1] state that it is unaccompanied by a fall of blood pressure, owing, as they believe, to the nitrous oxide depressing the inhibitory action of the vagus.

The Administration of Ethyl Chloride by the Open Method.

The open method of administering ethyl chloride is to be preferred to the "closed" method, in those cases in which any delimitation of oxygen would be harmful, or be attended by unfavourable symptoms ; for instance, children, pregnant women, or patients suffering from abdominal distension, mild cases of compensated heart

[1] Edinburgh Medical Chirurgical Society, *Lancet*, Feb. 12, 1910.

disease, emphysema and swellings in the neck. This type of patient should always be anaesthetised with a free supply of air. The open method is useful for beginning the administration of ethyl chloride to patients who are highly nervous, and to those who might be frightened by an inhaler with a bag.

Contra-indications.

The method is contra-indicated in alcoholic patients and in those addicted to the use of drugs. Excessive smokers and muscular men are prone to struggle and to become violent under the influence of ethyl chloride, if freely diluted with air. The open method of administration therefore should not be adopted in these cases.

The Apparatus.

The author's inhaler may be used (see fig. 24), or a Rendle's mask (fig. 33) if furnished with a rubber cushion to make it accurately fit the patient's face. With the former inhaler the procedure is simple and is more exact than when a Rendle's mask is used; the air-slots are closed, and an ample supply of gauze is fixed in position.

Induction of Anaesthesia.

The inhaler is applied accurately to the patient's face, and he is instructed to breathe naturally through it, and when the valves are seen to be working properly the ethyl chloride may be dropped upon the gauze. This must be done very gradually at first, until the patient becomes accustomed to the vapour, but as soon as tolerance is established, the drug may be given more freely. The ethyl chloride should not be sprayed upon the gauze as this causes the formation of a layer of frost, and thus obstructs inspiration. The nozzle of the ethyl chloride tube should be placed in contact with the gauze, and the stopcock only slightly opened, so that the drug is made to drip into the substance of the gauze, and is not allowed to escape directly into the outside air. As the patient becomes anaesthetised his respirations will deepen and become more rapid. His face will flush. His pulse increases in frequency and fulness. If the administration be continued, a slight laryngeal stertor will develop; the globes of the eyes become fixed and staring, and the conjunctival reflex (see p. 150) will disappear. The drug should be given gradually but continuously until these signs manifest themselves. In patients suitable to the method there will be no struggling, but there will be some muscular rigidity, which cannot easily be abolished, as the supply of ethyl chloride is too freely diluted with air to produce a deeper plane of anaesthesia.

Dose. No definite statement can be made with regard to the appropriate dose in a given case, the administration must be persisted in by continuous dropping until anaesthesia is established. Should any difficulty be experienced in obtaining anaesthesia, a closed inhaler may be substituted.

Duration of anaesthesia. After the removal of the face-piece a narcosis lasting at least one minute to two minutes may be expected, provided tracheal stertor has been produced and the conjunctival reflex dulled or abolished.

Recovery from anaesthesia will be more protracted than after nitrous oxide gas, and may often be characterised by a period of intoxication and obstructiveness. The patient is more difficult to manage, and is less amenable to reason than when ethyl chloride is given by the closed method.

After-effects are of less common occurrence than when the closed method is adopted, but headache and nausea are not infrequently experienced; they are, however, of short duration and rarely require special treatment.

The Operation Period following an Ethyl Chloride Administration.

On removal of the face-piece one full breath of air should be allowed before the operation is begun. The pupils thereafter soon contract, the reflexes return, and after a time, varying from one to three minutes—depending upon the depth of anaesthesia produced—the patient recovers consciousness. The signs of returning consciousness and incomplete anaesthesia are "screwing up" or "watering" of the eyes, contraction of the facial muscles, phonation, and purposive movements of the hands during the operation. When these signs first show themselves the patient has not recovered consciousness sufficiently to be able to experience pain or to remember what has taken place, for he is still in a condition of intoxication; but as full consciousness is rapidly regained, it is not wise to continue the operation for more than 20–30 seconds after the first purposive movements have been made by the patient; for if he experiences the least pain, he will consider that the administration of the anaesthetic was unskilled, if not indeed a failure.

After-effects of an Ethyl Chloride Administration.

The after-effects vary with the method and duration of the administration, the amount of delimitation of oxygen, and the extent of re-breathing imposed upon the patient. That is to say, if too small a dose has been given and the patient has been made to re-breathe his own expired "air" for some minutes, in order to make up for the inadequate dose, unpleasant after-effects are more likely to be experienced than if a larger dose had been given and anaesthesia thus induced more rapidly.

Similarly, after-effects are more rarely met with after an open inhaler has been used and there has been no delimitation of oxygen and no re-breathing, although the actual duration of anaesthesia may have been greater and a larger quantity of ethyl chloride inhaled. There is also greater freedom from after-effects, when the administration is preceded by nitrous oxide.

The most common after-effects are *faintness*, *nausea*, *vomiting*, *collapse* and *headache*.

Treatment of After-effects.

The patient should not be moved from the chair for ten minutes or more after the administration. Directly he has washed out his mouth, the chair should be lowered so that he is placed in the recumbent position. This position should, if possible, be maintained until his circulation—as evidenced by the colour and pulse—has recovered from the depressing action of the drug. Faintness and nausea are often brought on by moving a patient too soon after an administration, whereas a good recovery might have been secured by better management. An excellent plan to prevent these complications is to give a hypodermic injection of strychnine ($\frac{1}{60}$ grain) during the induction of anaesthesia, as soon as the patient has lost consciousness. In the event of faintness, collapse, or nausea supervening, the patient will derive very great benefit from a cup of tea without either milk or sugar, but with the addition of a teaspoonful of brandy if necessary, and sipped as hot as can be borne.

Smelling aromatic ammonia " salts " will help to abolish the nauseating taste of the anaesthetic if this be experienced. The first "meal" after the administration, which can be taken as soon as desired, may be a cup of clear soup or meat extract with or without some thin toast, according to the patient's inclinations, but if there be the least feeling of gastric disturbance, it is better to withhold solid food as long as this sensation lasts.

Emergencies, Dangers and their Treatment.

The dangers arising in the course of a dental operation under an anaesthetic have been already fully dealt with in the chapter on Nitrous oxide (see pp. 66-86), but there are certain special dangers in connection with ethyl chloride. They are:

(1) Idiosyncrasy, or unusual susceptibility of the patient to the action of the drug, with consequent rapid induction and risk of overdose before the depth of anaesthesia reached is realised. This condition is generally accompanied by *failure of respiration.*

Ethyl chloride kills by paralysing the respiratory centre after a full inspiration, and with the chest in a condition of over-distension and fixity. If this condition be unrelieved the heart will quickly succumb from the effects of uneliminated ethyl chloride still circulating in the blood.

The treatment, therefore, is to immediately restore the respiration after first having emptied the chest of its contained air. It is useless to attempt artificial respiration until this has been accomplished. It may only be necessary to stop the administration and draw the tongue forward, at the same time exerting gentle pressure upon the lower ribs and upper part of the abdomen; but unless air can be heard to issue from the lungs, and to enter on the subsequent recoil of the elastic chest wall, the patient must at once be placed upon his side with the mouth held open and the tongue drawn forward. The anaesthetist must then gently exert pressure upon the lower ribs and upper abdomen, attempting to press upwards the diaphragm. This will have the effect of emptying the chest and thereafter artificial respiration may be continued in the ordinary manner. If oxygen be at hand, the tube in connection with the oxygen cylinder may be placed in the patient's mouth, and oxygen thus allowed to flow, while the artificial respiration is being continued, or, failing oxygen, smelling salts may be applied. Nitrite of amyl will not relieve the heart, since the vasomotor system is already dilated. A hypodermic injection of strychnine may be given —but this is of entirely secondary importance to efficient artificial respiration. A hypodermic injection of pituitary extract is of more value, and is a powerful cardiac stimulant. This remedy should invariably be carried by the anaesthetist; it is supplied in convenient "ampoules" by Burroughs & Wellcome. A dose of brandy will also help to restore the patient. If the failure of respiration be due to obstruction from foreign matter entering the larynx or lungs, the patient must be placed upon his side, or in the prone position, and an attempt made to expel the obstruction by sudden but not too forcible compression of the lower ribs, and artificial respiration continued by Schäfer's method (see plate V.).

Schäfer describes his method as follows: "To effect artificial respiration, put yourself athwart or on one side of the patient's body in a kneeling position and facing his head. Place your hands flat over the lower part of the back (on the lowest ribs), one on each side, and gradually throw the weight of your body forward on to them, so as to produce firm pressure—which must not be violent—upon the patient's chest. By this means the air (and water, if there is any) is driven out of the patient's lungs. Immediately thereafter raise your body slowly, so as to remove the pressure, but leaving your hands in position. Repeat this forward and backward movement (pressure and relaxation of pressure) every four or five seconds. In other words, sway your body slowly forwards and backwards upon your arms twelve to fifteen times a minute, without any marked pause between the movements. This course must be pursued for at least half an hour, or until the natural respirations are resumed. If they are resumed, and, as sometimes happens, again tend to fail, the process of artificial respiration must be resorted to as before."

The author has seen a large mass of blood clot, which had been inhaled and caused laryngeal obstruction, thus blown out upon the floor by compression of the chest, after which a few movements of artificial respiration quickly restored the patient. If, however, the patient had not been placed upon his side, but allowed to remain on his back this clot would doubtless have been blown only into the pharynx, again to be inhaled at the next inspiratory recoil of the chest, and thus the efficient entry of air prevented.

(2) *Circulatory failure.* This may occur especially in patients with heart disease, but is more rare than respiratory failure. The best treatment is a hypodermic injection of pituitary extract and strychnine, placing the patient flat and stimulating the respiration by ammonia held to the nostrils, in addition to inhalations of oxygen. As soon as the patient is able to swallow, a dose of brandy may be given.

(3) *Profuse salivation* is sometimes met with during the induction of anaesthesia by ethyl chloride. This must be treated by holding the patient forward in the chair with the head in a forward position, so that the saliva may drain outwards and not run backwards with the risk of being inhaled. Sponging out the mouth is useless, as the " irritation " of the sponging only excites further salivation.

(4) *Foreign bodies in the air-passages.* Stumps or teeth may fall backwards, with consequent risk of exciting spasm of the glottis or of being inhaled into the lung. Here prevention is better than cure, and as

PLATE V.

SCHÄFER'S METHOD OF ARTIFICIAL RESPIRATION.

Showing mouth kept open with a gag and tongue forceps applied.

To face page 166.]

ethyl chloride is usually given for extensive extractions and often for roots of teeth, a good plan is to place a sponge upon a holder at the back of the mouth, as soon as the face-piece is removed and before the operation is begun. The sponge fits the pharynx more accurately than the mouth "spoon" which has been devised for this purpose, and thus more effectively prevents the inhalation of foreign bodies. It has the additional advantage of absorbing blood and saliva and preventing their passage into the larynx.

CHAPTER VI.

ETHER.

Characters.

ETHER $(C_2H_5)_2O$ is obtained from ethylic alcohol by a process of dehydration brought about by the action of sulphuric acid.

Until recent years ether was the routine anaesthetic employed for most dental operations requiring a longer anaesthesia than could be obtained from a single administration of nitrous oxide gas. But now that the methods of prolonged nasal administration of nitrous oxide have been perfected, ether has fallen into disuse, and is employed only for those patients in whom prolonged administrations of gas are inadvisable, or when muscular flaccidity is necessary.

Only two varieties of ether may be used for inhalation; they are (1) the *Aether Purus* or purificatus (B.P.) prepared from absolute ethylic alcohol, and having a specific gravity of ·720; and (2) the *Rectified Ether*, prepared from methylated spirit. This also has a specific gravity of ·720. Formerly anaesthetists advised the employment only of Aether Purus on account of the greater likelihood of unpleasant after-effects following the inhalation of the ether made from methylated spirit; but the latter is now so well prepared that it is almost indistinguishable from the more expensive Aether Purificatus.

Ether is a colourless, limpid, very volatile liquid, having a pungent characteristic smell and burning taste. Its vapour is almost twice as heavy as air; it is inflammable, and when mixed with certain proportions of air, is explosive. Ether should therefore not be used near a naked flame or in the presence of the actual cautery.

Ether readily decomposes on exposure to light; it should be kept in a cool, dark place, preferably in yellow-tinted bottles. To test its purity before use the anaesthetist should pour a little upon his hand; if the vapour be free from any irritating or unpleasant smell and no residue be left on evaporation, it may safely be inhaled, but otherwise it should not be used, lest bronchial irritation be set up accompanied by coughing and profuse salivation. Even the vapour of the purest ether if inhaled in too great concentration or insufficiently diluted with air causes considerable irritation, salivation, and secretion of mucus.

Ether is a powerful cardiac and respiratory stimulant; but it causes general congestion and consequent free bleeding from wounds; it also stimulates the mucus and salivary glands, and is therefore not a satisfactory anaesthetic for operations upon the mouth.

Examination of Patient.

The patient must first be examined to ascertain whether he be a fit subject for the administration of an anaesthetic, and it is best to carry out this examination in the same routine manner on every occasion, so that no point of importance may be overlooked. The following system is recommended: first the mouth, next the respiratory system, and lastly the circulatory system, noting in addition any other characteristics of the patient.

The *mouth*. Detachable dentures must be removed, and crowns and loose teeth noted, as these must be avoided by the prop or gag in the event of the administration being proceeded with. Notice the condition of the tongue and pharynx; if the tongue be large and furred and the pharynx congested, excessive use of alcohol or tobacco may be suspected, and the ether should be preceded by some rapidly acting anaesthetic, *e.g.* nitrous oxide or ethyl chloride, until the second stage of anaesthesia has been quickly tided over, and struggling thus avoided.

The respiratory system. Place the hand upon the patient's chest, and direct him to take a deep breath, to test the degree of chest expansion. If the chest be rigid or expands badly, or the patient coughs, he will probably take ether unsatisfactorily (see pp. 172 and 173), and the merits of chloroform and ether mixture (CE_2) should be considered in preference. At the same time, the condition of the corset should be noticed, and if tight it should be undone throughout its whole length ; loosening the upper part alone is useless, for under deep anaesthesia the respiration is carried on almost solely by the diaphragm, and if this muscle be not allowed ample room for action respiratory embarrassment and jactitation will result. If there be great abdominal swelling, swelling of the ankles also should be looked for, and if present it is best to select some other anaesthetic. Listen to the respirations over each side of the chest with the stethoscope ; if there be adventitious sounds or diminished breath sounds, this should decide against ether.

The circulatory system. Listen to the heart sounds, and if murmurs are heard advise against the administration of ether, unless by the open method, being guided in your decision by the condition of the pulse, since the patient's pulse and colour will indicate how far the valvular incompetence is compensated.

Although ether is a heart stimulant, its tendency to produce respiratory embarrassment may thereby overstrain a heart afflicted with valvular disease. Such a heart may be sufficiently compensated to do its work under normal conditions, but may be quite incompetent to withstand unusual strain.

If, in conjunction with adventitious heart sounds, the pulse be soft, compressible, and rapid, any anaesthetic is contra-indicated which involves pulmonary engorgement, as this is inevitably associated with right-sided engorgement of the heart.

Look for swellings about the neck (*e.g.* goitre), for exophthalmos, and note the condition of the pupils.

If no abnormality be found, the administration of ether may be proceeded with.

Contra-indications.

Owing to its irritating properties, ether should not be administered to *young children* (unless by the open method), to *patients with rigid chests*, to those prone to *bronchitis* and *asthma*, to patients suffering from *atheroma, chronic nephritis, emphysema, aneurism, chronic pharyngitis*, or *smoker's throat*; to *alcoholics* or to *old people*. Young children are very intolerant of the vapour of ether. It irritates their delicate mucous membrane, causing profuse salivation and secretion of mucus, and may give rise to troublesome cough or respiratory embarrassment by inducing spasm of the glottis. Its administration is liable to be followed by bronchitis. Children are not easily anaesthetised with ether, they object strongly to its smell and taste, become very frightened and usually struggle. If ether be administered to patients who suffer from *chronic bronchitis, emphysema*, or *asthma*, it will almost certainly set up troublesome coughing and be likely to be followed by acute bronchitis.

Atheroma. In this condition the blood vessels become thickened and inelastic, and instances have been recorded of their having ruptured under the strain of the increased blood pressure produced by ether. There is greater risk of this occurring in cases of *aneurism*.

Chronic nephritis prohibits the inhalation of ether except by the open method, because ether has been proved to set up "cloudy swelling," or a mild degree of inflammation of the renal cortex, and quite commonly produces temporary albuminuria.

In chronic pharyngitis the throat is very irritable, and severe coughing and great discomfort are experienced if ether vapour be inhaled.

Alcoholics pass through a more prolonged period of intoxication during the second stage of anaesthesia, owing to the large quantities of the ether necessary to anaesthetise them ; in this condition they may struggle violently, and incur the risk of injuring themselves or any objects within reach. They are difficult to anaesthetise, and remain under the influence of ether for a very short time ; they are, however, rarely sick after its inhalation.

Old people, especially those with rigid chests, are prone to bronchial irritation by ether, and bronchitis is very likely to follow its administration to them, unless given by the open method and freely diluted with air. If, however, morphine ($\frac{1}{8}$ grain) combined with atropine ($\frac{1}{150}$ grain) be given hypodermically before the administration of ether is begun, they pass quietly and easily under its influence, and much smaller quantities of the ether are required than would otherwise be necessary.

Morphine is nevertheless contra-indicated if the patient be suffering from albuminuria.

Preparation of Patient.

This is in all respects the same as is followed before the administration of ethyl chloride (see pp. 137, 138). But in addition, the patient should be advised to avoid such articles of diet as are known to overtax the functions of the liver, such as the starches and sugars, condiments and alcohol. In this way "after-sickness" may be avoided, since its onset is often due to disturbance of the liver functions in addition to those of the stomach.

Posture.

The position of the patient matters little so far as the safety of an administration of ether is concerned, provided certain precautions be observed (see ethyl chloride, p. 137); that is to say the patient will take the ether equally well in the sitting or the recumbent posture. It is absolutely necessary, however, not to alter the position of the patient when once the administration is begun. The posture most convenient to the operator should from the first be assumed, for it is dangerous to begin the administration with the patient lying down, and then to sit him up when he is under the influence of the anaesthetic (see p. 213).

Methods of Administration.

Two main methods of administration are employed:

(1) By means of an **open inhaler.**

(2) By means of a **closed inhaler.**

In the latter method the administration may be preceded by (*a*) *nitrous oxide*, (*b*) *ethyl chloride*, (*c*) the various *mixtures of chloroform, ether, and alcohol.*

On hygienic grounds an open inhaler is preferable, but owing to the more protracted induction of anaesthesia and the greater quantity evaporated into the room, its routine employment cannot be recommended in dental surgery, especially if the operation is to be undertaken at the dentist's house. Moreover, since dental operations are of short duration, the disadvantages incidental to re-breathing from a closed inhaler are minimised.

(1) The Administration by the Open Method.
The Apparatus.

The author's open inhaler (fig. 24) has been devised for the administration of ether by this method.

This inhaler consists of an ordinary face-piece (A), such as is employed in the administration of nitrous oxide, which fits upon an L-shaped piece of metal tube, carrying at the upper extremity of the vertical arm a conical portion (F), over which gauze (D) is stretched by a ring (E).

This gauze carrier is detachable, and is pierced by a series of holes halfway round the circumference of its collar. By rotating the collar these holes are made to pass over a slot cut in the tube beneath, so that extra

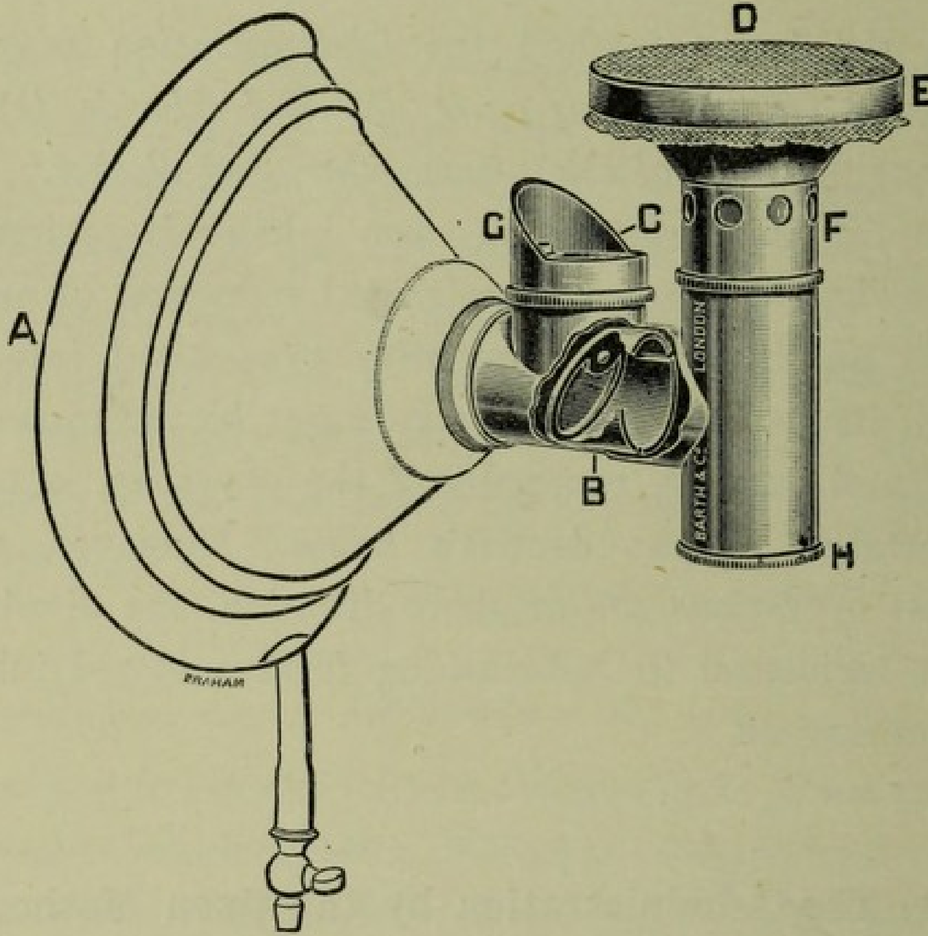


FIG. 24.—HILLIARD'S INHALER FOR ADMINISTERING ETHER BY THE OPEN METHOD.

air can be admitted to dilute if necessary that inhaled through the gauze.

The horizontal portion of the L-tube plugs into the vertical portion, and contains a detachable collar carrying a rubber inspiratory valve (B) opening towards the face-piece. The tube has an opening upwards between this valve and the face-piece, over which is fixed another detachable collar carrying the expiratory valve (C), which opens outwards away from the face-piece. This valve is of rubber, and is protected by a little cowl (G), which also serves to direct the patient's expirations away from the anaesthetist's face. The vertical arm of the L-tube is continued downwards for half an inch, and is closed by a cap (H) ; by this means any excess of the anaesthetic that may be poured upon the gauze will be collected, and thus protect the patient's face from being burned. The calibre of the apparatus has been made sufficiently wide to allow of free breathing without any sense of obstruction or discomfort, and only so much gauze must be fixed over the carrier as permits of unobstructed respiration—never more than twenty layers of gauze need be used. When the apparatus is accurately fitted over the patient's face, inspiration can only take place through the gauze and through the valve (B), the inspired air thereby becoming laden with the anaesthetic vapour in proportion to the degree of saturation of the gauze. The expired air passes out through the valve (C), closing the valve (B), and is thus prevented from passing back through the gauze ; consequently there is practically no waste, for the patient inhales almost the whole of the anaesthetic dropped upon the gauze, the loss by evaporation into the outside air being negligible. Dosage is therefore more accurate with this than with any other form of open inhaler ; the induction of anaesthesia is more easy and less protracted, but greater care must be exercised in the administration than when a loosely fitting mask is used. More gauze will have to be fixed on the inhaler to successfully anaesthetise those patients who require large quantities of ether than for those needing smaller quantities; for instance, alcoholic patients will need many layers of gauze, so that the inspired air may pass through a large volume of ether, whereas the small quantities of the anaesthetic required by children can be taken up by a few layers only.

Before the administration is begun the anaesthetist should see that the valves are working properly; and having fixed from 12 to 20 layers of gauze upon the gauze-carrier, should by actual test upon himself ascertain that no discomfort or respiratory oppression is experienced in breathing through the inhaler before using it upon a patient. If there be any obstruction to free breathing through the inhaler, the patient will experience a sense of suffocation; his lungs, the right side of his heart, and the venous system throughout the body will quickly become engorged with blood, and will induce profuse salivation and secretion of mucus, great swelling of the tongue, severe bleeding from the extraction wounds, and often free sweating.

The Administration.

Having selected a suitable face-piece, and gently applied the inhaler, with the air slot widely open, to the patient's face, in the manner described (see ethyl chloride, p. 144), the patient should be instructed to breathe quietly and naturally, and by a few quiet words discouraged from breathing hurriedly or excitedly. The ether may now be poured upon the gauze drop by drop, and at the same time the air slot gradually closed. As soon as the patient tolerates the vapour, the air slot may be completely closed and the ether given more freely, but its exhibition by continuous dropping should be persisted in throughout the administration. It is generally necessary to give the ether at the rate of 60 to 80 drops per minute, and better results are thereby obtained than by giving larger quantities at longer intervals. The induction of anaesthesia must not be hurried, and if the drug be given continuously in gradually increasing quantities, the patient will in most cases pass quietly into narcosis without struggling and with very little mucus secretion. Struggling is generally due to too strong a vapour or to delimitation of oxygen, and is consequently rarely seen when the open method is employed. If struggling occurs during the induction of anaesthesia by the closed method, it may usually be overcome by temporarily increasing the supply of air.

As induction of anaesthesia proceeds a sense of fulness and throbbing in the head, buzzing in the ears, and a feeling of warmth throughout the body are experienced. The pulse meanwhile increases in frequency and fulness, the respiration becomes deeper and more rapid, and later still definitely stertorous. The patient's face shows signs of congestion, and if a closed inhaler be used this is accompanied by cyanosis of increasing depth, until air be admitted. If, on the other hand, an open inhaler be employed, the patient's colour remains good, and there is absence of cyanosis and lividity. Thereafter, consciousness soon becomes disordered and sensibility to pain is diminished or lost; although the patient responds to painful stimuli, these will not be remembered on returning to consciousness.

Signs of Anaesthesia.

As the narcosis deepens general muscular flaccidity is induced; the lid reflex, after preliminary exaggeration, becomes dulled until finally lost; the pupils gradually dilate, until in deep anaesthesia the corneal reflex disappears (see ethyl chloride, p. 151), and later still the pupils dilate widely, and do not react to light. This last occurs only in the most profound degree of anaesthesia which it is never necessary to induce in dental surgery.

The rapidity and completeness of the patient's recovery from anaesthesia depends proportionately upon the duration of the administration of the anaesthetic, and the depth of anaesthesia induced. In estimating the degree of anaesthesia, the size of the pupil and the activity of the light reflex should be judged together and in relation to one another. If taken separately, each may be a fallacious guide, as, unless the size of the pupil be observed before the administration is begun and its variation from that normal noted during the narcosis, the anaesthetist may be misled by considering the size of the pupil alone; but if he has the additional evidence of its activity to light, he will be enabled to judge more accurately of the patient's true condition. It will generally be found that in the lighter degrees of anaesthesia the pupil contracts, becoming too small to exhibit the light reflex, later it dilates and the degree of dilatation depends upon the amount of delimitation of oxygen; in a given depth of anaesthesia the pupil will be smaller if an open inhaler is being used than it would be if a closed inhaler had been employed. Similarly, the light reflex is modified by other reflexes, since the pupils will suddenly dilate and be temporarily fixed and insensitive to light, if the anaesthesia be insufficiently deep while painful operations are in progress; the pupils will, however, soon resume their normal size if the painful operation which caused them to dilate be discontinued.

(2) The Administration by the Closed Method.

If a closed inhaler be selected for the administration of ether, this may be conducted by one of the following methods:

1. By ether *alone.*
2. By ether preceded by *nitrous oxide.*
3. By ether preceded by *ethyl chloride.*

4. By ether preceded by the *chloroform and ether mixture* (CE_2) or by the *alcohol, chloroform, and ether mixture* (A.C.E.).

For the short operations of dental surgery the closed method of etherisation will be generally found more useful than the open method, owing to the more rapid induction of anaesthesia, to the smaller quantity of ether required, and to the smaller quantity exhaled into the room, since the patient, instead of being allowed a free supply of air as in the open method, is made to breathe into and out of an india-rubber bag.

1. The Administration of Ether by itself.
The Apparatus.

The inhaler most commonly used is that known as the Clover's inhaler, or Dr. Hewitt's modification of it (see fig. 27).

Clover's inhaler consists of a spherical metal ether chamber upon one half of which is fixed a cylindrical water jacket. The chamber has an orifice for filling which is fitted with a hollow glass plug. Both chamber and water jacket are pierced by a central tube having a slot cut about a third of the distance from either end, and opening into the ether chamber. Immediately opposite these openings or slots the tube is of a wider diameter than in the remainder of its length. Into this central shaft is accurately fitted another tube with corresponding slots, but having between them a partition occluding its calibre. Upon one end of the tube is fitted the face-piece, and upon the other the india-rubber bag. An indicator is fixed upon the inner tube between the face-piece and the water jacket, and

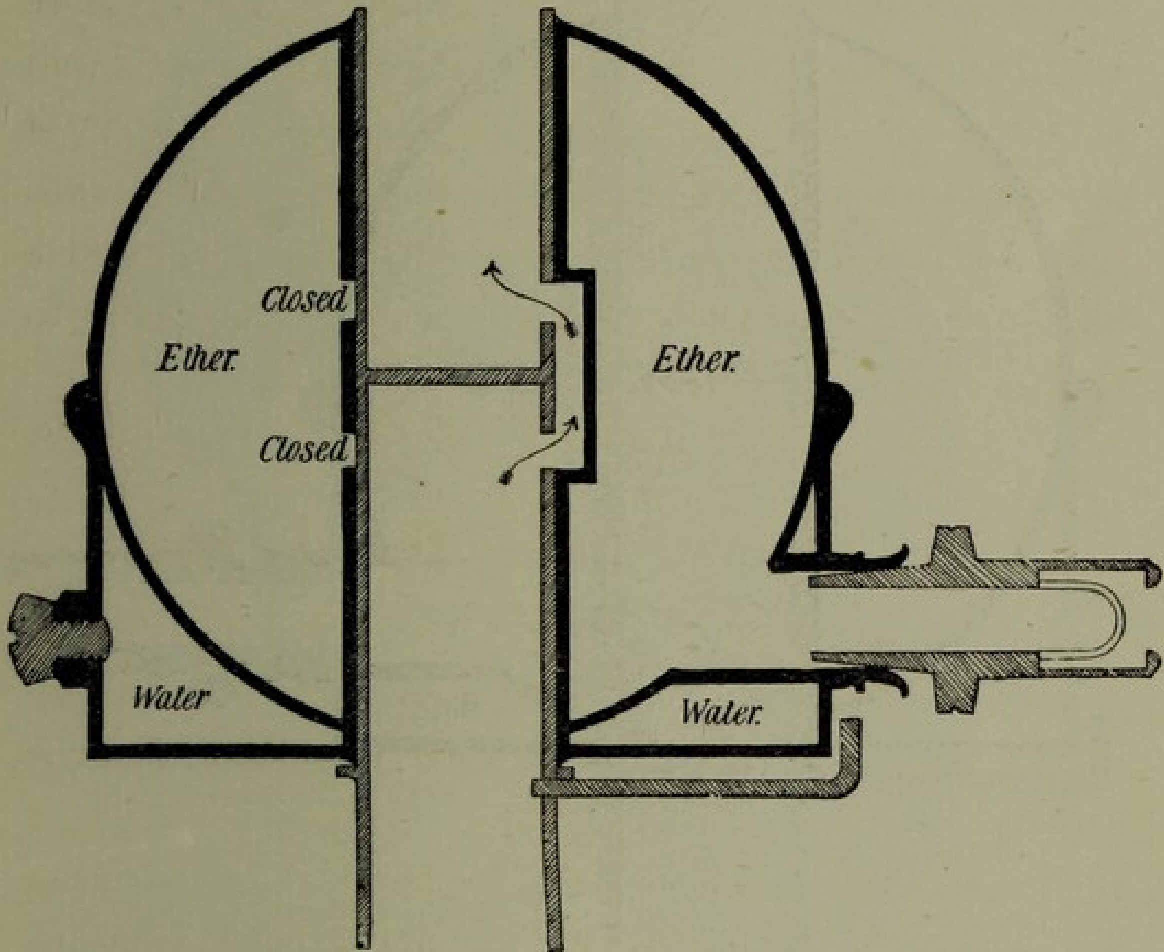


FIG. 25.—SECTION THROUGH CLOVER'S REGULATING ETHER INHALER.

The indicator is at 0 and air-current passing from the face-piece to the bag and back, without traversing the ether chamber.

points to figures placed round the circumference of the water jacket, dividing each half into four equal portions. By rotating the ether chamber around this inner tube, the slots are made to hit or miss one another, so that air drawn through the inner tube from the bag can be made to pass either entirely through the ether chamber (see fig. 26), or only through the tube (see fig. 25), or partly in both directions, the proportion of respired air passing through the ether chamber being indicated by the pointer. When, for instance, the slots in the

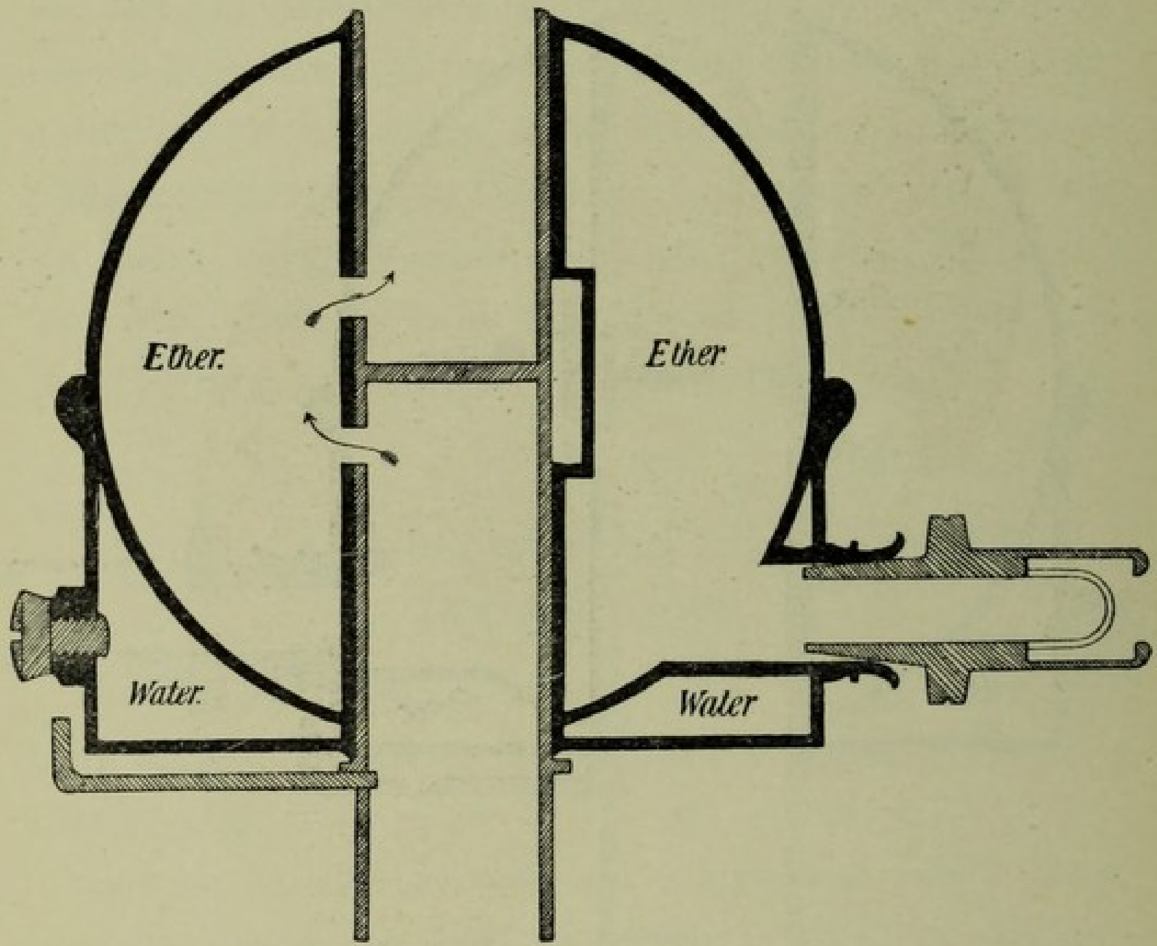


Fig. 26.—Section through Clover's Regulating Ether Inhaler.

The indicator is at **4** (or full) and air-current passing from the face-piece to the bag and back, entirely across the ether chamber.

two tubes do not correspond, the indicator points to 0, and no air enters the ether chamber; it traverses the bye-pass made by the increased diameter of the shaft piercing the ether chamber. When, on the other hand, the ether chamber is rotated until the indicator points to 4, the slots in the two shafts do correspond, and the whole of the respired air passes through the ether chamber. Intermediate positions of the slots correspond with numbers between 0 and 4, and indi-

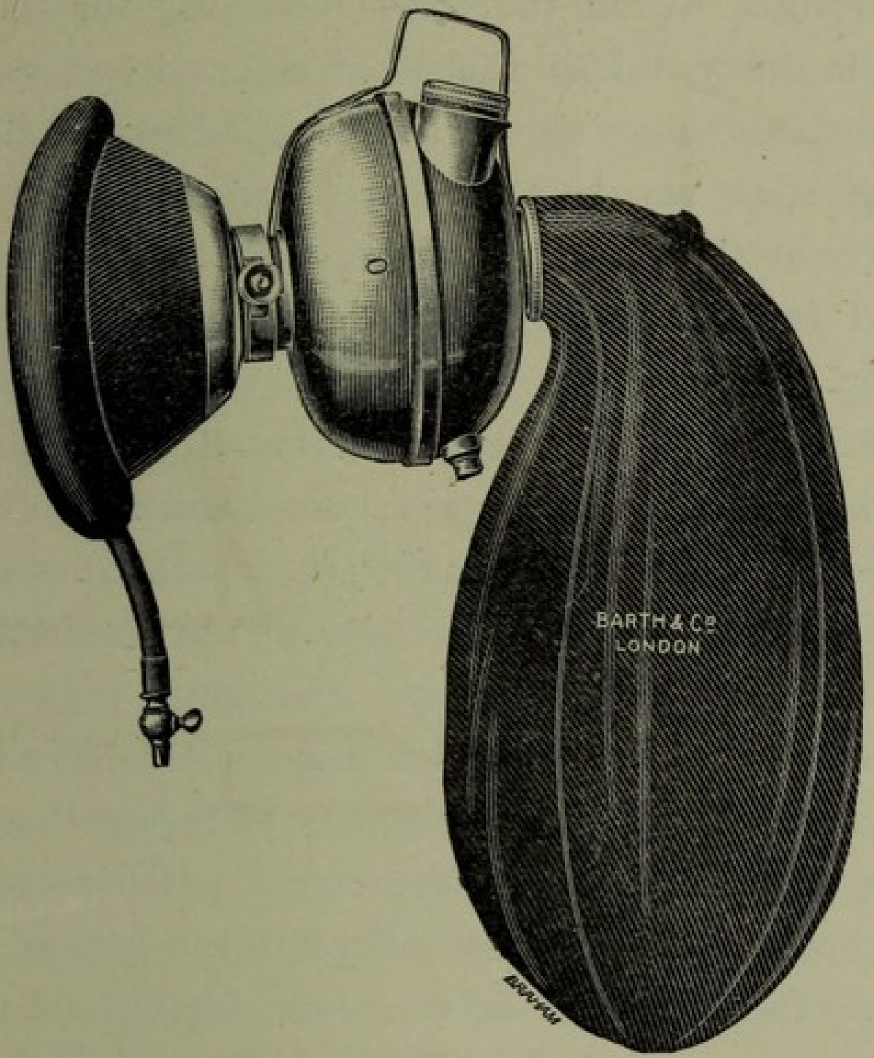


FIG. 27.—HEWITT'S MODIFICATION OF CLOVER'S REGULATING ETHER INHALER.

cate that one-fourth, one-half or three-quarters of the volume of respired air can pass through the ether chamber.

Sir F. Hewitt[1] describes his modification of this apparatus as follows:

"It differs from Clover's original pattern in the

[1] *Anaesthetics and their Administration*, Macmillan, 1907.

following particulars: (1) Its internal calibre or air-way is very much larger; (2) instead of the ether reservoir rotating upon the central tube, the central tube rotates within the fixed reservoir; (3) the face-piece is screwed into the ether reservoir so that the latter cannot be unexpectedly detached from the former; (4) the ether reservoir can be adjusted, whatever the position of the patient may be, so that ether may be poured into it through its wide-mouthed filling-tube without removing the inhaler from the face. In order to secure these improvements, I found it necessary to materially modify the internal mechanism of Clover's original apparatus, and to have two separate inner tubes which are made to revolve as one tube by the indicating handle which fits into each. The large bore of the apparatus is distinctly of advantage, not only in lessening the initial unpleasant sensations of re-breathing, but in reducing the asphyxial phenomena (stertor, cyanosis, and laboured breathing) of well-established ether anaesthesia. The apparatus is, moreover, useful, and indeed was more particularly designed for administering nitrous oxide and ether in succession."

The Administration.

Select a suitable face-piece, and fix it to the inhaler—one that is not large will probably fit the patient best. Now turn the indicator to No. 2, and pour an ounce of ether into the ether chamber, and then tightly close the plug, turn the indicator back to 0, and blow through the apparatus to expel any trace of ether which might at the outset disturb the patient by its pungent smell. Now fix on the rubber bag.

A mouth prop must invariably be placed between the jaws to ensure a perfectly free air-way, for otherwise serious respiratory obstruction may result from engorgement and swelling of the tongue, particularly if the patient already suffers from nasal obstruction.

All being ready, gently apply the face-piece (see ethyl chloride, p. 144) with the indicator at 0, but before it is fitted over the mouth instruct the patient to take a good breath of air, and then exhale into the bag directly the face-piece is accurately fitted. Repeat this process by alternately raising and lowering the face-piece, until the bag is three-quarters full, and do not afterwards lift the face-piece until anaesthesia is established. The success of the induction of anaesthesia largely depends upon accurate adjustment of the inhaler, and if this admits of leakage of air, the ether vapour will be too much diluted and the induction will be protracted and probably noisy and accompanied by struggling. When the patient has been made to re-breathe into the bag three or four times, and has become accustomed to the inhaler, the ether may be very gradually turned on, by rotating the ether chamber. There is the risk of an excess of ether vapour escaping directly the ether inlet is opened, because the warmth of the patient's breath has caused the ether to evaporate rapidly in the chamber, and the vapour is in consequence often under pressure and at first comes over with a rush. As soon as the ether is tolerated and the breathing becomes free and steady, the strength of vapour may be more rapidly increased, but if the patient shows any sign of intolerance, as by holding his breath, swallowing, coughing, or struggling, the strength of the vapour must be temporarily reduced or even a breath of air admitted. As soon as the indicator reaches No. 1 on the scale the ether chamber may generally be rotated a little at each expiration, and after the mark No. 2 is passed the strength of the vapour may be still more rapidly increased.

The anaesthetist should endeavour by gradual and judicious steps to reach the full strength of vapour before the patient has been re-breathing long enough to produce undue congestion and cyanosis. If he attempts to hurry through the earlier stages, the strong and pungent vapour will irritate, and so stimulate the mucus and salivary glands to secretion, and the patient will cough and rapidly become congested and cyanosed. The aim should be to gradually anaesthetise (paralyse) the nerve terminations in the respiratory mucous membrane, so that when this is attained the mucus glands are unaffected even when the most concentrated ether vapour is exhibited to them.

As soon as the full strength of vapour is reached, a breath of air may be admitted, for by this time the patient is sure to be showing signs of deprivation of oxygen. The administration must be continued, and a breath of air given every fourth or fifth breath of ether until the conjunctival reflex (see p. 149) is abolished. The administration may now be stopped provided an anaesthesia of no more than four or five minutes is required, but if a longer narcosis than this is necessary, the administration may be pushed until the corneal reflex (see p. 151) is also abolished; this procedure is, however, not recommended, and is attended by certain risks (see p. 152).

2. The Administration of Ether preceded by Nitrous Oxide.

In order to save the patient from the unpleasantness of inhaling ether, it has been a common practice to first abolish consciousness by a preliminary administration of nitrous oxide. When a light degree of anaesthesia has been thus produced, ether is first added to the nitrous oxide, and then substituted for it, and finally the anaesthesia is continued by its means alone. By this method the period of induction of anaesthesia is shortened, no discomfort is experienced by the patient, and the administration proceeds quietly and is rarely characterised by struggling or excitement.

The Apparatus.

The best apparatus to use for this method is the author's modification of Hewitt's nitrous oxide apparatus (see fig. 10) and Hewitt's modification of Clover's ether inhaler (see fig. 27) combined, as shown in the illustration (see fig. 28).

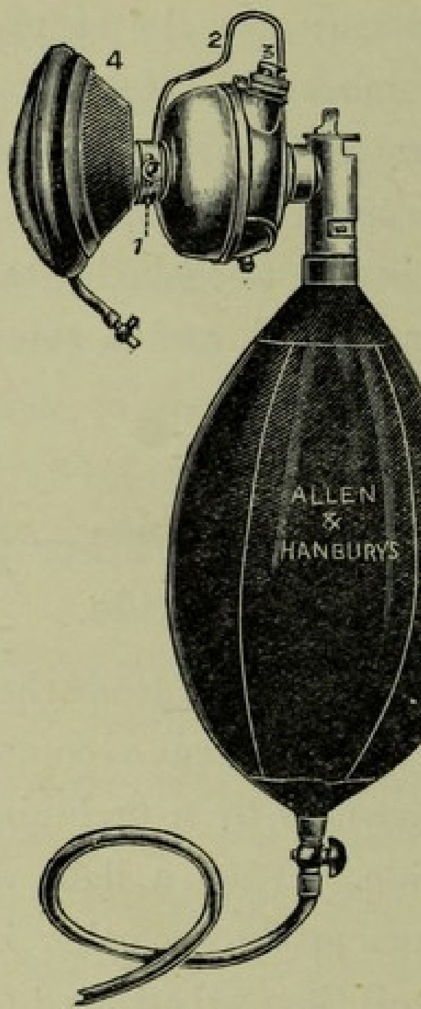


FIG. 28.—HEWITT'S LARGE-BORE INHALER, WITH GAS-BAG ATTACHED.

1. Metal tube (large bore) tunnelling ether chamber.
2. Indicator for registering the amount of ether the patient is inhaling.
3. Opening for filling ether chamber (shown with stopper *in situ*).
4. Face-piece which screws on to ether chamber and can be locked in any position.

The bag of the gas apparatus should be fitted with a vulcanite tap at its lower end, so that after it is filled with gas it may easily be disconnected from the tubing connecting it with the gas cylinders (see fig. 28). It is not necessary to have the small india-rubber bag usually sold with the Clover's apparatus, as the gas-bag can be made to serve all purposes required by the method, and india-rubber is expensive and quickly perishes unless in constant use.

The Administration.

All the usual preliminaries having been observed with regard to examination (p. 170) and posture of the patient (p. 174), the gas-bag is almost filled with gas. It must not be over-distended, or there will be an unpleasant rush of gas upon the patient's face when the gas is turned on at the stopcock. An ounce of ether is poured into the ether chamber, and the gas apparatus is then connected to it at one end and the face-piece at the other (see fig. 28). With the gas stopcock open to air only, and the indicator of the ether chamber pointing to 0, the anaesthetist should apply the apparatus to his own face and blow through it, to free it from any ether vapour that might be in the airways, the pungent taste and smell of which might cause discomfort to the patient. He should then inspire through the apparatus to see that the valves are acting properly. Everything else being ready and the patient in the required position, the apparatus may be gently applied (see p. 144); it should be held in such a way that its weight is borne by the anaesthetist's hand and not by the patient's face. The best way to hold the inhaler is with the face-piece between the thumb and index finger of the left hand, the ether chamber resting upon the back of the hand, and the gas-bag hanging down over his wrist. The remaining fingers of the left hand are thereby left free to support the chin and keep the jaw forward, and thus ensure a perfectly free air-way, on the maintenance of which the success of the administration largely depends. The anaesthetist's right hand supports the patient's head. If a free air-way be not maintained, and the jaw be allowed to fall backwards and carry with it the tongue, which may be sucked further into the pharynx, complete respiratory obstruction may result, with consequent congestion, cyanosis, jactitation, and all the signs of asphyxia. The anaesthetist should always hold in his right hand a Mason's gag, so that it is at once available should the necessity for its use arise.

The gas should not be turned on at the stopcock until the face-piece has been applied and is seen to be fitting accurately, as shown by the effective working of the valves. As soon as the patient is breathing quietly and naturally through the apparatus the gas may be admitted, the patient exhaling into the outside air until the contents of the gas-bag are reduced to about one-third. The valves should then be thrown out of action, so that to-and-fro breathing into the bag is enforced. After a few respirations the ether chamber should be rotated a quarter of an inch, as shown by the indicator, and the ether thus gradually admitted.

Thenceforward the strength of ether vapour may be increased with every breath by further slight rotation of the ether chamber, until the mark "F" is reached, indicating full ether. It is important to give sufficient gas and not to admit the ether too soon, for otherwise the patient may show intolerance of the pungent vapour, and may struggle, cough, hold his breath, or attempt to tear away the inhaler, or spasm of the glottis may be set up by the irritating vapour. The whole object of the preliminary administration of the nitrous oxide is to render the patient unconscious of the unpleasant features of ether inhalation; also to anaesthetise the nerve terminations of the respiratory mucosa, and thus render them insensible of the irritating action of the ether and unresponsive to its stimulation. If this be effectively carried out, the patient will neither cough nor struggle when the ether is turned on, and little or no mucus or saliva will be secreted. A certain amount of congestion and cyanosis are, however, inevitable accompaniments of the induction of anaesthesia by this method, and considerable experience is necessary to prevent their occurrence in excess.

If, on the other hand, signs of intolerance of the ether vapour are exhibited, the strength of ether must be reduced and only increased again when the respirations become deep, regular, and free.

As soon as "full ether" is reached the patient may be allowed a breath of fresh air, either by raising the face-piece during an inspiration, and then re-applying it so that the following expiration may enter the bag, or by opening the stopcock during an inspiration and closing it during the succeeding expiration. This procedure should be repeated every fourth or fifth breath to prevent undue cyanosis.

The administration of the ether should be continued until the conjunctival reflex (see p. 149) is abolished, as this will allow of four or five minutes succeeding anaesthesia. It should not be pushed to abolition of the corneal reflex, because the coughing reflex will in that stage also be in abeyance, with the consequent risk of blood or other foreign matter being inhaled, and causing immediate asphyxia, or subsequent injury to the lung.

If the ordinary type of Clover's inhaler be used and it be necessary to replenish the supply of ether, the apparatus must be removed from the face and the indicator moved to 2, or thereabouts, to provide an exit for the displaced air and prevent its otherwise bubbling up as fresh ether is poured into the chamber. This procedure is not necessary if Hewitt's wide-bore inhaler be employed. Before re-applying the face-piece the indicator should be turned back to less than 1, because the fresh ether will give off a stronger vapour than that last inhaled, and coughing may be thus excited.

Some idea as to the amount of ether in the chamber may be gained by feeling its temperature, for so long as it contains ether the lower half will remain cooler than the upper, but so soon as all the ether is used up, the whole ether chamber becomes warmed by the patient's breath. The glass-domed cap to the stopper of the ether inlet is also intended for showing whether there be any ether in the chamber, and its quantity may be gauged by the amount of tilting required to make the ether run into the glass dome of the stopper.

The signs of anaesthesia and other details connected with the narcosis produced by this method are the same as those produced by ether alone, and are discussed under that head (see pp. 186 *et seq.*).

Owing to the shorter period of induction of anaesthesia by this method, unpleasant after-effects are less commonly met with than after the administration of ether alone. The method is, however, more difficult to apply successfully than the administration of ether alone, and is therefore not recommended unless an experienced anaesthetist be available.

This method is not recommended for children, for whom ether preceded by ethyl chloride or by the chloroform and ether mixture (CE_2) will be found more suitable. The CE_2 mixture administered throughout is, in the author's opinion, preferable in these cases.

3. The Administration of Ether preceded by Ethyl Chloride.

The administration of ether for the production of anaesthesia is not infrequently preceded by ethyl chloride, owing to its being more pleasant to inhale than ether alone, and owing to the fact that the induction of anaesthesia (by its means and in a closed inhaler) is more rapid with any other anaesthetic.

By the adoption of this method the patient is saved the unpleasant consciousness of the smell, pungency, and irritating properties of the ether. Its advantages over the preliminary administration of nitrous oxide are that it acts more rapidly, it does not produce cyanosis or other signs of asphyxia, and that the subsequent exhibition of the ether does not need to be gradual, full doses can be given from the outset, since ethyl chloride rapidly abolishes the laryngeal reflex; consequently the patient does not cough when a concentrated ether vapour is presented to him.

The method is more easy of application than the combination of gas and ether, but the disadvantage is that it is more dangerous (see ethyl chloride, pp. 131, 132). The method is a good one for anaesthetising children on account of the rapidity with which consciousness is abolished; it is useful also when a longer anaesthesia than can be obtained by gas and oxygen is required. The addition of ether upon the ethyl chloride produces a considerably longer anaesthesia than can be obtained with ethyl chloride alone.

The Apparatus.

The simplest apparatus is Carter-Braine's modification of Ormsby's ether inhaler (see fig. 22).

The mixture may also be given by means of a Clover's inhaler, by either of two ways :

(1) By *putting the required dose of ethyl chloride into the bag,* and allowing the patient to breathe to and fro into the bag five or six times before turning on the ether and completing the anaesthesia in the usual way.

(2) By *putting the required dose of ethyl chloride into the ether chamber,* and producing a light degree of anaesthesia with it, and then pouring the ether into the chamber and proceeding with the ether administration in the usual way (see p. 186).

The Administration.

This latter method has the advantage over the former in being somewhat more gradual, but it also has the disadvantage that the course of the administration has to be interrupted for the ether to be poured in, the inhaler meanwhile having to be removed. During this interruption the patient necessarily inhales a few breaths of air, in consequence of which the anaesthesia may be so lightened that he may show some intolerance of the ether when this is applied.

The administration by the method of pouring the ethyl chloride into the bag. The patient having been properly prepared, examined as to his fitness for taking an anaesthetic, and placed in the chair, the dose of ethyl chloride that will probably be required is poured into the bag.

In deciding as to how much will be an appropriate dose, the anaesthetist is guided by the patient's weight, muscular development, and state of health (see p. 133), bearing in mind that alcoholic persons will require more than others, that a plethoric person will need more than one suffering from anaemia, and that children need least of all.

A suitable prop must invariably be placed between the patient's teeth, the Mason's gag held in the anaesthetist's right hand, and the tongue forceps fixed conveniently upon his coat before the administration is begun.

The patient is now instructed to take a breath of air and exhale into the apparatus, care being taken meanwhile to accurately fit the face-piece. In this way the ethyl chloride vapour is diluted, and can thereafter be inhaled without discomfort. Re-breathing is allowed to continue for about half a minute, and as soon as the patient is breathing freely, deeply, and without embarrassment, the ether chamber may be rotated so that the patient's breath is made to pass through it and mix with the ether vapour. This must be done gradually at first, but as tolerance of the irritating vapour is established it may be more and more rapid, the aim being to reach "full ether," by the time the signs of full anaesthesia, viz. stertor, fixity of the globes of the eyes, dilated pupil, and loss of ocular reflexes, have manifested themselves, this being accomplished without undue congestion. If, however, the patient coughs or shows other signs of intolerance of the ether, the ether chamber must be turned back again, and the strength of vapour thus reduced for a few breaths longer, until tolerance is properly established. In forming judgment upon this point the time factor is a helpful guide, for it may safely be assumed that if the patient do not exhibit some sign of anaesthesia by the time the administration has lasted 60 seconds, either the face-piece has not been fitting properly and too much air has been allowed, or that he is an abnormal patient and has a peculiar resistance to the action of ethyl chloride. In either case a further dose must be sprayed into the bag, and the inhaler immediately re-applied.

In conclusion, the author may state that he considers this method has a very limited field of usefulness in dental surgery; that he does not recommend it, but prefers the CE_2 mixture, administered throughout, to those patients requiring a longer anaesthesia than that which can be produced by ethyl chloride alone.

4. The Administration of Ether preceded by Mixtures containing Chloroform.

Either the chloroform and ether mixture (CE_2) or the alcohol, chloroform and ether mixture (ACE) may be used (see p. 230).

The administration of ether is preceded by chloroform containing mixtures, on account of their being more pleasant to inhale, and because they are very much less irritating than ether alone. The objective is to gradually render the nerve terminations in the respiratory mucous membrane insensitive, so that the irritating vapour of ether may be subsequently administered without producing stimulation of the salivary and mucus glands. When ether alone is given these glands rapidly become congested, secrete freely and give rise to respiratory obstruction, with consequent engorgement of the lungs and right side of the heart.

The Apparatus.

Either the author's inhaler (see fig. 24), or a Rendle's mask (see fig. 33), or Braine's modification of Ormsby's inhaler (see fig. 22) may be used. The first is to be preferred in young children, as any form of bag-inhaler is more likely to frighten them and is open to objection, owing to the delimitation of oxygen incurred in their use. It must furthermore be remembered that there is a distinct element of danger in administering chloroform containing mixtures by means of a bag-inhaler, and if a Braine's inhaler be adopted throughout the administration, the air valve must never be closed so long as the chloroform containing mixture is being given.

The Administration.

The patient must be placed in the recumbent posture with one shoulder slightly raised, so that the head may be turned to one side without twisting the neck and obstructing the air-way, and in order that blood and saliva may drain freely from the mouth (see plate VI.). If a Rendle's mask be used, care must be taken in the choice of the sponge. This should be a honeycomb sponge, and should not fit the inhaler too tightly, lest its air channels become compressed and respiration through it be rendered difficult. A suitable quantity of plain sterile gauze may be used in preference as it can be burned after the administration, a fresh portion being used for each case. For the details of the administration see pp. 233 and 234.

As soon as the second stage of anaesthesia is reached, the Braine's inhaler should be substituted for the Rendle's mask, and pure ether for the chloroform and ether mixture (CE_2). In this way the anaesthesia is rapidly deepened, and all struggling and excitement are obviated. The administration of ether should be continued until the conjunctival reflex is abolished (see p. 189) when the administration should be discontinued. In a normal patient the resulting anaesthesia should last four or five minutes, and this will generally be found sufficient for all ordinary dental operations. If, however, a more protracted anaesthesia is desired, it may be continued either by re-applying the inhaler with a fresh dose of ether, after swabbing out the mouth, or preferably by the cautious administration of chloroform by means of a Junker's inhaler and mouth tube, provided the patient be maintained in the recumbent posture (see plate VI.).

Recovery.

Recovery from an administration of ether depends directly upon the duration of the administration and the depth of anaesthesia produced. A short administration and the production of a light degree of narcosis only will generally be followed by a rapid recovery free from unpleasant after-effects. But since all anaesthetics are poisons, and therefore lower the vitality of the patient to whom they are administered, the ultimate effects of the poison will depend upon its dose and the length of time during which it is given. During the course of the patient's recovery of complete consciousness he passes inversely through the same stages as those traversed in his progress towards narcosis, the reflexes being regained in an inverse order.

The effect of anaesthetics in general is to inhibit metabolism, *i.e.* the production of heat is impaired, if not entirely suspended, and as the patient continues to lose heat, he will easily become chilled during the operation or subsequently until the recovery from the anaesthetic is complete. It is therefore of the greatest importance to keep patients warm after the administration of an anaesthetic, and protect them from cold during an operation. All operative manipulations involve some shock, and if in addition to the poisonous effects of the anaesthetic the patient be exposed to cold, his vitality will be further impaired.

During the last stages towards recovery the patient will often be able to do what he is told and answer questions apparently intelligently, but may lapse into intervals of semi-consciousness during which he may talk absolute nonsense or speak of personal matters he would not have mentioned while in possession of all his faculties. He is in this stage still suffering from an intoxication, and should be left very quiet ; it is better that his friends should not see him until he is fully conscious, and that he be left in the care of a nurse. Patients will usually retain no recollection of incidents occurring during the process of their recovery of consciousness, but may form all sorts of ideas and misapprehensions based upon overheard and misinterpreted conversation : no talking should therefore be allowed in the patient's room.

After-effects and their Treatment.

The after-effects of anaesthetics in general have been already considered (see pp. 86 and 161), but there are some after-effects peculiar to ether, such as *vomiting*, *nausea*, *headache*, *faintness* and *gastric catarrh*, *lithaemia* or even *albuminuria*.

Vomiting. After a short dental operation vomiting is not very common, and if it occurs is generally slight. It is usually produced by the patient having swallowed blood or saliva saturated with ether during the period of unconsciousness ; a tumblerful of hot water with half a teaspoonful of bicarbonate of soda or a teaspoonful of Worcester sauce will in most cases be found an effective remedy. The onset of vomiting may often be prevented if the patient be allowed to lie down for an hour immediately after the administration. This is always desirable, as it must not be supposed that the profound changes in the nervous system produced by anaesthetics can be instantly recovered from, and that the patient can at once safely and comfortably resume his ordinary occupations as if nothing had occurred. He has, in fact, been subjected to a considerable strain and shock, from which rest is the best aid to recovery.

Nausea and *headache* are generally of quite short duration, and are often cured by a cup of tea without sugar or milk, but with a slice of lemon. If, however, the symptoms persist ten grains of aspirin (acetyl-salicylic acid) may be given, followed by a wineglassful of hot water, the patient being advised to remain lying down until relieved.

Faintness. This is seldom severe, and may be cured by inhalation of nascent ammonia, produced by the ampoules supplied by Burroughs and Wellcome, or by a teaspoonful of sal-volatile in water containing 10 drops of tincture of nux vomica. A cup of hot bovril or other meat extract will sometimes be preferred, particularly if the patient has been fasting for several hours. A hypodermic injection of strychnine sulphate (gr. $\frac{1}{60}$) may be given.

Gastric catarrh sometimes follows a more prolonged administration of ether. It is characterised by nausea and sometimes by vomiting, foul tongue, unpleasant taste in the mouth, loss of appetite, and general feeling of malaise. It is often produced by the ether having been pushed too rapidly, causing excessive secretion of saliva, which, becoming saturated with ether, is swallowed, and acts as an irritant to the gastric mucous membrane. The patient should be recommended to restrict himself to a fluid diet and take a mixture containing bismuth and the alkalies combined with a bitter stomachic and nux vomica administered half an hour before food.

Lithaemia and *albuminuria* are characterised by diminished excretion of urine, of high colour and loaded with urates. It is due to derangement of the functions of the liver and damage to the renal cortex resulting from the excretion of the ether. It is accompanied by headache and feelings of exhaustion and irritability. It should be treated by flushing out the kidneys, liver, and bowels by copious draughts of hot water, or with Vichy or Contrexeville water, and by a simple diet, free from sugar and salt, low in the carbo-hydrate content, and consisting chiefly of some easily digested proteid, *e.g.* junket, milk jelly, fish, a lightly boiled egg, or minced chicken. Alcohol and condiments should be forbidden.

Difficulties and Dangers and their Treatment.

Difficulties and dangers of anaesthetics in general are discussed on pp. 68–86; those which are specially liable to arise during an administration of ether are *spasm of the glottis*, *respiratory obstruction*, *respiratory failure*, *vomiting*, and *profuse salivation*. *Collapse* sometimes supervenes during recovery, but may be avoided by keeping the patient warm, and not allowing him to move too soon after the operation.

Spasm of the glottis may be caused by the presentation of too concentrated a vapour, or by the inhalation of saliva or other foreign matter. It is best treated by measures which stimulate respiration, *e.g.* ammonia held to the nostrils, smacking the patient's face or chest with the end of a towel wrung out of cold water, by tongue traction with forceps, or by passing the finger into the patient's throat and hooking forward the base of the tongue and epiglottis.

Respiratory obstruction is most commonly due to spasm of the glottis, but may result from cyanosis and congestion causing engorgement of the tongue and clenching of the jaws, all of which hinder oral breathing; it may also be produced by too strong a vapour, by too protracted re-breathing into the bag, or by the inhalation of foreign matter. It is treated by opening the mouth and drawing forward the tongue, by respiratory stimulation (see above), by artificial respiration, or as a last resort by tracheotomy.

Respiratory failure may occur if the administration of the ether be pushed to abolition of the corneal reflex together with dilatation of the pupils. The administration must be at once stopped, and artificial respiration with oxygen resorted to, if simple compression of the lower ribs and abdomen prove ineffective. Cardiac stimulants are also called for, or cardiac failure will quickly supervene upon failure of the respiration.

Vomiting and *profuse salivation* are usually preceded by rather violent swallowing movements. The inhaler must be removed, and the patient bent forward in the chair with his mouth open so as to aid the escape of the vomit or excess of saliva, which might otherwise be inhaled and set up laryngeal spasm. Unduly protracted induction of the early stages of anaesthesia may lead to vomiting during the administration ; insistence upon three or four hours' abstention from food before the anaesthetic is given will limit the frequency of its occurrence.

After the administration any ether remaining should be emptied out, and the apparatus washed through with warm water, then with a weak antiseptic and finally with plain water. It should then be hung up to drain and dry.

CHAPTER VII.

CHLOROFORM.

Varieties.

Three varieties of chloroform ($CHCl_3$) may be used for inhalation anaesthesia, they are made respectively from *ethylic alcohol*, from *methylated spirit*, and from *acetone*, and are now produced in so pure a quality that either may be used with equal safety. Chloroform is prepared from ethylic alcohol by distilling with water, calcium hypochlorite (bleaching powder) and calcium hydrate (slaked lime). The impure product derived after distillation is carefully purified by washing with water and then with strong sulphuric acid, it is finally re-distilled and collected. About 1 per cent. of alcohol is added to preserve it, for pure chloroform rapidly becomes acid, and gives off irritating vapours.

The safety of the chloroform depends largely upon the care bestowed upon its purification and less, if at all, from the three sources from which it may be obtained. The chloroform produced from pure alcohol is more expensive than that made from methylated spirit, but the anaesthesia produced by the one variety is indistinguishable from that produced by the other. Some anaesthetists state that the chloroform made from methylated spirit produces after-sickness more frequently than that made from pure alcohol; no such dictum has yet been supported by facts.

Chloroform made from acetone differs somewhat from that made from alcohol. The latter contains about 0·25 per cent. of ethyl chloride, which is sufficient to produce an observable clinical effect, although that effect is but slight and is generally overlooked. Even this small percentage of ethyl chloride has a stimulating effect, and patients anaesthetised with chloroform containing it generally present a better colour during induction, and pass into a condition of unconsciousness more rapidly and quietly than when acetone chloroform is used. The author has made numerous experiments with mixtures of chloroform containing various proportions of ethyl chloride with a view to producing a mixture that would act more rapidly and precisely than chloroform alone, and would by its stimulating action prevent or retard the fall of blood pressure otherwise incidental to chloroformisation. A mixture containing one part of ethyl chloride in sixteen of chloroform (*i.e.* half a drachm to the ounce) was found to be the best for this purpose, and the author now uses that mixture in preference to pure chloroform. These results were published in a paper read before the Chelsea Clinical Society.[1]

[1] See *Medical Magazine*, Feb. 1906.

Characters.

The chloroform of the British Pharmacopoeia prepared from pure alcohol contains a small proportion (0·5 per cent.) of rectified spirit to preserve it, and has after this addition a specific gravity of 1·4. Its vapour density is four times greater than air. A bottle of chloroform will therefore feel very much heavier than a bottle of ether of the same size, so that, even in the event of a bottle being wrongly labelled, the anaesthetist should be warned of the mistake by its weight. The mistake would not much matter if ether were being given instead of chloroform, but would probably prove fatal were chloroform put in a closed ether inhaler instead of ether. Not less than 40 to 50 per cent. of ether vapour in the inspired air are required to anaesthetise a patient with that drug—indeed, the percentage often rises to 60 per cent. or 70 per cent. in a Clover's inhaler, when the indicator is turned to "full"; whereas any percentage of chloroform above 4 per cent. is dangerous, and should never be exceeded even during the induction of anaesthesia. A half per cent. of chloroform vapour in the inspired air is sufficient to maintain anaesthesia when once established.

Chloroform is easily decomposed if exposed to sunlight and heat; it must be stored in a cool, dark place, and kept in orange-tinted bottles, as this colour excludes the actinic rays of white light. In order to test its purity before use a little should be poured into the anaesthetist's hand and the vapour inhaled. If there be no unpleasant smell, and if no residue remain after evaporation, the chloroform may be considered pure. If, however, it leaves a greasy stain on evaporation or smells of chlorine or garlic, or is unpleasant to inhale, or excites cough, it should be discarded.

Advantages and Disadvantages.

Chloroform produces an almost ideal type of anaesthesia in any patient, and were it not for its extremely lethal properties, the drug would have come into general favour as an anaesthetic in all dental cases except those which require an anaesthesia of only a brief duration. But on account of its peculiar action as a heart muscle poison, and the rapidity with which it causes cardiac failure, as well as its anodyne influence upon the nervous system, it is too dangerous a drug to use for trivial operations, or even for those of a more serious nature, if any other suitable anaesthetic agent is available. It is a very satisfactory anaesthetic for young children and for old persons with rigid chests and a tendency to bronchitis or emphysema ; in cases of goitre, or of inflammation about the respiratory passages, for instance, alveolar abscess, angina Ludovici, septic tonsillitis, and diphtheria ; in cases of abnormally high arterial tension, and in aneurism.

Chloroform is the most suitable anaesthetic with which to continue or prolong anaesthesia during operations upon the mouth, which last too long for a single administration of ether to suffice. The patient is stimulated by the ether, and will thus be less susceptible to the depressing action of the chloroform, and there is consequently less risk in administering it in this sequence ; only very small doses are necessary to maintain the anaesthesia once induced. The chloroform vapour is conveniently supplied by means of a Junker's apparatus, through a small mouth tube, which does not get in the way of the surgeon during the operation (see plate VI.). The author considers this method of prolonging anaesthesia preferable to the intermittent administration of ether.

Precautions to be observed before the Administration of Chloroform.

Unless the case be necessarily one of emergency, it is advisable to prepare the patient for the administration of chloroform a few days before the operation. He should be advised to regulate the action of the bowels, to refrain from smoking, except in the strictest moderation, and to take a heart tonic such as ten minims of tincture of nux vomica, with five minims of standardised tincture of strophanthus three times a day. The patient should be advised to take his ordinary meals at the usual hours, and the time of the operation should be fixed about half an hour before the accustomed time of a meal. In this way, the patient is not weakened by a period of starvation, and yet his stomach may reasonably be expected to be empty, so that there is little risk of vomiting occurring during anaesthesia. All clothing should be loosened about the neck, chest, and abdomen. After the patient has once been placed in the position chosen by the surgeon, in consultation with the anaesthetist, he should not be raised from that position during the administration, lest the increased load thrown upon the heart produce a condition of fatal paralytic dilatation.

The condition of the pulse must be carefully noted before the administration is begun, in order that the amount of cardiac depression may be estimated, should this occur during anaesthesia.

Apparatus.

Until the last few years it was thought that chloroform could be safely administered without any special form of apparatus. The simplest form of mask, merely a bent wire frame covered with lint or flannel, or even a folded towel or handkerchief, upon which the chloroform was sprinkled, was until recently considered all that was necessary as a means of administering one of the most deadly drugs in the pharmacopoeia. As a natural result of this unscientific and inaccurate method of dosage many patients lost their lives. The mortality, indeed, became so high that various commissions have from time to time been held with a view to discovering whether a safer method of administration could not be found. Finally, Mr. Vernon Harcourt, late Professor of Chemistry and Physics at Oxford University, devised an apparatus for the dosimetric administration of chloroform, which in its most recent form is extremely accurate and comparatively simple in construction (see fig. 29).

The principle of the apparatus consists in making the patient's inspirations pass by means of valves over the surface of the chloroform, contained in a vessel of a certain sectional area, the expirations passing directly into the outside air. Since the inspired air, while passing over the surface of the chloroform, will invariably absorb a definite amount of chloroform vapour at each breath, provided the temperature remains constant, the percentage of chloroform evaporated at each inspiration can be exactly regulated by the mechanism —the risks of overdose are therefore reduced to a minimum, for the apparatus is so constructed that it cannot deliver more than 2 per cent. of chloroform vapour in the inspired air. The space of this book will not admit of a detailed description of the apparatus, but this can be obtained from the makers, Messrs. Griffin and Co., of Aldwich ; the illustration sufficiently indicates its form. The author merely wishes to impress upon the reader the extreme importance of accurate dosage when administering this powerful drug ; he is convinced that this cannot be done with anything like the same accuracy by means of a mask and drop bottle, as is made possible by the apparatus above mentioned, or by other inhalers which have been designed with the same end in view by Waller,[1] Levy,[2] and Hilliard.[3]

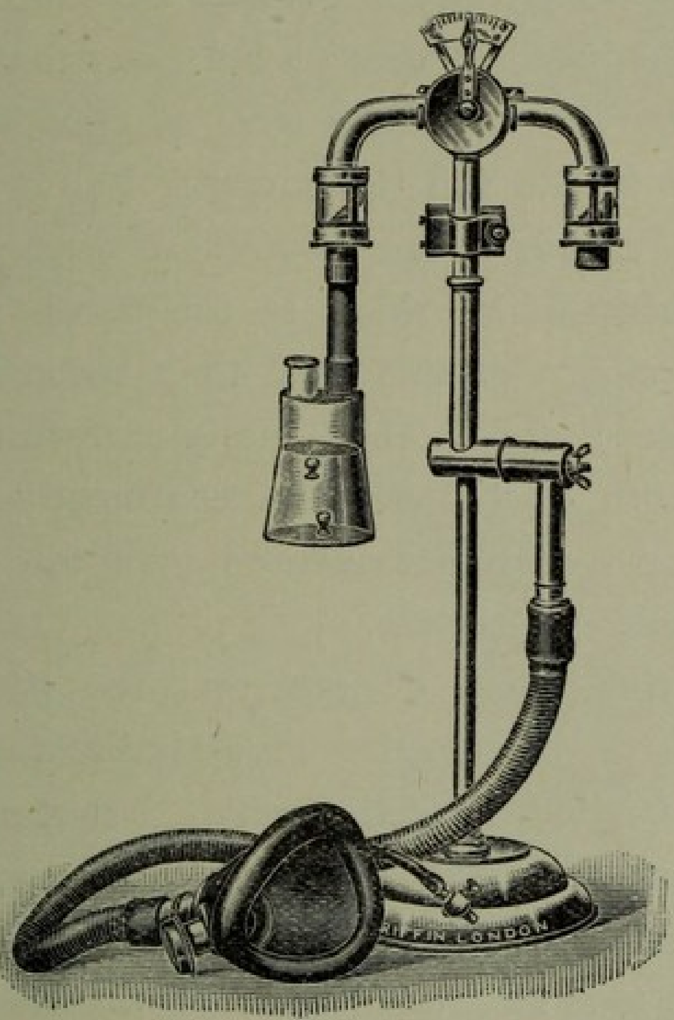


FIG. 29.—VERNON HARCOURT'S REGULATING CHLOROFORM INHALER.
Showing index pointing to 1 per cent. on scale.

The percentage of chloroform vapour in the inspired air should never exceed 4 per cent., and this strength of vapour is never necessary except during the induction of anaesthesia, and should be reduced to 2 per cent., or less, as soon as anaesthesia has been established. In

[1] See *Med.-Chir. Trans.* 1905, lxxxviii., pp. 685–690.
[2] See *Lancet*, May 27, 1905. [3] See *Lancet*, July 29, 1905.

most cases 0·5 per cent. of vapour will be found sufficient to maintain anaesthesia, for as soon as the tissues have been saturated with chloroform vapour and anaesthesia is complete, it is only necessary to administer that amount of chloroform which would be exhaled at each breath, if the administration were stopped, and thus to balance the intake and the output. If, for instance, a 2 per cent. vapour in the inspired air were required to produce anaesthesia—owing to the tissues storing up a certain amount of this until they become saturated (anaesthetised), and if then the administration of the same strength of vapour were continued—the tissues would become over-anaesthetised (overdosed), and the patient would quickly die.

During the period of induction the percentage of chloroform vapour exhaled at each breath, compared with that inhaled, is at first small, but gradually rises until by the time full anaesthesia is established the amount exhaled nearly equals that inhaled. This is due to the fact that the blood and the tissues at first store up a larger proportion of the chloroform from the inhaled vapour and thus less is exhaled, but as they become saturated, a smaller percentage of the inhaled vapour is so stored, and thus relatively more is again exhaled. It is imperative, therefore, to reduce the strength of vapour as soon as the required degree of "saturation" is reached.

The percentage of chloroform evaporated from an ordinary mask and mixed with the inspired air has been

PLATE VI.

CHLOROFORM ANAESTHESIA MAINTAINED BY A JUNKER'S MOUTH TUBE.

Showing position of patient and anaesthetist. Mouth gag *in situ* and mouth tube introduced between its opened blades.

[*To face page* 216.]

estimated to be about 4 per cent., provided the mask fit the face loosely and there be free dilution of air around it, and the chloroform be allowed to evaporate freely from the outside surface ; but if this free dilution be prevented, the percentage of vapour rapidly rises, and the risk of overdose is incurred.

Another form of apparatus in common use, and one that is very convenient in dental surgery is the Junker's inhaler (see fig. 30 and plate VI.), for with it, by means of a mouth tube, the administration may be continued after removal of the face-piece, and while the operation is in progress. In this apparatus air is pumped, by means of hand-bellows, through a tube, the end of which is immersed in a bottle containing chloroform, and the mixture of chloroform vapour and air is delivered through a separate tube in the stopper of the bottle connected with a mask or a mouth or nasal tube. The size of the bellows is such that when fully compressed approximately 4 per cent. of chloroform vapour is delivered. The author has devised a foot-bellows (see fig. 30) for use with this apparatus, which is convenient when the anaesthetist's hands are occupied in holding a gag and supporting the patient's head during an operation. A special form of mask is supplied with the apparatus, consisting of a dome-shaped wire frame covered with flannel, beneath which is fixed the delivery tube, the extremity of which is pierced by a series of small perforations. A better form of mask is Vajna's, modified by Buxton (see fig. 31), which is made of a deep frame of hardened glass shaped to fit the face. Its open side is traversed by the perforated delivery tube, and

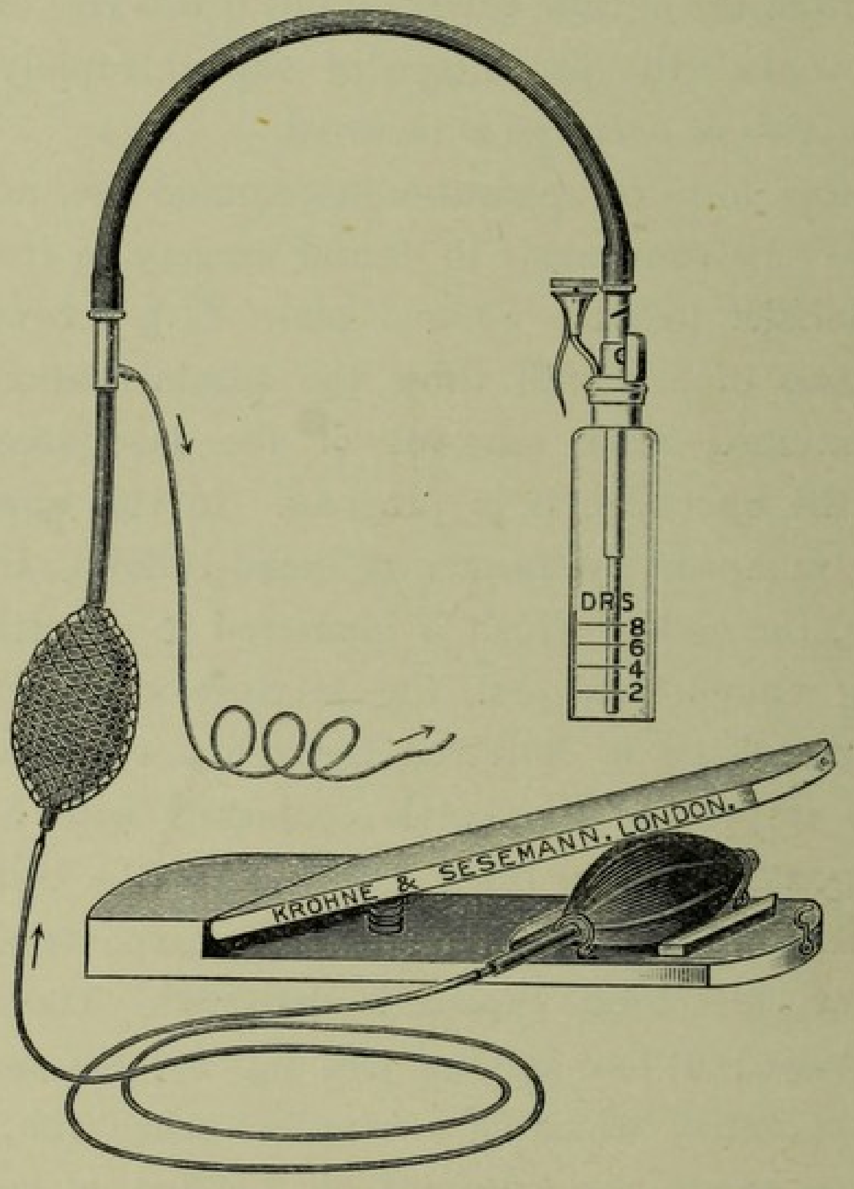


FIG. 30.—JUNKER'S CHLOROFORM INHALER.

Showing the apparatus fitted with Hilliard's foot-bellows in place of the ordinary hand-bellows.

over this is fixed a hinged wire frame, by means of which gauze, or lint, or other suitable material, may be stretched over the open side of the mask. If the quantity of chloroform delivered by the bellows prove insufficient to induce anaesthesia, extra chloroform may be sprinkled upon the gauze.

The best form of mouth-tube is a short length of ordinary "compo" pipe—of small calibre, such as is used by gas-fitters. Being soft and flexible it can

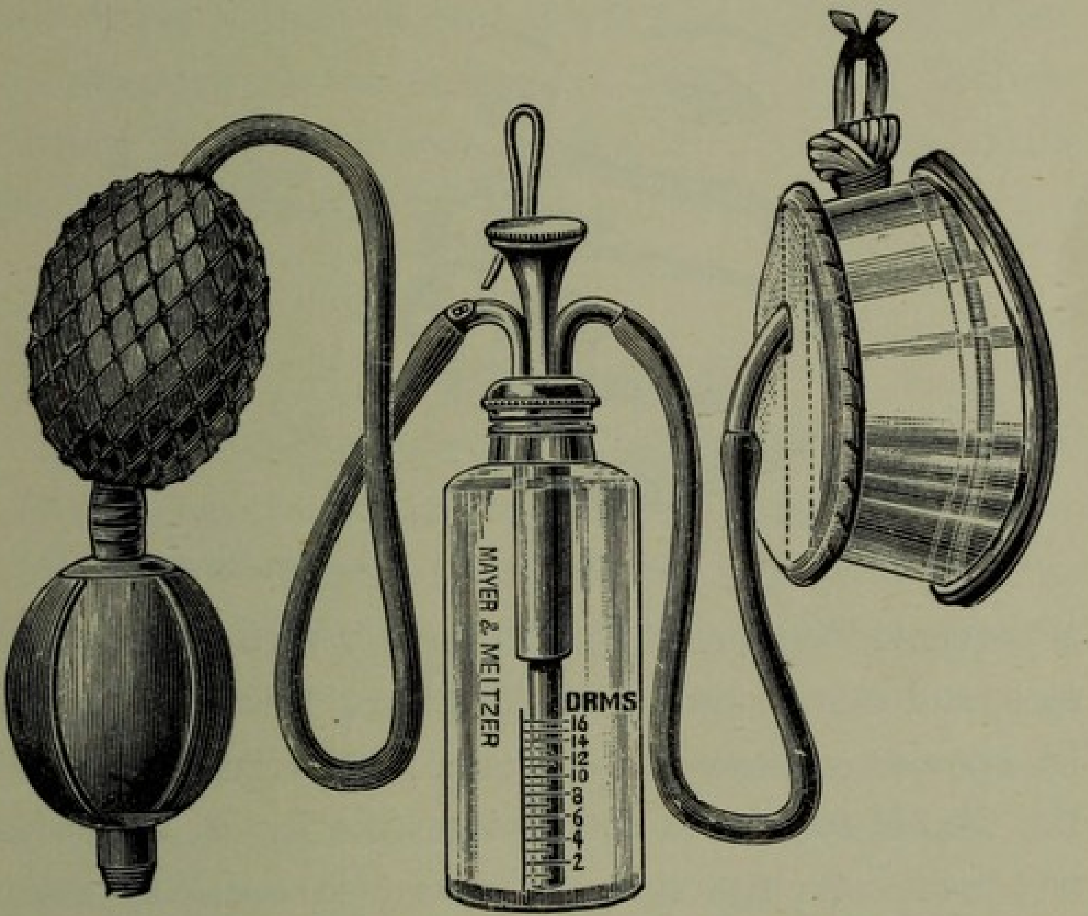


FIG. 31.—BUXTON'S MODIFICATION OF VAJNA'S CHLOROFORM INHALER.

easily be made to fit round the side of the patient's head, and thus be self-retaining.

The best form of open mask for use with chloroform is that known as Schimmelbusch's mask as modified by Dr. Dunkley[1] (see fig. 32). It is an improved form of the original Skinner's mask, which was merely an oval

[1] *Lancet*, July 29, 1911.

wire frame, over which flannel was stretched by means of two wires crossing the frame at right angles in the form of a dome. Dunkley's mask is more convenient, as with it fresh gauze or lint can be used for every case, and by means of the trough-shaped frame, the gauze

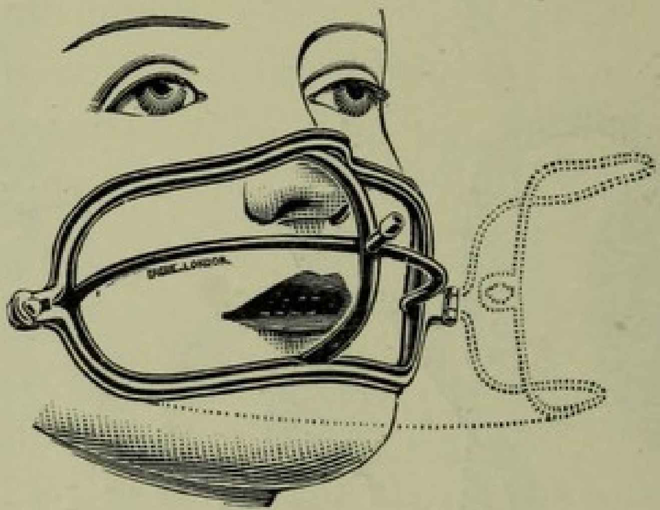


FIG. 32.—DUNKLEY'S MODIFICATION OF SCHIMMELBUSCH'S MASK.

is prevented from coming into contact with the patient's face, and thus there is no risk of burn, even if the gauze be allowed to become too wet. In the Skinner's mask the flannel surrounds and incloses the frame, and when wet will burn the skin if allowed to come into contact with it.

Posture.

The patient should always be placed in the recumbent or semi-recumbent position, on account of the depressing action of chloroform upon the heart and vasomotor system. One shoulder should be raised, so that the head may be turned to the opposite side without unduly twisting the neck, and thus obstructing the trachea (see plate VI.). This posture enables blood and saliva to drain out of the angle of the mouth, and prevents it gravitating backwards with the risk of causing respiratory spasm or obstruction; consequently the necessity for sponging out the mouth does not arise. The patient must never be moved during the administration of the anaesthetic from the posture at first assumed, lest circulatory failure be brought on by the extra strain thrown upon the heart.

The Administration.

If a Schimmelbusch's mask be used, it must not be held too close to the patient's face at first, and only a few drops of chloroform should be sprinkled upon it. The aim should be to present to the patient a gradually increasing strength of vapour, and as tolerance is established, to bring the mask into closer contact with the face. If too strong a vapour be presented, the patient will hold his breath and struggle; whereas, if the drug be administered gradually, a normal patient will pass into a condition of narcosis quietly and without resistance. The mask may be allowed to rest lightly on the bridge of the nose from the beginning, so long as it is held at an angle away from the mouth—in this way irritation of the eyes will be avoided while the patient exhales the vapour. The mask should always be moved away from the face, during an expiration, when fresh chloroform is to be applied; in this way there is no risk of the chloroform dropping through the gauze or lint upon the patient's face. The chloroform should never be poured on in such quantity as to drip off the lint upon the face, or even to wet the lint as far down as the margins of the inhaler, for if lint wet with chloroform rests upon the skin, a severe burn will be caused at the point of contact.

The induction of anaesthesia must never be hurried; ten minutes should be allowed. Sudden increase in the strength of vapour presented to the patient must be avoided, since this is the most common cause of inhibition of the heart. If the patient hold his breath, the inhaler must be removed until normal breathing is resumed; brushing the lips lightly with a towel will stimulate respiration temporarily withheld. After holding the breath the succeeding inspiration is always a deep one, and were fresh chloroform to be poured upon the mask while the breath is being held an overdose might easily be administered, when the next breath is taken.

During the administration of the anaesthetic and during the operation, it is of paramount importance to maintain a perfectly free air-way, for unless this precaution be observed, respiratory obstruction results, the intra-thoracic pressure rises, the blood absorbs a greater proportion of the percentage of chloroform in the alveolar air, and the patient may become quickly overdosed and die from uneliminated chloroform.

Respiratory obstruction is invariably associated with right-sided engorgement or dilatation of the heart, and if this condition be allowed to occur during an administration of chloroform, the heart muscle may be so depressed by the action of the drug that it may be unable to contract upon the abnormal quantity of blood in the heart chambers, and fatal syncope may result.

If struggling complicates the administration, the inhaler should be removed until the struggles subside, and although the patient is usually not fully conscious when struggling begins, he may be soothed by being spoken to in a quiet tone. When normal breathing is again established, the administration should be resumed, and if then the patient again struggle, he should be rapidly tided through this stage of excitement by increasing the strength of vapour, or by sprinkling pure ether on the mask for a few breaths.

The best guide as to the progress of the anaesthesia is the respiration, which becomes regular and more deep as consciousness is abolished; it is characterised by a faint stertor. Sometimes, however, the respiration becomes very light and inaudible, and this indicates one of two conditions, either too light or too deep an anaesthesia. If too light, the patient is probably merely in a condition of sleep, and would be awakened by any painful operation; in this condition the pupils are small and the lid reflex brisk. The pupils may be even pin-point in size, and this indicates threatened impending vomiting; if, however, they be found to be widely dilated, although the lid reflex remains brisk, the patient is immediately about to vomit. In either case the lips should be briskly rubbed with a towel, and the strength of chloroform increased. If the pupils be found dilated and the lid reflex absent, this indicates too deep an anaesthesia ; the inhaler must be immediately removed, and the lips rubbed to stimulate respiration ; the inhaler must not be re-applied until the pupils have again contracted and the lid reflex restored.

The greatest care must be taken to maintain a free air-way throughout the administration, since even momentary respiratory obstruction produces pulmonary engorgement, which is recovered from with difficulty, and embarrasses the heart, the action of which is already depressed by the chloroform. The least lividity or congestion indicates obstructed respiration, which must be relieved as soon as observed.

Signs of Anaesthesia.

In deep chloroform anaesthesia the patient should present a good colour, and the narcosis should resemble normal sleep. The respirations are quiet, regular, and sleep-like, the pulse steady and somewhat slower and softer than normal. The muscles are relaxed and flaccid, and the conjunctival reflex is absent. The pupils should be somewhat smaller than normal, but remain active to light. It is never necessary in dental surgery to push the anaesthesia beyond this point, and if the pupil be dilated, the corneal reflex absent, respirations shallow, the pulse depressed, and the patient pallid, these signs indicate that the danger zone has been entered, and if the administration be persisted in, the patient will succumb.

In using a Vernon Harcourt regulating inhaler (see fig. 31), the success of the administration depends upon an accurately fitting face-piece, for if leakage be permitted, the maximum strength of vapour (2 per cent.) delivered by the machine will be insufficient to induce anaesthesia. The administration is begun, as with a mask, by allowing the patient to breathe only air at first until he has become accustomed to the inhaler and the new conditions of respiration. When breathing is regular the chloroform may be turned on, and the strength of vapour gradually increased by means of the stopcock, upon which the percentage of vapour delivered is automatically indicated. The time taken to induce anaesthesia with this inhaler is somewhat longer than when an ordinary mask and drop bottle are used ; fifteen minutes should be allowed for the induction period, although the patient should be able to tolerate the full strength of vapour (2 per cent.) at the end of five minutes.

The method of inducing anaesthesia by means of a Junker's inhaler is not recommended, but it is an extremely useful apparatus for continuing, by means of a mouth tube, the narcosis previously obtained by ether. In using the Junker never more than one ounce of chloroform should be placed in the bottle, and the anaesthetist should assure himself that the bellows and delivery tube are properly fixed to their respective tubes in the stopper of the bottle; for should the bellows by mistake be fixed to the delivery tube of the bottle, and the delivery tube to the bellows tube on the bottle, pure chloroform would be squirted into the patient's throat with the risk of instant death.

Difficulties and Dangers and their Treatment.

Special difficulties and dangers may arise during an administration of chloroform; these are *persistent struggling*, *vomiting*, *respiratory failure*, and overdose characterised by *syncope*.

Struggling. If this be more persistent than the slight struggling already referred to, it calls for special treatment. It usually occurs in alcoholic subjects, or those addicted to the excessive use of drugs or tobacco. Rather than run the risk of overdosing the patient by greatly increasing the amount of chloroform given, it is better to change the inhaler for a few breaths, and give chloroform and ether mixture (CE_2), or ethyl chloride in a closed inhaler, the Ormsby (see fig. 24) being the most convenient. As soon as the struggling subsides and the breathing becomes regular, the administration of pure chloroform upon an open mask may be resumed. There is considerable risk of heart failure during struggling, for during the struggles the breath is held, and considerable strain is thrown upon the heart; it may dilate under this strain, and being depressed by the chloroform already inhaled, may be unable to contract against the peripheral resistance, and fall into a condition of fatal paralytic dilation.

Respiratory failure. This is generally secondary to heart failure, but in some cases it is observed while the pulse is still of fair tone. It is best treated by rubbing the lips briskly with a towel, and by temporarily substituting ether for the chloroform upon the open mask.

Syncope. Heart failure arising during an administration of chloroform is due either to overdose, or to reflex inhibition (shock)—the latter is more likely to occur in patients who are the subjects of **status lymphaticus** (see page 21). Status lymphaticus cannot be diagnosed with certainty during life, and its presence can only be surmised, but after death the conditions found are characteristic. Patients who are the subjects of this condition are usually of highly nervous disposition, thin and pale, with flabby hands ; the shape of the head is abnormally long antero-posteriorly, the palate is high-arched, and the tongue large. They are generally mouth-breathers, owing to the presence of enlarged tonsils and adenoid growths in the nasal-pharynx. The pulse is quick and soft. There is usually some enlargement of the thyroid gland, and the lymphatic tissue throughout the body is hypertrophied. The thymus gland is persistent, and will give a dull note upon percussion over the upper part of the sternum. Microscopically, the heart muscle is often found to be in a condition of fatty degeneration.

Patients suffering from this condition are liable to attacks of syncope, following upon the least shock, for instance, cases of death from taking a cold bath have been reported, and they are more liable to reflex cardiac inhibition as the result of painful operations being performed during light anaesthesia. Should syncope occur in them, it is rarely recovered from. The anaesthetist should therefore be mindful of this condition, and never administer a general anaesthetic if he suspect its presence.

Syncope is characterised by sudden pallor of the face and lips, the colour becoming ashen grey and livid. The pulse stops, the respirations fail, the pupils dilate widely, do not react to light, and the cornea becomes insensitive.

On the occurrence of syncope the administration must of course be stopped. Ammonia should be held to the nostrils, and artificial respiration by Sylvester's method (see p. 72) resorted to ; meanwhile the mouth should be kept open, and the tongue held forward. A hypodermic injection of strychnine ($\frac{1}{30}$ gr.) should be given, or preferably, an injection of pituitary extract. Cloths wrung out of hot water should be placed over the praecordium, and an attempt made to compress the heart against the chest wall by pressing upwards with the hand, beneath the margin of the ribs. Should these measures prove ineffectual, it is justifiable to make an abdominal incision, and pass the hand inside the abdomen and rhythmically compress the heart through the diaphragm ;

this means has restored suspended animation in some instances.

Vomiting occurring during an administration of chloroform to a properly prepared subject is generally due to an unduly protracted induction of anaesthesia. Should it occur, the administration must be stopped, the head turned well to one side, and the mouth cleared of any vomited matter ; the lips should be lightly rubbed with a towel and the administration resumed as soon as possible, and a deeper plane of anaesthesia more rapidly induced.

After-effects.

The recovery from chloroform takes somewhat longer than after ether narcosis, and until recovery is complete, the patient should not be moved.

After-effects are chiefly *vomiting* and *headache*, and the treatment for both is discussed under ether (see p. 203). Vomiting immediately after an administration of chloroform is less common than after ether ; but if it occurs, it generally lasts longer. Vomiting of a more severe type, accompanied by deficient excretion of urine, furred tongue, deficient action of the liver, and acute headache followed by delirium and coma sometimes comes on three or four days after a prolonged administration of chloroform to certain types of patients, particularly children. It is attributed to *delayed chloroform poisoning*, and is very fatal ; post-mortem examination reveals a form of degeneration of the liver, closely resembling that found in acute yellow atrophy. No cases have, however, been reported of this condition arising after only short administrations of chloroform, such as occur in dental practice, and their further consideration does not therefore come within the scope of this book.

Since chloroform is infinitely more dangerous than all the other anaesthetics, its use should be reserved for those cases in which the other anaesthetics would be unsuitable, and then only administered by a medical man experienced in its use. The person who performs the operation should never at the same time administer the anaesthetic.

The Mixtures of Alcohol, Chloroform, and Ether.

The **A.C.E. mixture** and the **CE_2 mixture.** The A.C.E. mixture is composed of one part of alcohol, two parts of chloroform, and three parts of ether, the strength of chloroform, the active agent in the mixture, therefore being two in six. This mixture was introduced to obtain the desirable features of chloroform anaesthesia without its dangers. The alcohol was added on account of its stimulating properties, in order to counteract the depressing action of the chloroform. The ether was added partly as a diluent, partly as a stimulant, and partly on account of its anaesthetic properties. The mixture has in recent years been discarded by many anaesthetists in favour of the CE_2 mixture. This, as the name implies, is a mixture of one part of chloroform and two parts of ether, the strength of chloroform (1 in 3) remaining the same as in the A.C.E. mixture (*i.e.* 2 in 6). The CE_2 mixture has certain advantages over the A.C.E. mixture. It does not cause so much after-sickness; it acts more rapidly, and is equally safe, for ether is a better anaesthetic than alcohol; it is a better stimulant, and it dilutes the chloroform with equal efficiency. The combination was therefore selected by Sir F. W. Hewitt for administration to H.M. King Edward VII. on the occasion of the operation for appendicitis which he underwent immediately prior to his coronation; it has been popularly known among London anaesthetists as "King's Mixture" ever since.

Apparatus.

A Rendle's mask is usually employed for its administration (see fig. 33), but the author's open inhaler

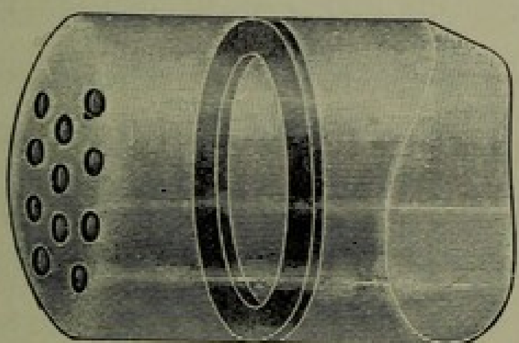


FIG. 33.—RENDLE'S MASK.
Showing diaphragm for retaining a sponge or gauze in position.

(see fig. 24), described under ether, will prove more efficacious. The Rendle's mask is an oval cylindrical mask of clear celluloid—shaped at one end to fit over the patient's face and dome-shaped at the opposite extremity—having a sufficient number of holes perforated in the dome through which the patient breathes. A suitably shaped honey-combed sponge is fitted into the dome, and this is held in place by a crescentic-shaped diaphragm fixed halfway between the extremities of the inhaler. The sponge must not be tightly packed into the dome, lest it be compressed and cause respiratory obstruction by its impermeability. Some anaesthetists fit a detachable rubber cushion over the free end of the inhaler to make it fit the patient's face more accurately and comfortably.

Posture.

The safest position for the patient for an administration of any chloroform-containing mixture is undoubtedly the recumbent posture; if this position be assumed at the beginning of the administration, it must invariably be maintained throughout. Considerable danger is incurred if the patient is raised from the recumbent to the sitting posture while under the influence of an anaesthetic, as the alteration of position may cause heart failure. It is sometimes permissible to anaesthetise the patient in the sitting posture, as this is often more convenient to the surgeon; but if this position be assumed, the anaesthetic must be given all the more cautiously. In the event of any fall in blood pressure being observed, the administration must be at once discontinued, the patient immediately placed in the recumbent position, and no more of the anaesthetic given until the normal blood pressure returns. The patient must not again be raised so long as the administration continues.

The Administration.

A few drops only of the anaesthetic are at first poured upon the sponge. The inhaler is then held over the patient's face resting lightly upon the bridge of his nose, and at an angle away from the mouth ; he is encouraged to breathe quietly and naturally, the distance between his mouth and the inhaler being shortened at each breath until the inhaler is in close contact with his face. By this time most of the anaesthetic which had been poured upon the sponge will have evaporated ; the inhaler must therefore be removed during an expiration, and a further dose rapidly poured upon the sponge, care being taken not to spill any upon the sides of the inhaler, lest the excess run down and burn the patient's face. This procedure must be repeated at regular intervals, the anaesthetist being guided as to the necessity for replenishing the anaesthetic by occasionally smelling the distal end of the inhaler during an expiration, to ascertain whether the anaesthetic vapour is of sufficient strength. It is useless to keep the inhaler applied, if there be insufficient anaesthetic on the sponge. The aim should be to progressively deepen the narcosis until the degree of anaesthesia required is reached. It is bad management to produce a certain depth of anaesthesia and then, by failure to add more of the anaesthetic, to allow the patient to partly " come round," before a fresh dose is given. This irregularity of dosage prolongs unnecessarily the induction of anaesthesia ; it is likely to induce vomiting during the administration, and to produce unpleasant after-effects. It is better practice to dose by continuous dropping than to give larger quantities of the anaesthetic at longer intervals. Either mixture is pleasant to inhale, and the symptoms produced by inhalation are identical with those of ether.

Signs of Anaesthesia.

The signs of anaesthesia are the same as those of ether, viz. slightly stertorous breathing, rise of blood pressure, flushing of the face, small pupil, and loss of the conjunctival reflex (see p. 180). In dental surgery it is never necessary to carry the depth of anaesthesia beyond abolition of the conjunctival reflex ; the danger zone is immediately entered beyond this point. Abolition of the conjunctival reflex will in most cases ensure an anaesthesia lasting five or six minutes, but if this length of time be insufficient for the operation, the narcosis may be prolonged by means of minute doses of chloroform administered by a Junker's apparatus and mouth tube.

Difficulties, Dangers, and their Treatment.

Difficulties and dangers arising in the course of an administration of CE_2 or A.C.E. are those common to all anaesthetics, and have been discussed elsewhere (see pp. 66-86), but there are in addition the risks of *heart failure*, *respiratory failure*, *vomiting*, and *struggling* during the induction of anaesthesia that need special mention.

Heart failure and respiratory failure are almost invariably caused by too concentrated a vapour, or to excess of the anaesthetic. They may, however, occur after the administration has been stopped and the operation begun. Heart failure is of sudden onset, and may occur without warning, or may be due to the pain of the operation causing reflex inhibition of the heart owing to the anaesthesia being too light. This is more likely to occur in highly sensitive subjects and more especially in those suffering from **Status Lymphaticus** (see p. 21). The treatment of cardiac failure is discussed on p. 228, the obvious remedies being diffusible cardiac stimulants.

Respiratory failure, as distinct from respiratory obstruction, does not occur suddenly; the respirations gradually become more and more shallow before they finally cease, and are accompanied by pallor and fall of blood pressure. Such respiratory failure is due to overdose in an unduly susceptible subject, and the other signs of too deep an anaesthesia will be observed, namely, loss of tonicity of the eyelids, loss of conjunctival and corneal reflexes, and if allowed to proceed still further, dilatation of the pupil. The anaesthetic must be immediately withheld, the lips briskly rubbed with a towel, ammonia held to the nostrils, and rhythmic compression of the chest resorted to. If these measures do not quickly restore the respiration, the patient must be placed in the recumbent position, the mouth must be held open with a Mason's gag, the tongue gently drawn forward with forceps, and artificial respiration performed (see p. 72). Oxygen, if available, should be supplied through a tube held in the mouth, while artificial respiration is continued. As respiratory failure is always followed by cardiac failure, heart stimulants should also be administered directly failure of respiration is observed. A hypodermic injection of strychnine ($\frac{1}{30}$ gr.) should be given, and cloths wrung out of hot water applied over the praecordium; these measures must, however, be secondary to the artificial respiration, and should be left to an assistant while the anaesthetist himself performs the artificial respiration.

Vomiting. During the administration vomiting is not common unless the induction of anaesthesia has been unduly delayed; it is, however, more likely to arise under the A.C.E. mixture than with other anaesthetics. It is preceded by swallowing movements, pallor, fall of blood pressure, and pin-point pupils, but immediately before its onset the pupils dilate. Threatened vomiting may often be averted by briskly rubbing the lips, and by increasing the strength of vapour administered. If it has actually occurred, the administration of the anaesthetic must be stopped ; the patient, if sitting, must be bent forward in the chair, and the mouth cleared to prevent any of the vomited matter being inhaled. If the patient be in the recumbent posture, he must be turned upon his side, and the mouth kept clear. When the vomiting has ceased, the anaesthetic may be resumed.

Struggling may occur if the induction of anaesthesia be delayed ; it can usually be stopped by spraying a little ethyl chloride into the mask, or by pouring a teaspoonful of pure ether upon the sponge, and thus rapidly deepening the anaesthesia. Occasionally, however, it is induced by presenting to the patient too concentrated a vapour ; this " takes his breath away," he experiences a sense of suffocation, and consequently struggles for air. Alcoholic subjects, excessive smokers, and highly nervous people are the most prone to struggle during the induction of anaesthesia.

The special danger of struggling under chloroform has been already emphasised (see pp. 226 and 227).

After-effects.

The after-effects of chloroform containing mixtures may be the same as those following the inhalation of chloroform, and are discussed under that head.

Vomiting is more common after the A.C.E. mixture than after the CE_2 mixture, and is more likely to supervene if the administration has been prolonged. Its treatment is discussed on p. 229.

Headache is a not infrequent sequela ; it seldom lasts long, and will usually be relieved by a cup of tea, but if this prove ineffective, five grains of aspirin may be given with benefit.

Treatment of After-effects.

The patient should be allowed to rest for at least an hour before being moved after the operation. He should be kept warm and protected from cold air and draughts. Before being moved he may be given a cup of weak tea without milk or sugar, but with a thin slice of lemon, or a cup of hot bovril or other meat extract if preferred. This will remove any taste of the anaesthetic that remains, and will stimulate the patient, and he will be less likely to feel faint on leaving the operation table. If, however, the hot fluid be not retained, and a sense of faintness persist, a hypodermic injection of strychnine (gr. $\frac{1}{60}$) should be administered. For the next succeeding two or three days he should be kept on a light and easily digestible diet, with a very moderate amount of sugar and starchy food to obviate the risk of overloading the liver (see delayed chloroform poisoning, p. 229), the functions of which are always temporarily impaired after taking chloroform or any of its mixtures.

The liver and kidneys should be flushed out and the bowels kept active, by drinking freely of hot water for a day or two following the administration, since in addition to some derangement of function due to the anaesthetic, some septic absorption almost inevitably occurs from the operation wounds in the mouth.

CHAPTER VIII.

LOCAL ANALGESIA.

THE term local analgesia implies a loss of sensation to painful stimuli without the production of loss of consciousness. Analgesia is a more accurate term than anaesthesia, for in many cases tactile sensation is not completely lost, although pain in the same area is abolished.

The improved technique of producing local analgesia has been largely responsible for the advances made in this form of anaesthesia. In dental practice, local analgesia is capable of being put to many purposes, and has the prospect of further increase in the future, but it is not yet destined to displace general anaesthesia.

The mucous membrane of the mouth responds to the four varieties of sensation, viz. those of *pain*, *pressure*, *heat*, and *cold*. The sensory nerves supplying the teeth and gums are derived from the fifth cranial nerve, and the terminations of this nerve or its main branches must be intercepted on their course to the basal foramina, by mechanical, by chemical, or by thermal agencies, if a paralysis of their conducting power is desired.

Action of Local Anaesthetics.

Before mentioning the various ways in which local analgesia may be obtained, a preliminary note on the present views held of the action of local anaesthetics may serve a useful purpose.

Local anaesthetics are chemical compounds and, as such, are employed usually in weak solutions. The contained drug when brought into contact with sensory nerves, paralyses, but causes no permanent injury to them. This effect is dependent upon the presence in these agents of certain atom groups, designated by Ehrlich as anaesthesiphorous atom groups. It is probable that these atomic groups enter into certain chemical combinations with the protoplasm of the nerve substance, and the nerve remains paralysed until the newly formed compounds are split up and the poison eliminated by the circulating blood.

M. Chevalier[1] suggests that the action of a local anaesthetic may be due to an incomplete and transient coagulation of the albuminoids, causing a modification in the osmotic tension of the cellular fluid. In this way the normal functions of the protoplasm are suspended; thus the sensory nerves lose their sensation, those endowed with motor and trophic functions are temporarily incapacitated, and tissue-respiration is modified.

[1] *Lancet*, November 27, 1909, page 1647.

All local anaesthetics should be *isotonic*, that is, of equal osmotic pressure to that of the tissues, or the tissues with which they come into contact will be injured.

A solution that causes neither swelling nor shrinking of the red blood cells is said to be isotonic. All isotonic solutions possess the same freezing point, which corresponds to that of the blood, viz. 0·56° centigrade. The isotonicity of a solution can therefore be determined by observing the behaviour of a red blood cell when brought into contact with the solution, or by obtaining its freezing point.

Solutions can be rendered isotonic by the addition of any of the indifferent salts of sodium, *e.g.* the chloride, sulphate, phosphate, and carbonate. The solutions employed must be at the body temperature when injected, or they will act as protoplasmic poisons.

A physiological (*i.e.* isotonic) solution of sodium chloride at the body temperature contains 0·92 per cent. of sodium chloride.

A *hypotonic* solution, or one that contains less than its complement of salts, gives off water to the tissues and takes up their salts, thereby causing swelling of the tissue cells and alteration in their structure.

A *hypertonic* solution, or one containing more than its complement of salts, abstracts water from the tissues, and the latter abstract the salts from the solution, thereby increasing the ratio of salts in the tissues, and causing the tissue cells to shrink and become crenated.

Inflammation or gangrene may result from the injection, if the freezing point of the anaesthetic solution be sufficiently remote from that of the blood. The subcutaneous injection of a 0·92 per cent. solution of sodium chloride at the body temperature produces a raised white wheal, which is unattended by pain or alteration in sensation, and which disappears completely within a few minutes; whereas the injection of pure water, or any solution that is not isotonic, is accompanied by pain. Solutions that are not isotonic are protoplasmic poisons. The temporary paralysis of sensation following the injection of a hypotonic or hypertonic solution results from direct injury to the nerve cells. If the percentage of salts required to produce an isotonic solution be diminished or increased, the pain caused by their injection varies in a like ratio with the departure from isotonicity.

The efficiency of a local anaesthetic solution is ascertained by noting the quantity required to render anaesthetic a wheal produced by an isotonic solution of sodium chloride, and by observing the duration of anaesthesia so obtained. The production of inflammation and pain are indications that the agent employed is injurious to the tissues.

Methods of producing Local Analgesia.

Local analgesia for dental purposes may be obtained by means of the following ways :

(1) Drugs painted or sprayed over the area desired to be rendered insensitive (**Superficial or Surface Anaesthesia**).

(2) Drugs which, by extracting heat from a part, cause a contraction of the underlying vessels, and thus indirectly interfere with the nutrition of its contained nerve-fibres (**Terminal Anaesthesia**).

(3) Drugs made to penetrate the tissue by means of electrical changes (**Cataphoresis**).

(4) Drugs injected into the area for operation (**Infiltration Anaesthesia**).

(5) Drugs injected into or around the nerve trunks supplying the operative field (**Regional or Conduction Anaesthesia**).

(1) **Superficial Anaesthesia** is obtained by drugs, known as local anodynes, which produce their desired effect by depressing the termination of sensory nerves ; prominent among these are cocaine, aconite, carbolic acid, and menthol. Opium has but very feeble anaesthetic properties when applied locally to inflamed parts. Some of these drugs in stronger solution have an escharotic action (*e.g.* carbolic acid), and then come into the category, known in dental surgery, as obtundents.

The action of an obtundent must be clearly differentiated from that of an anodyne or anaesthetic. The former produce a permanent destruction of tissue, whereas the latter merely give rise to a temporary paralysis in its conducting power. Obtundents are generally employed for the purpose of allaying the sensitiveness of dentine, but if used in close proximity to the pulp of a tooth, or in too powerful a form, they cause a dilation of its vessels, which may terminate in gangrene of the tooth-pulp. Some of the less active forms of obtundents lead to a slow calcification of the dentinal fibril and a formation of secondary dentine in the pulp-chamber, a condition much to be desired in certain cases. The more active forms of obtundents cause a coagulative necrosis of the albuminous contents of the dentinal canals, or gangrene in the case of vascular structures, thereby intercepting the transmission of sensory impulses.

Obtundents are therefore in no sense anaesthetics; the sensation of the part only becomes lost by its destruction. This last condition is actually aimed at, as one of the methods of rendering a pulp insensitive, as a preliminary to its removal, and although from a scientific point of view the method appears to be at variance with surgical principles, the practical results are good when the technique is carefully performed.

When it is necessary to only produce a superficial anaesthesia of the mucous membrane, drugs of the nature of cocaine and its salts, or any of the drugs commonly injected used in stronger solutions, will usually suffice.

(2) **Terminal Anaesthesia** results from the action of an anaesthetic upon the terminal branches of a sensory nerve, probably owing to paralysis of their end-organs, and as an example of this, the application of a freezing mixture may be quoted. Terminal anaesthesia may also be produced by a peri- or endo-neural injection of a local anaesthetic. The condition produced is similar to that of a frost-bite, the vaso-constriction of the arterioles producing a temporary paralysis of the nerves traversing the frozen area, owing no doubt to the poverty of their nutrition.

Drugs, the evaporation of which causes such intense cold that the parts subjected to their influence become bloodless and so lose their sensibility, are occasionally brought into use for this purpose, *e.g.* the chlorides of ethyl and methyl, ether, etc. The anaesthesia, however, is superficial and transient, applicable only to a few cases, and produced in these with some amount of discomfort. The ether spray is more effective when applied to a part in which the circulation is sluggish, such a condition can be artificially brought about by obstructing the circulation above the site of desired anaesthesia, *e.g.* by the application of an Esmarch's bandage. The bandage should not be applied so firmly as to completely obstruct the circulation, or the patient will experience a great deal of pain when the circulation becomes restored ; nor should the bandage be permitted to remain on for too long a period, or there will be danger of gangrene ensuing.

Method of Application of Refrigerating Agents.

1. The gums should be dried, and the area to be rendered insensible shut off as far as possible from the surrounding parts by a cloth, cotton-wool, or other suitable material.

2. The spray should be conveyed in a small jet and continued until the gum is blanched on both sides, and over an area well beyond that occupied by the tooth. The gum should remain in this bloodless condition for a few seconds before the spray is discontinued.

The operation must be quickly carried out, and if an assistant is available, the spray may be continued during its progress. The method is not applicable if a difficult extraction is anticipated, or in proximity to an inflamed periosteum, sensitive dentine, or an exposed pulp. Under these conditions, which are those for which teeth are usually removed, the access of cold would give rise to acute pain. For single loose teeth or roots the method may be employed, but it presents no advantages over other methods.

In some of the cases in which ethyl chloride has been employed locally in the form of a spray, sufficient of the vapour has without doubt been inhaled to produce a general effect.

(3) **Cataphoresis** (Greek, to carry along).

The principles involved in cataphoresis are those of osmosis and electrolysis.

The medicinal agents employed, or rather their ions, are made to permeate the tooth-substance by means of an electrical current; the electro-negative ion enters the dentine, and produces the desired anaesthetic effect. The current can be controlled by means of an ammeter, or regulated by increasing or diminishing the number of cells in the battery.

The technique of cataphoresis is briefly as follows:

The rubber-dam is inserted over the tooth it is desired to render anaesthetic, and any loose débris is removed from its cavity. The drug, which is usually a preparation of cocaine, is soaked up in cotton-wool and placed in the cavity of the tooth; the positive electrode makes a contact with the cocaine solution, and by means of a clamping arrangement can be fixed in position; the negative electrode is in contact with some other part of the patient's body, or can be conveniently held in his hand. The cavity of the tooth must be kept constantly moist with the cocaine solution for ten to twenty minutes or even more. The negative electrode should be moistened with water or held in a damp cloth. The time required in the actual anaesthetising of the dentine, during which there is some discomfort in the tooth, and the necessary preparation to carry out the technique of the operation are serious drawbacks to its general use, especially now that quicker and more reliable methods are at hand.

The advantages of cataphoresis are that it can be applied without any preliminary excavation of a sensitive cavity or the penetration of a needle, as in other methods. The anaesthesia lasts for an hour or more, and the drug is under control and not liable to produce degenerative pulp changes.

(4) **Infiltration Anaesthesia** is obtained by filling or saturating the tissues with an anaesthetic, regardless as to the position of nerve trunks, thus paralysing all the sensory nerves in the contained area, in contrast to regional anaesthesia, where the area for operation is rendered analgesic by one or more peri- or endo-neural injections. Infiltration anaesthesia annuls the transmission of sensory impulses in the nerves which traverse the infiltrated area, whereas regional anaesthesia cuts off their transmission to the higher centres in the brain at a point corresponding to the site of injection, so that sensory paralysis follows in the nerve distributing area below this level.

In general surgery a combination of both methods is often advantageous.

In dental surgery infiltration anaesthesia is that usually employed, although, for the removal of loose teeth and roots, superficial anaesthesia will often suffice.

Many unnecessary terms have crept into the literature of local anaesthesia, where there has been some slight modification in the technique; thus, the terms "pressure" and "high pressure" anaesthesia, "bone" or "diploic" anaesthesia and others might well be eliminated.

(5) **Regional** or **Conduction Anaesthesia** is the term applied to that form of anaesthesia which results when the conducting power of a sensory nerve is inhibited

in some part of its course from the periphery to the brain or spinal cord. The nerve conduction to the brain or spinal cord, as the case may be, is cut off at the site at which the anaesthetic is introduced.

Regional anaesthesia is procured by means of a peri- or intra-neural injection of a local anaesthetic. This method is applicable only to nerves which can be accurately located from the surface, easily reached by the needle, and not in the vicinity of important structures. Peri-neural injection is sometimes applied to the mandibular nerve as it enters the inferior dental foramen. The needle of the syringe is inserted behind and about half an inch above the upper surface of the third lower molar, and, thence guided by the feeling of the bone, is carried to the outer side of the lingula at the orifice of the inferior dental canal. The needle must be kept close to the bone after penetrating the mucous membrane at the anterior border of the ascending ramus, and the fluid can be injected as the needle is slowly pushed onwards for an inch or so. The lingual nerve, owing to its proximity, is not infrequently involved in anaesthetising the mandibular nerve.

In making deep injections in the proximity of large vessels, the needle should first be introduced while attached to an empty syringe, and if, on withdrawal of the piston, little or no blood appears in the barrel, the syringe may be disconnected from the needle, filled with the anaesthetic solution and reattached to the needle. The contents of the syringe may then be discharged into the tissues with but little risk of injury to any important vessel.

For intra-neural injection the nerve is first rendered insensitive by infiltration analgesia ; some of the solution employed is then injected directly into the nerve trunk. This has the effect of causing an instantaneous dissolution of its conducting power and producing an anaesthesia of about half an hour's duration.

Intra-neural injection is liable to be followed by a fatty degeneration of some of the nerve fibres, as shown by V. Lier in the case of the sciatic nerve in rabbits, whereas peri-neural injections of the same solutions produced no degeneration. Crile's experiments showed that an intra-neural injection produced an anaesthesia of less duration than that of a peri-neural injection, so that the former method seems to possess no advantages over the latter.

A spinal or subarachnoid injection acts as a " block " to the transmission of sensory impulses up the cord, and motor impulses to the periphery ; in other words, the portion of the cord influenced by the anaesthetic becomes isolated from the remaining portion of the nervous system. A subarachnoid injection may, therefore, be compared to an intra-neural injection of a mixed nerve, regarding the sheath of the nerve as comparable to the spinal theca of the cord, the drug employed in both cases coming into contact with the unprotected nerve fibres.

The term, local anaesthesia, as usually understood, implies that form of anaesthesia brought about by the injection of drugs into the tissues, whether the injection be directed towards individual nerve trunks or merely into anatomical areas.

The various tissues of the body vary greatly in their degree of sensibility, thus bone-substance, bone-marrow, and cartilage are themselves insensitive, the visceral peritoneum and tendons possess but little sensibility, whereas the protective coverings of the body, the periosteum and parietal peritoneum, possess marked sensibility.

Qualities of Drug necessary for Local Injection.

Drugs intended for hypodermic injection must be capable of fulfilling certain conditions, and these are:

1. An analgesic power equal to, or not far removed from, that of cocaine.
2. Sterile, or capable of being rendered so, by thermal changes (*i.e.* boiling).
3. Free from substances likely to cause local irritation, or produce general toxic effects. This statement necessarily implies that the solution must be isotonic.
4. The composition and the quantities of the ingredients must be known.

Other desirable qualities are that the drug employed should be compatible with adrenalin chloride, sufficiently soluble in water to form a 2 per cent. solution, and that it should possess the property of rapid diffusion in the tissues.

The toxicity of any drug can be determined by animal experimentation. The lethal dose of novocaine (subcutaneous) for rabbits is 0·35–0·4 grammes per kilo body weight, that of stovaine being 0·15 grammes, and cocaine 0·05–0·1 grammes. Stovaine in 5 to 10 per cent. solutions is capable of producing gangrene. Braun found experimentally that a lethal dose of cocaine, if combined with adrenalin and injected into a rabbit, produced little or no toxic effect.

Drugs employed.

A large variety of preparations have been advocated for producing local analgesia. This would seem to suggest that their action depends not so much on the pharmacological properties of the drug as on its chemico-physical effect on the nerve elements. Probably this is of a toxic or poisoning nature, acting temporarily as a block to their conducting power.

Those most commonly in use are *cocaine*, *beta-eucaine*, *stovaine*, and *novocaine*. Others less frequently employed are *tropa-cocaine*, *alypin*, *nirvanin*, *anaesthesin*, *acoine* (hydrochloride), and *holocaine* (hydrochloride).

Cocaine is an alkaloid obtained in the form of a white crystalline powder soluble in water and alcohol. The hydrochloride is the salt most commonly used for local injection.

Cocaine was one of the earliest drugs to be employed for producing local anaesthesia by injection, and, like other new remedies, bore the brunt of experimentation, which, to some extent, accounts for the disrepute into which this drug has fallen. When introduced cocaine was used in too large doses, and as the adrenalin preparations were then unknown, the effect of these large doses was not counteracted. The large quantity of cocaine used was thus absorbed in a shorter period, so that its effect was further intensified. The early trials with cocaine as a local anaesthetic were often instances of its abuse rather than of its rational use. Schleich was the first to show that analgesia could be effectively produced by using very weak solutions of cocaine.

A lethal dose of cocaine was found to produce no toxic effect on a rabbit, if allowed to enter the circulation after being retained in a limb for half an hour by means of a tourniquet. Whether retention in the tissues allowed the drug to become converted into some inert substance, or the organism in the interim produced some anti-body capable of combating the harmful effect of cocaine, can only be surmised. A third view might be advanced accounting for this phenomenon by the dilution of the cocaine solution, thus the partial obliteration of the circulation would lead to increased transudation of lymph from the vessel walls in the occluded limb, carrying with it some of the contained drug, and the latter would, therefore, reach the medulla after the release of the tourniquet in smaller and less concentrated doses.

A few drops of cocaine (of 10 per cent.–20 per cent. strength) applied to the floor of the fourth ventricle cause immediate respiratory paralysis; the animal, however, may be resuscitated by artificial respiration. Cocaine circulating in the brain of a rabbit produces restlessness, convulsions, and general paralysis, followed by death from respiratory failure.

The action of cocaine is first to excite and then paralyse, but the latter is accompanied by certain disadvantages which have limited the use of this drug.

Cocaine has a greater affinity for the sensory than for the motor nerves; it is a vaso-constrictor, but the addition of adrenalin chloride produces a further constriction of the vessels.

The sensory phenomena are abolished in the following order: light touch, temperature, pain, and pressure; after these the motor faculty becomes impaired. This order is reversed during recovery from the poisoning, motion being the first of the faculties to be regained.

Solutions of cocaine and other soluble local anaesthetics should be prepared from distilled water, and the salt (sodium chloride, 0·9 per cent.) added before boiling, or a standardized saline solution employed. If solutions of cocaine are kept for a long period, or heated to boiling point, the drug is apt to be converted into the inert alkaloid ekgonin. Solutions must be freshly prepared and not subjected to prolonged or repeated boiling.

One c.c. of a one per cent. solution of cocaine will usually be sufficient for tooth extraction in an adult; this amount is equivalent to employing one centigramme of cocaine (grain $\frac{1}{6}$). At the extremes of age one half of this dosage may suffice.

Beta-eucaine is a synthetic compound, and although not so efficacious as cocaine for producing analgesia, it is less toxic, and can be rendered sterile by boiling. The hydrochloride and the lactate are the salts usually employed; the latter has the advantage in being more soluble than the former in the proportion of 7 to 1. It is slightly irritant and a vaso-dilator, so lessening the vaso-constrictor effect of adrenalin chloride. Eucaine-B is not sufficiently soluble in cold water to produce a 2 per cent. solution, but on warming a solution of this strength can be readily obtained.

Eucaine-A is no longer used, owing to its irritating properties.

Stovaine (hydrochlorate of amylene) is a white crystalline powder produced from tertiary amylic alcohol. It is freely soluble in water. Its solutions are acid in reaction, and liable to cause inflammation in the area of injection, or if containing 5 per cent. to 10 per cent. stovaine, may produce gangrene. Solutions of stovaine can be boiled without decomposition. The drug has a vaso-dilator effect, which is not overcome by the constricting effect of adrenalin chloride. Its analgesic and toxic properties approach those of cocaine in their intensity; in fact, it is stated to be a more powerful anaesthetic, weight for weight, than cocaine. Stovaine has been employed in surgery, chiefly in connection with spinal analgesia.

Novocaine (hydrochloride of para-amido-benzoyl-diethyl-amino-ethanol) was discovered by Einhorn as a synthetic compound derived from the amido-benzoic-acid series. It is a white crystalline powder, freely soluble in water (1 : 1), and forming a neutral solution, which can be rendered sterile without decomposition. Novocaine is a non-irritant, and its toxic properties do not appear to be pronounced. Reclus[1] states the toxic properties of novocaine to be half those of stovaine and four times less toxic than cocaine. Unlike stovaine, a 10 per cent. solution of novocaine may be injected without producing pain or irritation, although a solution of this strength is rarely required. The local effect of novocaine is intensified and prolonged by combination with adrenalin chloride. Novocaine complies the most favourably of all the local anaesthetics with the essential qualities of an ideal anaesthetic (see p. 252).

Novocaine is incompatible with alkalies, and as this applies to some of the other local anaesthetics, a separate steriliser should be kept for the purpose of preparing the syringe and needles.

Tropa-cocaine (benzoyl-pseudo-tropine) was obtained by Giesen in 1891 from the Java coca leaves, and a year later was synthetically produced by Liebermann. Tropa-cocaine produces an anaesthesia less intense and

[1] *Lancet*, July 18, 1908.

more transient than that of cocaine. It is soluble in water, and its solutions can be boiled without decomposition. The drug is slightly irritant to the tissues, but is said not to depress the heart. Tropa-cocaine is antagonistic to adrenalin chloride, so that the addition of the latter does not increase the analgesic power of tropa-cocaine.

Alypin is a synthetic compound closely allied to stovaine in its chemical formula. It is a more toxic drug than cocaine in the ratio of 1·25 to 1, and is somewhat irritating to the tissues. Its anaesthetic power is enhanced by the addition of adrenalin chloride.

Nirvanin is soluble in water, and can be sterilised without reducing its activity. Its anaesthetic properties are inferior to those of cocaine.

Anaesthesin is almost insoluble in water, and is endowed with no special property to commend it in place of those anaesthetics already mentioned. The same applies to **Acoine** and **Holocaine.**

Adrenalin Chloride as a coadjutant of the abovementioned drugs requires some description as to its properties. Epinephrine or adrenalin,[1] the active principle derived from the suprarenal glands, was first isolated by Abel. Adrenalin is a poisonous alkaloid; the commercial preparation is composed of a solution of hydrochloric acid made *in vacuo,* and containing 0·1 per cent. adrenalin chloride. It should be kept in ruby-coloured

[1] Other names applied to this substance are adrenine, suprarenine, suprarenaline, vasoconstrictine.

bottles carefully stoppered, as it readily decomposes on exposure to light and air. The drug is the active principle of the suprarenal gland, and is obtained by making a watery extract from the dried glands of the sheep or ox. The solution may be sterilised by boiling.

More recently adrenalin has been prepared synthetically, and the manufactured article possesses equal vaso-constrictor properties and greater stability, being unaffected by light or by boiling when in dilute solution. When added to a solution of eucaine, the synthetic product undergoes the same colour change as does the ordinary adrenalin solution.

Adrenalin causes a marked rise in arterial blood pressure when injected (intra-venous) into the circulation, accompanied first by acceleration, then slowing, and finally again by acceleration of the heart. This rise of blood pressure is largely due to constriction of the vessels of the abdominal cavity, produced by the direct action of the adrenalin on the muscle of the vessel walls, or on the nerve terminations in them, as it occurs after destruction of the vaso-motor centre, or after section of the splanchnic nerves and paralysis of the ganglia on the vaso-motor constrictor nerves.

The acceleration of the heart is due to stimulation of the terminations of the accelerator nerves in the heart muscle; the acceleration later gives place to a slowing of the heart, owing to excitation of the vagus centre by the increase in blood pressure, as it is lessened on section of the vagi, and disappears under atropine.

Finally, the vagus centre becoming exhausted, the blood pressure begins to fall, and the accelerator stimulation again comes into prominence, with the result that the heart contractions are quickened.

The effect of adrenalin on the heart and vessels is somewhat similar to that of digitalis, and its action is probably both on the medulla and directly on the muscular coats of the arterioles. The former is indicated by the slowing of the pulse, and the sustained and strengthened systole of the heart; the latter by the marked contraction of the peripheral arterioles. The action of digitalis, however, is slower in its onset, more prolonged in its effect, and of less intensity.

The action of adrenalin on the arterioles is well seen in perfusing a mixture of blood and the extract through the vessels of an excised organ; the mixture passes through the organ and escapes less rapidly than when blood alone is perfused. The marked contraction of the vessels of a mucous membrane (*e.g.* conjunctiva), or of the mesentery when adrenalin is applied directly to them is a further illustration of its vaso-constrictor properties.

Adrenalin has no action on the unbroken skin or on organs without a sympathetic nerve supply, *e.g.* the lung and brain, consequently, when adrenalin is injected, these organs become congested to relieve the circulation in other parts.

Those secretions under sympathetic control (*e.g.* the saliva) are affected by adrenalin.

Adrenalin causes contraction of some forms of unstriated muscle and relaxation of others, the character of the response being determined by the nature of the normal impulses transmitted by these nerve fibres, *e.g.* inhibition of the peristaltic movements of the stomach and intestine, and contraction of the pyloric, ileo-colic, and internal anal sphincters. This peculiar action of adrenalin in producing either contraction or relaxation of unstriped muscle seems to indicate that its action is not directly on the muscle fibres, and as its effects correspond closely to those of sympathetic stimulation, it has been inferred that it influences the nerve-termination in the muscle. This view, however, is invalidated by the fact that the action of adrenalin persists after the degeneration of these nerve terminations or endings, unless it be assumed that the "myoneural junction," the locality at which the adrenalin acts, does not degenerate.

The short duration of the effect of adrenalin on blood vessels has been ascribed to its rapid excretion or oxidation, but this view is not supported by its continued action when allowed to enter a limb previously occluded by ligature, and after its effect has passed off in those parts in which it has already circulated.

Adrenalin, when injected subcutaneously, causes blanching of the tissues by contracting their contained arterioles, and its effects remain local.

When combined with alkaloids, such as cocaine, it retards their absorption, and so prolongs their local effect; thus sensation is suspended for over two hours when a solution of eucaine containing adrenalin is injected, whereas with the former alone, the analgesia lasts only for fifteen minutes. The analgesia is, however, produced more slowly when the combined drugs are employed.

The contraction of the arterioles produced by adrenalin chloride hinders absorption by the lymphatics, owing to the diminished flow of blood through the part, or in other words, by removal of the *vis a tergo*.

The credit of making known the advantages obtained by combining the active principle of the suprarenal gland with cocaine and allied drugs must be given to Braun.

Professor Paul Reclus,[1] however, does not favour the combination of adrenalin chloride with local anaesthetics, although the consensus of opinion among those who largely employ local anaesthesia is distinctly in favour of these mixtures.

Adrenalin chloride (0·1 per cent.) is generally used in 1 per mille solution, but often one-tenth, or even one-fifteenth, of this strength will suffice. It may be advantageously combined with most of the above-mentioned drugs for the purpose of localising, and so prolonging and intensifying their action; likewise, its constriction effect on the arterioles, causing blanching, determines when the tissues are well infiltrated and ready for operation.

[1] *La Presse Médicale*, January 3, 1906.

Adrenalin chloride should be discarded if it produces, on boiling, more than a faint pink solution; the solution should be nearly colourless. Suprarenal gland preparations oxidise rapidly when exposed to the air.

Braun fixed the subcutaneous dose of adrenalin chloride at 0·5 mgm., that is, 0·5 c.c. of adrenalin chloride solution (1 in 1000). If more than this quantity is injected a feeling of constriction of the chest is noticed, accompanied within a few minutes by palpitation of the heart and increased pulse rate. The poisoning, or toxic power, of adrenalin is diminished, like other drugs, with the degree of its dilution.

Large doses of adrenalin injected hypodermically into animals produce glycosuria, diuresis, and inflammatory changes in the liver and kidneys, and larger quantities cause prostration, collapse, and paralysis of the central nervous system, terminating in failure of respiration and oedema of the lungs. Multiple haemorrhages occur if the blood pressure has been greatly raised, and atheromatous degeneration of the aorta has been noted in the rabbit apparently from this cause.

In using any of the above drugs, the salt should be dissolved in distilled water according to the strength required, and sodium chloride added to make an isotonic solution (0·91 per cent. sodium chloride). A few drops of adrenalin chloride (0·1 per cent.) are then added, and the solution brought up to the boiling point. These solutions should be used at the temperature of the body.

Many of these anaesthetic drugs can be kept in tablet form, and made up as required. Normal saline solution is readily prepared from a tablet of sodium chloride dissolved and boiled in a definite quantity of water.

Lang[1] gives the following solutions as isotonic with the blood, and containing respectively 0·4 per cent., 0·8 per cent., and 2 per cent. novocaine, with three drops of adrenalin (0·1 per cent.) added to each 10 c.c.

Solution.	*A.*	*B.*	*C.*
Novocaine (4 per cent.) -	1 c.c.	2 c.c.	5 c.c.
Saline (4 per cent.) - -	2 c.c.	2 c.c.	2 c.c.
Adrenalin (0·1 per cent.) -	3 drops	3 drops	3 drops
Water, to - - - -	10 c.c.	10 c.c.	10 c.c.

Novocaine may be procured in the form of tablets or ampoules of a definite strength. In the latter case the drug has previously been sterilised, and is ready for use.

The author prefers making and sterilising his solutions as required, especially as the ampoules in which the drug is usually presented do not satisfactorily allow the needle of the syringe to reach the contents.

The following formula produces a ·2 per cent. solution of eucaine, and contains adrenalin chloride (·002 per cent.) and other ingredients in the quantities formu-

[1] *St. Bartholomew's Hospital Journal*, January, 1908.

lated by Braun and adopted by Barker, of University College Hospital:

B-eucaine 0·07 gram. = 1 grain.
Sodium chloride 0·27 gram. = 4 grains.
Aqua destillata 30 c.c. = 1 ounce.
Adrenalin chloride (1 in 1000) 3 minims.

This solution is prepared as follows:

An ounce of distilled water is poured into a glass beaker. To this are added one grain of B-eucaine and four grains of sodium chloride; the contents are then boiled for a few minutes, after which the beaker is cooled to blood heat, and three drops of adrenalin chloride (0·1 per cent. solution) are added. The solution should not be boiled for more than a few minutes, or it will become too concentrated and require the addition of distilled water to make up the original volume.

For tooth extraction a more concentrated solution of eucaine than the above may be employed, and this is prepared in a similar way, except that the ingredients, other than the eucaine, are reduced according to the degree of concentration required; thus a dram of distilled water will give a solution of eucaine of about 1·5 per cent. in strength, and a stronger solution than this would seldom be required. For the preparation of these smaller quantities a graduated test-tube can conveniently replace the glass beaker.

Compressed powders containing B-eucaine and sodium chloride in the above proportions are procurable.

Markham [1] favours eucaine lactate as a local anaesthetic, and gives clear and concise directions as to its preparation, and the method of filling and rendering sterile the glass ampoules for its reception.

Dr. Maurice Pôhl [2] gives an analysis of 625 injections of local anaesthetics, and classifies his results. He obtained the best results from alypin, whereas acoine, nirvanin, and anaesthesin gave poor results ; the last two drugs he describes as painful and useless. The injection was followed by syncope in two cases, in both of which cocaine was employed.

Dosage.

Local anaesthetics are generally used in 0·5 to 2 per cent. solutions. The toxicity of a drug depends on the concentration of its solution, as well as on the quantity used ; so that a larger quantity of a drug can be employed if the solution be weak. The idiosyncrasy of a patient to a particular drug must also be taken into consideration in determining the amount to employ, as what may be a safe dose for one person may have harmful effects on others.

Not more than a quarter of a grain of cocaine should be injected at one visit, and for safety the injection should be conducted with the patient in the supine or semi-recumbent position. A few minims of adrenalin

[1] *British Dental Journal*, Feb. 15, 1906.

[2] *British Journal of Dental Science*, Feb. 1, 1910.

chloride (0·1 per cent.) may be added advantageously to any of the above solutions. The solution of adrenalin chloride should be sterilised before or after its addition to the anaesthetic solution ; the latter method is more convenient owing to the small quantity of adrenalin used.

Local anaesthetics at first have a stimulating effect on the central nervous system, so that the patient may become talkative and restless. The pulse is increased in frequency and more forcible, and likewise the respiration.

A feeling of faintness associated with pallor, and even nausea and vomiting are symptoms which may be due to nervousness of the patient, or to the discomfort associated with the injection, and need to be differentiated from somewhat similar symptoms depending upon the toxic or poisonous effect of the drug.

The Advantages of Local Anaesthesia for Dental Operations.

1. There is *no need for any assistance*, the operator undertaking both the analgesia and the operation.
2. The analgesia lasts for an hour or more, so that the *operator is not hurried*, and the patient is spared a good deal of the after-pain resulting from the operation.
3. Almost, if not entire, *absence of after-effects*.

4. *No preparation of the patient beforehand is necessary.*
5. *The apparatus required is simple, cheap, and portable.*

In general anaesthesia the higher nerve centres are first affected by the drug, and through them the cranial and spinal nerves to the site of operation. Thus the whole system is saturated with a powerful drug to produce unconsciousness of pain during manipulations in some limited area. In local analgesia, *per contra*, the object in view is to produce a painless area of sufficient extent to permit the same manipulations to be undertaken, and to accomplish this without the general flooding of the tissues by a toxic agent.[1]

The Advantages of General Anaesthesia for Dental Operations.

General anaesthesia is preferable for *children*, or *adults lacking in self-control*, and for those cases presenting obstacles to the technique of local anaesthesia, *e.g. trismus of the jaws*, *suppuration around the teeth*, or *sinuses on the gum*.

It is *more reliable*, although the author believes local analgesia fails chiefly through want of technique being faithfully carried out. General anaesthesia has the advantage that the *patient is unconscious of the operator's*

[1] "The Methods of Local Analgesia," by Capt. J. W. H. Houghton, R.A.M.C., in *A System of Operative Surgery*, by F. F. Burghard.

manipulations, as with local analgesia these can be felt, although not giving rise to painful sensations.

The administration of a general *anaesthetic can be immediately checked* at the onset of unfavourable symptoms, whereas a drug injected into the tissues cannot be withdrawn.

There is no evidence in support of the statement that wound healing is delayed or otherwise interfered with by the injection of a local anaesthetic, provided the technique is carefully observed and isotonic and sterile solutions are employed. A reactionary dilation of the arterioles has been stated to follow the use of adrenalin, and to be a cause of the so-called "post-operative" haemorrhage. Braun has shown that no subsequent dilation of the arterioles takes place, and even if the vessels did become dilated beyond their normal calibre, the thrombi in their lumina would probably be firmly fixed by the time the constricting effect of the adrenalin had passed off. The tortuosity and the branching of the vessels would form a further buffer to the displacement of clots by the circulating blood.

Technique of Infiltration Anaesthesia.
The Apparatus.

The syringe. It is largely owing to improvements in this that have led to a fresh stimulus in local anaesthesia. Formerly a hypodermic syringe was used; this failed on account of the junctions being insufficiently water-tight and the syringe too weak for infiltrating dense tissue like the gum. The fluid escaped at the junctions or leaked back through the asbestos piston.

A good syringe should be powerful, and contain a solid, well-fitting piston, preferably the same length as the barrel. Unfortunately, the piston seldom fits the barrel sufficiently accurately to do away with washers, besides which the constant wear of metal against metal would sooner or later necessitate their employment. The least objectionable form of washer is one of asbestos, wound around the upper part of the piston before this is passed through the screw-nut.

The author has had several syringes made for him with the idea of avoiding washers, but the working of the syringe is never so accurate in their absence.

The upper part of the barrel of the syringe should be fitted with a stout cross-piece, to enable the operator to obtain a firm grasp while the piston is propelled into the barrel with the thumb or palm of the hand. The piston rod should terminate in a broad extremity for the comfort of the hand. All junctions must fit accurately.

The needle must not be over half an inch in length, and must be sufficiently stout for strength. It should screw on to the syringe, and abut against a firm washer for additional safety. Straight and curved needles are required, and when not in use should be threaded with a fine wire. The shaft and hilt of the needle should be in one piece, as this saves a joint, and the shoulder so formed presses against the puncture and prevents leakage. The needle may be made of steel or irido-platinum. Steel needles are finer and sharper than those of irido-platinum, but are more apt to rust, and being more rigid, are liable to break.

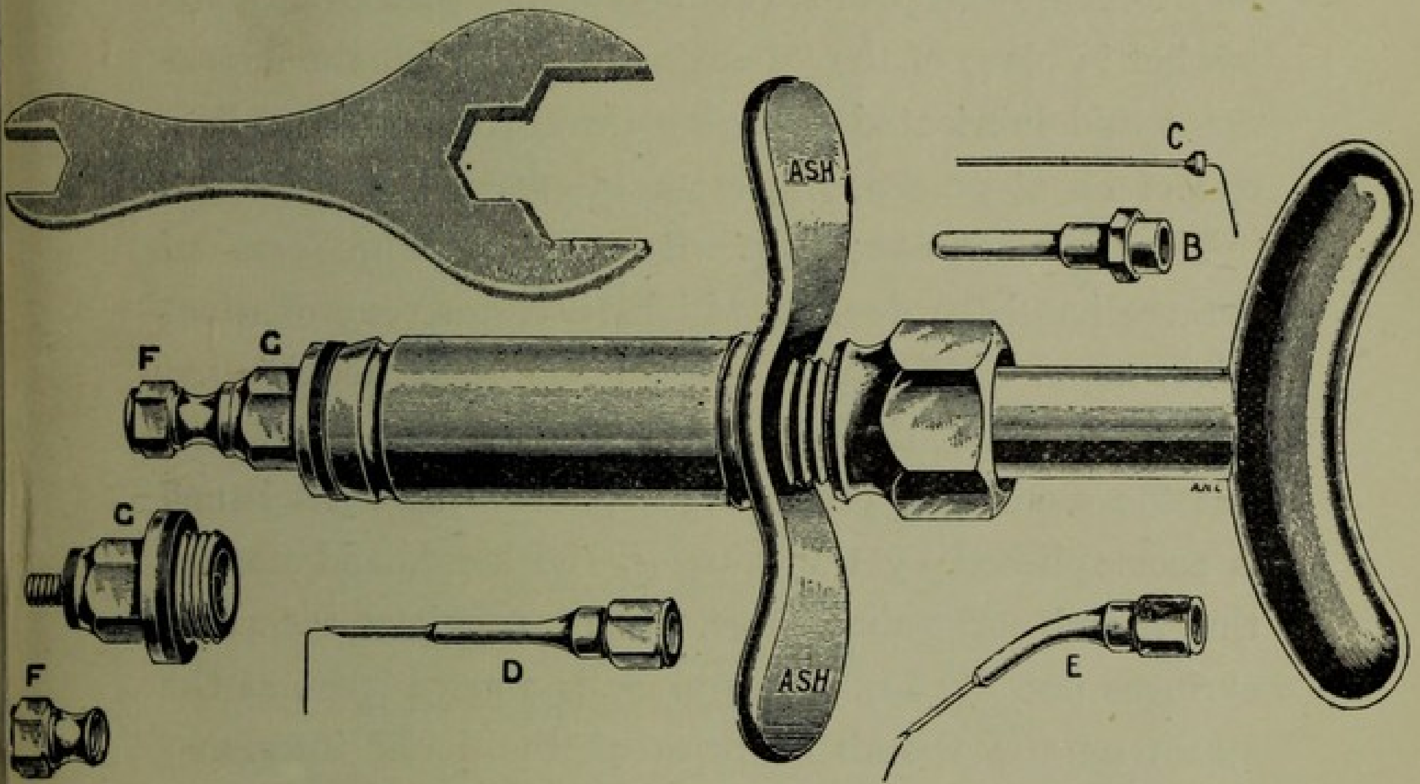


FIG. 34.—IMPERIAL SYRINGE FOR USE IN LOCAL ANALGESIA.

B. Mount for carrying a Schimmel's Needle.
C. Schimmel's Needle.
D. Straight Imperial Needle with Mount attached.
E. Curved Imperial Needle with Mount attached.
F. Cap for end of Syringe when not in use.
G. Removable End for receiving Needle and closing Barrel with interposed Washers.

The syringe must be made so that it can be easily taken to pieces, and every portion rendered capable of sterilisation.

The metal piston should be graduated in minims, and its barrel capable of containing at least half a drachm. An additional scale in cubic centimetres is a convenience for solutions that are put up in this measure, and may be superimposed on the smaller minim scale.

The *Imperial syringe* (fig. 34) comprises most of the above-mentioned points, and if employed with an asbestos washer in place of the "packings" sold with the instrument and lubricated with lysol or carbolised vaseline, one of its at present objectionable features is lessened.

The *Gunthorpe syringe.* Recently a new form of syringe has been devised which possesses some distinct advantages. The barrel, piston rod, and needles are similar to that of the Imperial syringe (see fig. 34), but the method of propelling the piston into the barrel is accomplished by the grasp of the hand, and not by the thumb or palm alone, as in previous forms of syringes (see fig. 35). This alone is a great gain, as the strain on the thumb or palm of the hand interfered with the delicacy required in inserting and steadying the needle, and consequently increased the risk of breaking the latter in the tissues. The propelling force is attained by means of a compressible trellis-like spring, the extremities of which are attached to the ends of powerful handles proceeding from the barrel of the syringe. The syringe is powerful, but yet easily controlled, and can be kept steady while injecting under great pressure.

To fill the syringe, the needle is sunk in the fluid after closing the handles, after which the handles are gradually separated. The barrel is discharged by approximating the handles with the grasp of the hand.

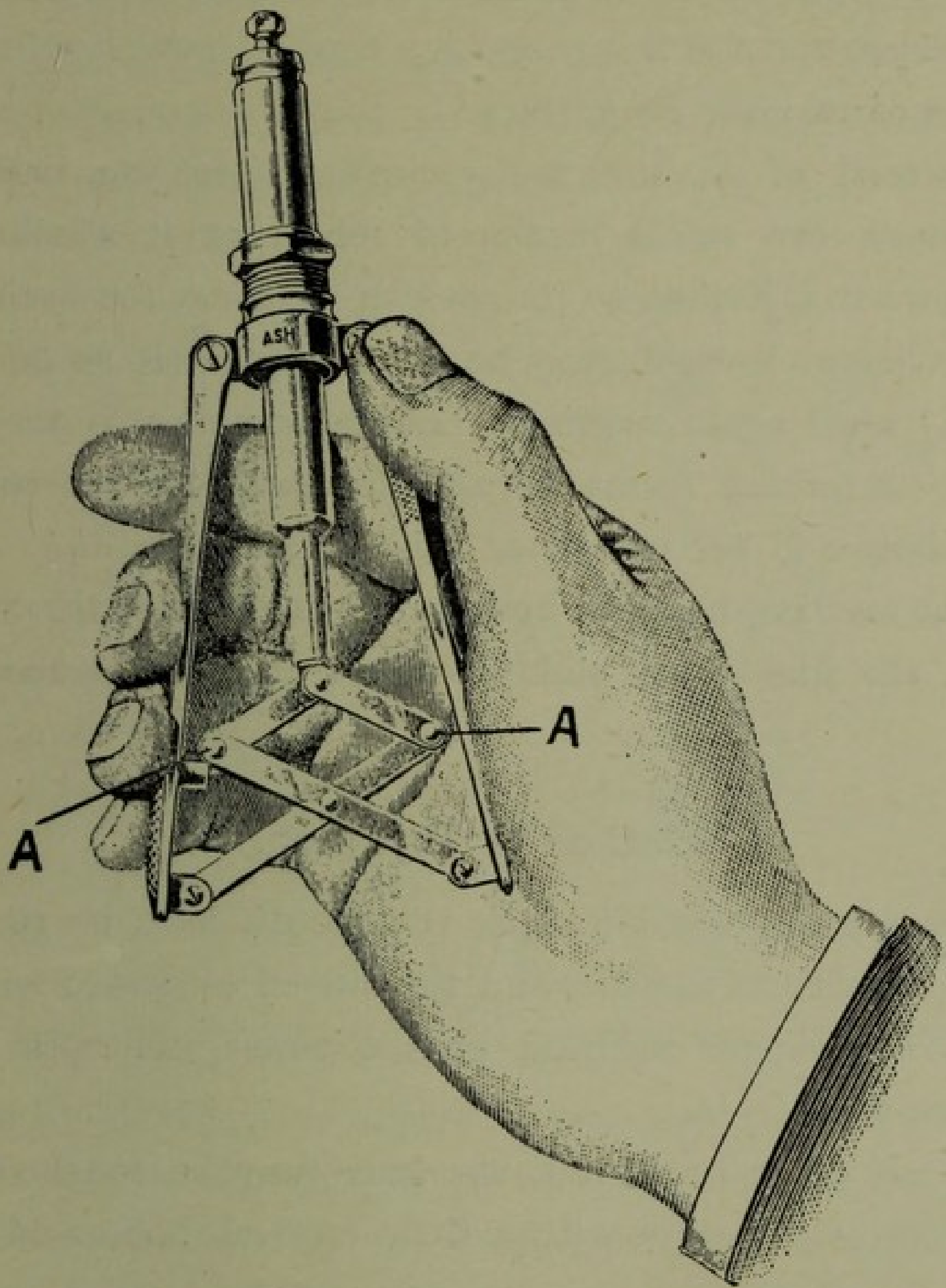


FIG. 35.—GUNTHORPE'S SYRINGE, SHOWING METHOD OF HOLDING.

The instrument is held somewhat like a pair of tooth-forceps, and can be well applied to any position (see fig. 35).

A small steriliser should be kept apart for sterilising the syringe and its accessories, as traces of alkalies are injurious to the action of these drugs. A metal piston will require some lubricant after removal from the steriliser, and for this purpose a drop of pure lysol may be smeared over its surface.

Instead of boiling the syringe before use, which, although the safest means of rendering it sterile, is somewhat injurious to its smooth working, the syringe, after being cleansed, may be kept in lysol (10 to 20 per cent.) until again required. Lang recommends a solution containing formaldehyde (formalin 20 per cent.) and borax (3 per cent.) for this purpose.

The needles should be boiled after being used, threaded with the fine wires, and placed in absolute alcohol.

Method of Injection.

Previous to the injection, the mouth may be rinsed with a weak antiseptic, and the site of puncture wiped with a stronger solution of the same antiseptic on cotton-wool.

If the prick be feared, the gum may be touched at the site of puncture with a little pure carbolic acid, or with a solution of cocaine (saturated) applied on a small pellet of cotton-wool, either of which will render the gum almost insensitive to the needle.

The needle is inserted obliquely into the gum at a point rather nearer the neck of the tooth than its apex, and to one side of its root, if the amount of soft tissue over the root is scanty. When the eye of the needle is well embedded in the mucous membrane, the solution can be slowly injected and the needle pushed on towards the apex of the tooth (figs. 36, 37).

One injection on either side of the gum usually suffices for a single-rooted tooth, whereas, for a molar, it is

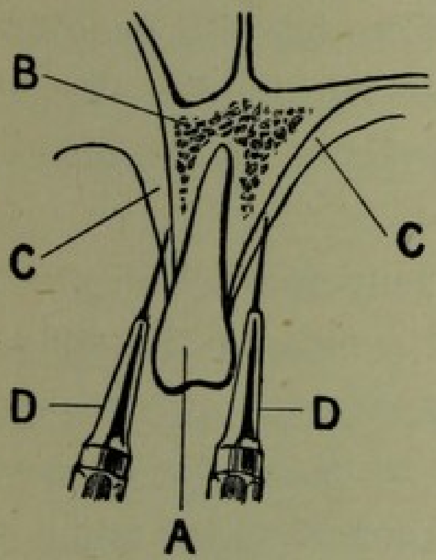


FIG. 36.—VERTICAL SECTION OF MAXILLA (PREMOLAR REGION).

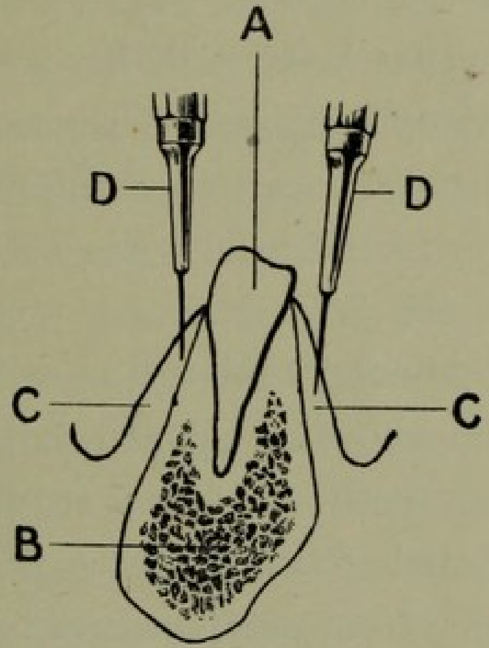


FIG. 37.—VERTICAL SECTION OF MANDIBLE (PREMOLAR REGION).

A. Tooth. B. Bone of jaw. C. Mucous membrane. D. Needle.

generally advisable to inject in two places on its outer aspect, and in one or two on its inner side.

The injection should be made slowly and gradually, occupying about half a minute over each puncture, and the needle retained in position for a few seconds even after the barrel has been discharged, as, until taken up by the circulation, the pressure of fluid in the tissues will be greater than that outside, and leakage will follow the withdrawal of the needle. If but little resistance is encountered, or, on the other hand, the piston cannot be driven on, the needle should be reinserted. The former circumstance may indicate that the needle has not been inserted sufficiently deep, and the fluid has consequently trickled back along the needle, or that the needle has been pushed into the loose cellular tissue in the sulci of the cheek or floor of the mouth, or that leakage of the solution has occurred through a pre-existing socket or sinus. The opposite condition, that of excessive resistance, generally implies that the eye of the needle has become occluded by the alveolus of the jaw.

About 20 minims of a 2 per cent. solution of any of the above-mentioned drugs will suffice to anaesthetise one tooth, and less is required in proportion when anaesthetising two or three adjacent teeth, as the analgesic zone from one puncture tends to spread to the adjoining teeth.

There should be no further discomfort after a puncture has been made on either side, as the operator should utilise the periphery of the preceding analgesic zone for any subsequent puncture.

A successful injection can be anticipated by the amount of resistance offered, and by the brawny feeling imparted to the tissues. In addition, blanching is well marked when adrenalin has been combined with the solution. The whole area occupied by the tooth should appear blanched and be allowed to remain in this condition for four or five minutes before extraction is undertaken. The mucous membrane may be previously tested with the point of the needle to ensure that anaesthesia is present.

The injected fluid will sometimes collect in the loose tissue of the sulci of the cheek and floor of the mouth, giving rise to a "boggy" feeling. This is usually an indication that more of the solution has been used than is necessary, or that the needle has been inserted deeper than is required. A healthy and firm mucous membrane will readily blanch, and a good analgesia can be anticipated, whereas, if the tissues be inflamed and oedematous, the vessels having lost their tone do not readily respond to the constricting effect of the adrenalin, and blanching is consequently but little marked. There is said to be some risk in injecting inflamed or suppurating tissues, owing to organisms or their resulting products being dispersed into the circulation.

When infiltration analgesia is used for the purpose of extirpating a living pulp from a tooth, or for decreasing the sensibility of dentine, or rendering painless other operations on the teeth themselves, the drug employed must reach the terminal branches of the fifth nerve entering the apical foramina of the teeth.

In many cases, when the surroundings of a tooth are well infiltrated, as for an extraction, the pulp of the tooth is likewise rendered anaesthetic, and may be removed painlessly ; in other cases, while the periosteum of the tooth-socket is anaesthetic, the pulp retains its full sensibility. It is difficult to reconcile these facts, as the two conditions occur under apparently similar circumstances.

Bone Injection.

To avoid failure in anaesthetising a pulp by the method of infiltrating its surrounding gum, it has been recommended to drill into the outer lamella of the alveolus in the region of the apex of the tooth, or through the summit of the adjoining septum (where the bone is frequently less dense), and inject some of the previously used fluid directly into its cancellous tissue.

For this bone injection, a strong short needle should replace the finer needle used for the submucous injection, the eye of the stout needle being received in the pit previously made with the dental drill.

The size of the drill and of the needle employed should bear a definite relation to one another, so that the eye of the needle is well embedded in the bone when the piston of the syringe is driven into the barrel and the contained fluid dispersed into the cancellous tissue.

The credit of suggesting this method of anaesthetising the tooth-pulp for rendering painless conservative operations on the teeth must undoubtedly be given to Mr. A. H. Parrott,[1] who has frequently demonstrated his method and written extensively on this subject.

Mr. Parrott recommends using 3–5 minims of novocaine for the submucous injection, and about the same quantity for the bone injection. These small

[1] *British Dental Journal*, December 15, 1910; *ibid.* 1909.

quantities can be well delivered by the Sykes' syringe (see fig. 38).

That the rupture of the pulp is an unimportant factor in the causation of pain during extraction is shown by those cases in which the pulp retains its sensibility after successfully anaesthetising the gum, and yet the tooth can be removed painlessly. The fact that teeth containing "dead" nerves cause as much pain in their removal as those containing "live" nerves is further support that the pain of extraction is largely due to stretching and rupture of the periodontal membrane.

Pulp Injection.

Pressure Anaesthesia is a variety of infiltration anaesthesia, and is brought about by substituting the syringe employed in the latter for some elastic "diaphragm," by means of which the drug placed in the cavity of the tooth is forced into its pulp tissue.

The drug is conveniently put up in the form of discs and cylinders, one of which usually suffices for anaesthetising a pulp. The pressure is obtained by means of a round or flat-ended plastic instrument, somewhat smaller than that of the cavity of the tooth; the interposed elastic substance, usually unvulcanised rubber, acts as a diaphragm or plunger in concentrating the pressure on the drug, and preventing its escape from the tooth-cavity.

Cocaine (gr. $\frac{1}{6}$) with adrenalin chloride (gr. $\frac{1}{300}$) seems to give the best results in this form of anaesthesia, and although it is desirable for an actual exposure of the pulp to be present, the drug will penetrate a thin layer of softened (decalcified) dentine, and partly, if not completely, anaesthetise the subjacent pulp.

If there is difficulty in obtaining a sufficient exposure, owing to the sensitiveness of the tooth, a drop of adrenalin chloride may be placed in the cavity, into which a few crystals of cocaine are dissolved, and a drop of formaldehyde (40 per cent.) added. The solution so formed is then forced into the dentine.

The pulp may be only partly anaesthetised at the first attempt, but the diminished sensibility will allow a good exposure to be obtained before the drug is reapplied.

The *technique* of pulp anaesthesia is as follows:

The cavity is first excavated, and as much as possible of the carious dentine lying over the pulp removed. The cavity is then cleansed with a small wool swab moistened in pure carbolic acid. This defines the exposure, and cleanses its surroundings, so diminishing the risk of forcing extraneous matter into the pulp chamber. The tooth should be kept dry throughout these manipulations, otherwise the open canal may become infected from the mouth, and the drug diluted by the saliva.

The cocaine is placed as near as possible over the pulp, or actually into the pulp chamber should a definite exposure exist. A few seconds are then allowed for some of the drug to be dissolved in any exudation from the pulp, and perhaps directly absorbed. If there is difficulty in placing the drug in position, the drug may be carried to the tooth on a pellet of amadou moistened in adrenalin chloride.

A piece of unvulcanised rubber, about the size of the cavity of the tooth, is then laid over the cocaine cylinder, confining the drug to the region of the pulp. Gentle and even pressure is then applied over the rubber disc in the direction of the tooth-pulp, preferably with a flat and slightly serrated instrument, but the form of the instrument will depend upon the position and shape of the cavity. The pressure must be maintained for thirty seconds or more, commencing with such light pressure that the instrument merely rests by its weight on the rubber disc, and gradually increasing this, until firm pressure is exerted; but should there be any discomfort, the pressure is temporarily relaxed.

After about half a minute, firm pressure can usually be applied over the pulp without causing any discomfort to the patient, and at this stage it is sometimes advisable to substitute a smaller instrument for driving on the remains of the drug into the pulp. The rubber disc will be partly invaginated into the pulp chamber in cases where a perforation exists.

If after half a minute or so firm pressure produces no discomfort, whereas at the beginning of the operation the slightest pressure in the cavity was intolerable, the operator may feel fairly confident that the pulp is anaesthetic, and his hopes may be confirmed by carefully excavating over the pulp and testing the latter with a probe.

After the pulp is rendered anaesthetic the pulp chamber is fully opened up and its contents removed. This procedure does not come under the title of anaesthetics ; suffice it to say that the drug may be reapplied should one or more of the roots remain sensitive. Under these circumstances the drug is placed in the pulp chamber, and by means of the interposed rubber-disc is forced into the canal or canals of the tooth.

Generally, when the body of the pulp has been rendered anaesthetic, the entire structure can be removed painlessly, and in this respect local anaesthetics have a distinct advantage over escharotics, as the latter destroying tissue by direct extension may fail—through the quantity used, its potency, or some curvature of the root—to produce complete destruction of the pulp.

A slight amount of traumatic inflammation, lasting twenty-four hours or more, not infrequently follows the extirpation of a pulp under local anaesthesia, and for this reason it is advisable to dress the tooth until this subsides. This inflammation is comparatively slight, and harmless to that which may follow the employment of an escharotic, where, in addition to the trauma, there is superadded the presence of gangrenous tissue.

The advantages of local anaesthesia for pulp extirpation are the following :

1. The pulp can be removed, and the tooth filled temporarily, or permanently, at the same visit.

2. An infective inflammation of the contiguous tissues is not likely to arise if asepsis has been carefully carried out, whereas, after the use of an escharotic the presence of gangrenous tissue must be always a source of infection.

3. The duration of analgesia is sufficiently prolonged to allow of careful and deliberate pulp extirpation, and is free from the embarrassing movements associated with a respiratory anaesthetic.

4. The constriction of the arterioles brought about by the action of adrenalin reduces the possibility of the tooth substance becoming stained with haemoglobin, whereas this condition is favoured by drugs of the nature of escharotics, which cause congestion and haemorrhages.

5. Further applications of a local anaesthetic can be readily applied, or, if necessary, this means can be superseded by one of the other methods, whereas a pulp inflamed from the use of an escharotic is not a favourable one for absorbing drugs.

Stagnation of the pulp vessels, whether from chronic inflammation, polypus, calcification, or other pathological conditions, renders the drug less easily absorbed. The previous application of coagulants of albumen, *e.g.* tannin, silver nitrate and carbolic acid, cause a similar difficulty by forming a protective layer over the pulp.

Dentine Injection.

Anaesthesia of dentine may be induced by injecting drugs directly into it ; for this purpose the point of a fine drill must first be embedded in the dentine, parallel with its tubuli, and sufficiently deep to admit the eye of a stout needle with a powerful syringe behind it. Some of the contained fluid in the syringe is then driven into the dentine, rendering it insensitive, and allowing the cavity to be freely excavated, or, if necessary, the pulp of the tooth to be removed.

The pit is drilled preferably in the cavity under treatment, but should this be in an inaccessible part of the tooth, anaesthesia of the entire tooth can be obtained by injecting through a pit made at a more accessible point, such as a coronal fissure, or on the buccal or the labial aspect of the tooth.

Mr. Wilton Thew, who has used this method of intra-dentinal injection to a considerable extent, employs a fine, flexible and coiled silver tube to convey the drug from the syringe to the tooth, and by this means cavities, previously inaccessible, can be approached. The spiral bend lessens any vibration conveyed to the end of the tube which might otherwise interfere with the contact or " joint " made with the dentine and so lead to leakage.

The distal, or sharp end of the tube, is made of steel and bent at a right angle, it carries a cup-shaped finger rest, by which it is guided and held in position in the dentine. Unless the dentine be soft (decalcified), it is advisable to drill a pit for embedding the nozzle of the syringe.

Mr. Thew advocates novocaine in 20 per cent. solution for the injection. He has found the teeth of young people to be more permeable than those of adults, while in some of the latter he has been unable to obtain anaesthesia.

More recently Mr. Thew has devised a syringe for use with his flexible conveying tubing. In this syringe the high pressure is obtained by concentrating the whole force of the hand-grip upon a piston of small diameter. The piston with its barrel is pivoted between two levers, shaped and hinged like the handles of a pair of forceps ; the piston is placed in a forward position between the handles to allow of greater leverage in closing the latter.

The method may be of use for the removal of a healthy pulp, as a preliminary to crown and bridge work, or if infiltration anaesthesia has failed and the sensitiveness of the dentine does not permit exposure of the pulp by excavation or drilling.

Cocaine (hydrochloride) with adrenalin chloride seems to give the best results in this method ; the former may be used in a concentrated solution, as the amount employed, usually a few minims, is so small.

The anaesthetic solution is forced slowly and steadily into the dentine, the pressure being maintained for two or three minutes, but temporarily relaxed should the patient complain of discomfort. After opening into the pulp-chamber, the pulp may be further anaesthetised with cocaine (pressure anaesthesia), should it be still sensitive.

A Sykes' syringe (see fig. 38) is usually employed, as it allows a high pressure to be obtained.

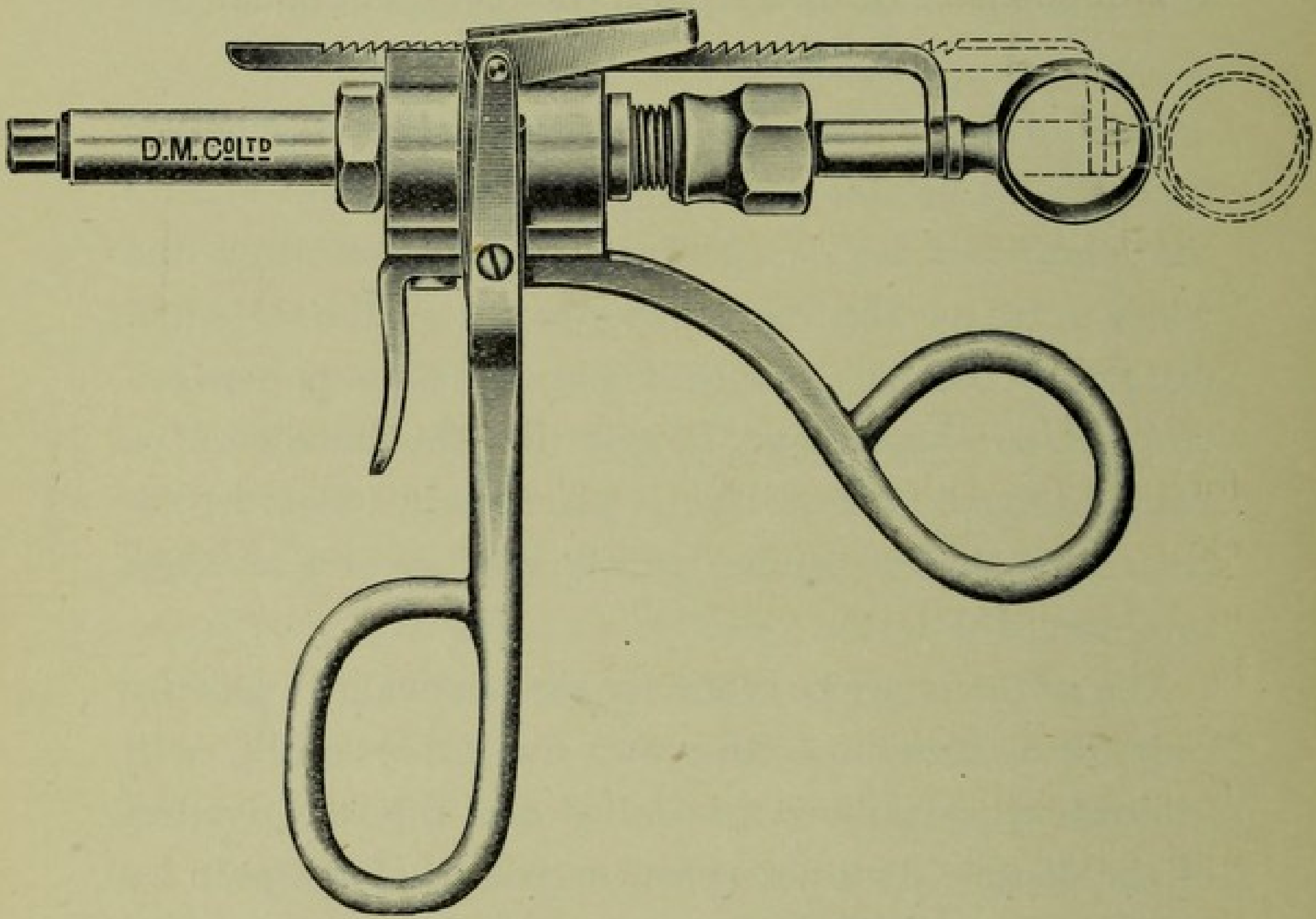


FIG. 38.—SYKES' SYRINGE.

To fill the syringe—raise the loop off the teeth of the ratchet and draw out the piston.

To inject—bring together the two handles (the loop, of course, resting on the ratchet). This has the effect of carrying the piston forward, and ejecting one minim of fluid through the nozzle with each movement.

In the Wilcox Jowett syringe the barrel tapers to a cone-shaped point, which subserves the purpose of a needle, and is introduced into the pit previously made in the dentine.

Difficulties, Dangers, and Sequels of Local Anaesthesia.

Difficulties and Dangers.

The difficulties, which may also be the cause of dangers, arise chiefly from the position of the tooth and its pathological condition.

For *back teeth* a mouth mirror is frequently necessary for pushing aside the tongue or cheek, and allowing a clearer view of the surroundings of the tooth. There may be difficulty in infiltrating the *lingual aspect of the lower molar region,* especially when the teeth have large crowns and are inwardly tilted ; this mechanical difficulty could be largely overcome if the needle-carrier were curved, so as not to impinge on the tooth during its insertion. The *outer aspect of the lower molar region* may also offer a difficulty, if the external oblique ridge be prominent, and prevent the needle from satisfactorily following the root of the tooth. In such cases it has been suggested that the freezing process might be employed on the side difficult of access for injection.

Malplaced teeth may give rise to difficulty in their infiltration, as well as in their subsequent extraction.

Difficulties and dangers arising from pathological conditions of the teeth or their surroundings may be due to :

Sinuses in the area of infiltration,

Injured tooth-sockets, as by previous attempts at extraction,

An *alveolar abscess*,

Suppuration around tooth-sockets, *e.g.* pyorrhoea alveolaris,

Macroglossia,

Microstoma,

and other less common conditions.

Sinuses on the gum or alveolar margin give rise to difficulty in infiltrating around a tooth, owing to the solution escaping through the sinus or tooth-socket, as fast as it is injected.

Organisms, toxins or their products, may be dispersed deeper into the tissues if the injection be made in their proximity, or these organisms might be carried into the circulation, should the needle of the syringe penetrate the lumen of a vessel.

Macroglossia and Microstoma offer mechanical difficulties to the technique of local anaesthesia.

Breakage of a needle. If a needle breaks in the gum, as a rule it is easily removed ; but if this accident occurs while injecting the inner surface of the lower jaw, more especially if a long slender needle has been used and deeply inserted, there may be great difficulty in removing the broken piece.

Should the broken piece reach the muscles of the tongue and floor of the mouth, or become embedded in the submaxillary gland, no time should be lost in having the needle localised by skiagraphy and removed. A needle will travel rapidly in muscular or glandular tissue, especially in a situation like the floor of the mouth, which is in constant movement. If treatment be delayed, the point of entrance of the needle will soon cease to be a guide as to its present position.

Sequels.

The unfortunate sequels of local anaesthesia are chiefly dependent upon the toxicity of the drug and the idiosyncrasy of the patient to that drug.

Anaemic patients and those liable to giddiness and faintness are not good subjects for local anaesthesia, and small doses may give rise to a further depression of their circulatory organs (*syncope*).

Toxic symptoms have been chiefly recorded in connection with cocaine. Cocaine is liable to produce constitutional symptoms, owing to its depressing action on the circulation through the medulla. Dr. Sauvey, however, makes the following statement, based on an analysis of 15,000 injections: "We cannot register one accident, not even an incident due to the use of cocaine." Dr. Sauvey recommends the horizontal position if the injection exceeds 1 c.c. of a 1 per cent. solution of cocaine (*i.e.* gr. $\frac{1}{6}$), and advises that the patient should maintain the recumbent position for at least a quarter of an hour after the operation.

Cocaine poisoning. The pulse is quickened after the injection of cocaine, owing to direct action on the cardiac muscle, or to depression of the vagus; larger doses, by stimulating the vagus, slow the pulse.

Stimulation of the respiratory centre causes rapid and deep breathing; later, owing to depression of this centre, the respiration becomes feeble, and death may ensue from asphyxia. The pupils become slowly dilated, reaching their maximum mydriasis within an hour or two, and in this condition they may remain for twenty-four hours. The dilated pupil reacts slightly to light and accommodation. The pupil effects are due to irritation of the sympathetic. Besides a feeble pulse, shallow respiration, and widely dilated pupils, there is a feeling of chilliness and restlessness, accompanied by delirium.

Convulsive movements are not uncommon, and are probably due to anaemia of the brain, induced by irritation of the vaso-motor centre.

The secretion of saliva is at first increased; later the secretion is diminished, so that dryness of the mouth becomes a clinical sign of cocaine poisoning.

Malaise and weakness lasting a few minutes may follow the use of an excessive dose of cocaine. In one recorded instance[1] malaise and muscular weakness

[1] E. M. Nason, *British Dental Journal*, Dec. 1, 1906.

lasted for ten days after a self-injected dose of 5 grains of cocaine.

Following an unsuitable dose of cocaine, whether from the quantity used, the method of its employment, or the personal susceptibility to the drug, the patient is seized with a feeling of faintness and giddiness, and if unsupported may fall. The pulse becomes quickened, weak or imperceptible at the wrist, the respiration quiet and shallow. A temporary and sudden lapse of consciousness followed by an equally sudden revival is not uncommon, and the patient may experience a succession of such attacks, each attack being preceded by cold sweating. The patient is not infrequently sick on the return of consciousness, and this sign is often a precursor of recovery. Headache and giddiness may persist for the remainder of the day.

If the patient be in the dental chair, his head should be bent forward, or, better still, the back of the chair tilted so that the supine position is assumed. The patient should be kept warm with blankets or rugs, and any tight clothing loosened. Brandy or hot coffee, or an ether draught should be administered, or, if unconsciousness is present, ether (ʒi) or strychnine (gr. $\frac{1}{50}$) injected hypodermically.

Amyl nitrite should not be administered, as it has been shown recently to have a harmful effect in cases of cocaine poisoning.

The patient must be watched throughout, and at the first sign of respiratory failure, artificial respiration must be resorted to and maintained for some time after the breathing has resumed, for the respiration is liable again to become weak after all apparent danger has passed. The first measures are most important, *i.e.* position and warmth, but, as the seriousness of the patient's condition cannot always be foretold, no time should be lost in preparing for emergencies.

Toxic symptoms arising from local anaesthetics other than cocaine are somewhat similar to those already mentioned, and require to be treated on the same lines.

Mr. W. S. Rose records a case of novocaine poisoning in a medical man, who was apparently in perfect health at the time of the operation. No ill-effect appeared until about an hour after the injection, and the more prominent symptoms were a loss of sensory and motor power in the limbs, shivering fits, followed by vomiting, loss of consciousness, and exhaustion. The patient rapidly improved under strychnine and brandy, together with rest in bed.

Paralysis of the central nervous system is the cause of death in cases of poisoning from local anaesthetics.

Adrenalin poisoning. Symptoms of poisoning arising from the injection of adrenalin chloride have been somewhat confused with those due to the associated local anaesthetic, and only recently has it been suggested that some of the graver symptoms may be due to the action of that poisonous alkaloid.

The injection of adrenalin has been followed by grave symptoms, where it has been employed for diminishing the blood-supply in the operative area, *e.g.* in submucous resection of the nasal septum. These symptoms are apparently unaccountable by the operation or the general anaesthesia under which it is performed.

Dr. Blumfield [1] records the symptoms of pallor and feeble breathing in a patient in whom six drops of adrenalin chloride solution (·025 per cent.) were injected into the mucous membrane of the nasal septum, as a preliminary to its resection. Chest compression together with lowering of the head and shoulders restored the patient.

Mr. A. D. Fleming [2] has noted faintness after the injection of adrenalin chloride in strengths similar to that employed in Dr. Blumfield's case, but never in solutions of 1 in 50,000 or less.

Death has occurred within a minute or two of the injection of a minim of a ·1 per cent. solution of adrenalin, but in the case cited there is doubt as to whether the operation may not have been the primary cause of the fatality.

The depressing effects of adrenalin appear to be exaggerated in the narcotised patient, and most of the fatalities have occurred during general anaesthesia.

[1] *Proceedings of the Royal Society of Medicine*, March, 1911.

[2] *Ibid.*

INDEX.

GLASGOW: PRINTED AT THE UNIVERSITY PRESS BY ROBERT MACLEHOSE AND CO. LTD.

SELECTED LIST
OF
NEW AND RECENT WORKS
PUBLISHED BY
H. K. LEWIS,
136 GOWER STREET, & 24 GOWER PLACE,
LONDON, W.C.

TELEGRAMS: Publicavit, London. (ESTABLISHED 1844). TELEPHONE: 10721 Central.

** For full list of works in Medicine and Surgery published by H. K. Lewis see complete Catalogue sent post free on application.*

W. MITCHELL STEVENS, M.D., M.R.C.P.

Fellow of University College, London; University Scholar in Medicine (London); Senior Assistant Physician to the Cardiff Infirmary; Consulting Physician to the Royal Hamadryad Seamen's Hospital; Lecturer in Pharmacology in University College, Cardifi.

MEDICAL DIAGNOSIS. Medium 8vo, with 177 illustrations, several in colours, including a coloured plate, 25s. net. [*Now ready.*

SIR RICHARD DOUGLAS POWELL, BART., M.D. LOND., F.R.C.P.

Physician In Ordinary to H.M. the King; Consulting Physician to the Middlesex Hospital, &c.

AND P. HORTON-SMITH HARTLEY, M.V.O., M.A., M.D. CANTAB., F.R.C.P.

Physician to Out-patients, St. Bartholomew's Hospital; Physician to the Brompton Hospital, &c.

ON DISEASES OF THE LUNGS AND PLEURÆ INCLUDING TUBERCULOSIS AND MEDIASTINAL GROWTHS. Fifth Edition, with 29 plates (6 coloured) and other illustrations in the text, 8vo, 21s. *nett.* [*Just out.*

G. E. SHUTTLEWORTH, B.A., M.D.

Medical Examiner of Defective Children to the Willesden Education Committee and formerly to the School Board for London; Consulting Medical Officer, National Association for the Feeble Minded, &c.

AND W. A. POTTS, B.A., M.D.

Consulting Medical Officer, National Association for the Feeble Minded; Chairman of the After-Care Committee, Member Special Schools Committee, Birmingham; late Medical Investigator, Royal Commission on Care and Control of Feeble Minded, &c.

MENTALLY-DEFICIENT CHILDREN: their Treatment and Training. Third Edition, with 18 Plates and other Illustrations, crown 8vo, 5s. *nett.*

1500, vi.—11.

R. W. ALLEN, M.D., B.S. LOND.

Late Clinical Pathologist to the Mount Vernon Hospital for Diseases of the Chest, Hampstead; late Pathologist to the Royal Eye Hospital, London.

VACCINE THERAPY, ITS THEORY AND PRACTICE. Third Edition, revised and enlarged, demy 8vo, 7s. 6d. *nett.*

H. CHARLTON BASTIAN, M.A., M.D., F.R.S.

Emeritus Professor of the Principles and Practice of Medicine in University College, London, etc.

I.

A TREATISE ON APHASIA AND OTHER SPEECH DEFECTS. With Illustrations, med. 8vo, 15s.

II.

PARALYSES: CEREBRAL, BULBAR, AND SPINAL. A Manual of Diagnosis for Students and Practitioners. With numerous Illustrations, 8vo, 12s. 6d.

III.

VARIOUS FORMS OF HYSTERICAL OR FUNCTIONAL PARALYSIS. Demy 8vo, 7s. 6d.

W. M. BEAUMONT.

INJURIES OF THE EYES OF THE EMPLOYED, and the Workmen's Compensation Act. Problems in Prognosis. Crown 8vo, 5s.

REGINALD R. BENNETT, B.SC. LOND., A.I.C.

Pharmaceutical Chemist, Pharmacist and Teacher of Pharmacy to University College Hospital, London, &c.

MATERIA MEDICA AND PHARMACY FOR MEDICAL STUDENTS. With an appendix on Incompatibility, fcap. 8vo, 4s. 6d. *nett.*

JOHN FAIRBAIRN BINNIE, A.M., C.M. ABERD.

Professor of Surgery, Kansas City Medical College, &c.

MANUAL OF OPERATIVE SURGERY. Fourth Edition, in two volumes, fully illustrated, post 8vo, bound leather, gilt edges, 14s. *nett each.*

W. IRONSIDE BRUCE, M.D.

Physician to the X-Ray and Electrical Departments, Charing Cross Hospital, &c.

A SYSTEM OF RADIOGRAPHY: with an Atlas of the Normal. With 111 Illustrations, folio, 15s. *nett.*

MILDRED M. BURGESS, M.D. LOND.

Late Assistant House Physician, Victoria Hospital for Sick Children, Hull; late House Surgeon, Royal Free Hospital; Assistant School Doctor, London County Council; Medical Officer, London County Council, Girls' Industrial School, Brixton Hill, S.W.; Lecturer on Infant Care, Home Nursing, First Aid and Health to the London County Council; Recognised Teacher of the Central Midwives Board; Medical Officer to the Girls' Onward Club, Lambeth.

THE CARE OF INFANTS AND YOUNG CHILDREN IN HEALTH. Crown 8vo, stiff paper covers, 1s. net.

JAMES CALVERT, B.A., B.SC., M.D. LOND.

Fellow of the Royal College of Physicians; Lecturer on Materia Medica, Pharmacology, and Therapeutics, to St. Bartholomew's Hospital.

PRACTICAL PHARMACY AND PRESCRIBING FOR STUDENTS OF MEDICINE; being the Course in Use at St. Bartholomew's Hospital. Second Edition, crown 8vo, interleaved, 4s. 6d.

HARRY CAMPBELL, M.D., B.S. LOND., F.R.C.P.

Physician to the North-West London Hospital.

I.

THE CAUSATION OF DISEASE. An exposition of the ultimate factors which induce it. Demy 8vo, 12s. 6d.

II.

FLUSHING AND MORBID BLUSHING, THEIR PATHOLOGY AND TREATMENT. Second Edition, with plates and wood engravings, royal 8vo. [*In the press.*

III.

DIFFERENCES IN THE NERVOUS ORGANISATION OF MAN AND WOMAN, PHYSIOLOGICAL AND PATHOLOGICAL. Royal 8vo, 15s.

IV.

HEADACHE AND OTHER MORBID CEPHALIC SENSATIONS. Royal 8vo, 12s. 6d.

ALFRED H. CARTER, M.D. LOND., F.R.C.P., J.P.

Examiner in Medicine for the University of London; Professor of Medicine, University of Birmingham; Consulting Physician to the Queen's Hospital, Birmingham, &c.

ELEMENTS OF PRACTICAL MEDICINE. Ninth Edition, revised throughout, crown 8vo, 10s. 6d.

I.

F. COLEMAN, L.R.C.P., M.R.C.S., L.D.S.

Assistant Dental Surgeon to St. Bartholomew's Hospital.

EXTRACTION OF TEETH. With 56 Illustrations, crown 8vo, 3s. *nett.*

II.

ANÆSTHETICS IN DENTAL SURGERY. With illustrations, crown 8vo. [*In preparation.*

ARTHUR COOPER, M.R.C.S., L.R.C.P.

Consulting Surgeon to the Westminster General Dispensary, &c.

THE SEXUAL DISABILITIES OF MAN AND THEIR TREATMENT. Second Edition, Enlarged, with Illustrations, fcap. 8vo, 5s. *nett.* [*Now ready.*

W. H. CORFIELD, M.A., M.D. OXON., F.R.C.P. LOND.

Late Professor of Hygiene and Public Health in University College, London.

I.

THE ETIOLOGY OF TYPHOID FEVER AND ITS PREVENTION, being the Milroy Lectures delivered at the Royal College of Physicians in 1902. Demy 8vo, 2s. 6d.

II.

DWELLING HOUSES: their Sanitary Construction and Arrangements. Fourth Edition, with Illustrations, crown 8vo. 3s. 6d.

III.

DISEASE AND DEFECTIVE HOUSE SANITATION, With Illustrations, crown 8vo, 2s.

SIDNEY COUPLAND, M.D., F.R.C.P.

Physician to the Middlesex Hospital, and Lecturer on Practical Medicine in the Medical School, etc.

NOTES ON THE CLINICAL EXAMINATION OF THE BLOOD AND EXCRETA. Third Edition, 12mo, 1s. 6d.

H. RADCLIFFE-CROCKER, M.D. LOND., B.S., F.R.C.P.

Late Physician for Diseases of the Skin in University College Hospital.

DISEASES OF THE SKIN: THEIR DESCRIPTION, PATHOLOGY, DIAGNOSIS, AND TREATMENT. Third Edition, with 76 Plates and 112 Illustrations, 2 vols., large 8vo, 30s. *nett.*

GEORGE M. GOULD, A.M., M.D.

I.

THE PRACTITIONER'S MEDICAL DICTIONARY, an illustrated dictionary of Medicine and allied subjects, including all the words and phrases generally used in Medicine, with their proper pronunciation, derivation, and definition. Second Edition, illustrated, medium 8vo, pp. xxvi. + 1043, gilt edges, rounded corners, bound in limp leather, 18s. *nett.*

II.

THE STUDENT'S MEDICAL DICTIONARY: Including all the words and phrases generally used in Medicine, with their proper pronunciation and definitions. Eleventh Edition, with numerous Illustrations, 8vo, 14s. *nett.*

III.

A POCKET MEDICAL DICTIONARY, giving the Pronunciation and Definition of the Principal Words used in Medicine and the Collateral Sciences. Fourth edition, containing 30,000 words. Dose List revised in accordance with the U.S.A. Pharmacopœia, 1905. 32mo, 5s. net.

C. GRAHAM GRANT, L.R.C.P. AND S. EDIN.

Divisional Surgeon H. and Thames Divisions Metropolitan Police, Surgeon Poplar Hospital, &c.

PRACTICAL FORENSIC MEDICINE, A Police-Surgeon's Emergency Guide. Second Edition, revised and enlarged, fcap. 8vo, 2s. *nett.* [*Just published.*

DR. RICHARD GREEFF.

Professor of Ophthalmology in the University of Berlin and Chief of the Royal Ophthalmic Clinic in the Charité Hospital.

ATLAS OF EXTERNAL DISEASES OF THE EYE, for Physicians and Students. Only authorised English Translation by P. W. SHEDD, M.D., New York. With 84 Illustrations in colour on 54 plates, demy 4to, 42s. *nett.*

O. C. GRUNER, M.D. LOND., M.R.C.S., L.R.C.P.

Formerly Clinical Pathologist to the General Infirmary, Leeds, &c.

STUDIES IN PUNCTURE FLUIDS. A contribution to Clinical Pathology. With 5 plates (2 coloured), and other Illustrations, demy 8vo, 7s. 6d.

G. OLIVER, M.D., F.R.C.P.

I.

STUDIES IN BLOOD PRESSURE: PHYSIOLOGICAL AND CLINICAL. Second Edition, revised and enlarged, roan, rounded corners, fcap. 8vo, 4s. *nett.*

II.

A CONTRIBUTION TO THE STUDY OF THE BLOOD AND BLOOD-PRESSURE. Founded on portions of the Croonian Lectures delivered before the Royal College of Physicians, London, 1896, with considerable extensions. With Illustrations, demy 8vo, 7s. 6d.

WILLIAM OSLER, M.D., F.R.C.P. LOND.

Regius Professor of Medicine, University of Oxford.

ÆQUANIMITAS: With other Essays and Addresses to Medical Students, Nurses and Practitioners of Medicine. Third Edition, Reprinted. Post 8vo, 6s. *nett.* [*Now ready.*

KURRE W. OSTROM.

Instructor in Massage and Swedish Movements in the Philadelphia Polyclinic and College for Graduates in Medicine.

MASSAGE AND THE ORIGINAL SWEDISH MOVEMENTS; their application to various diseases of the body. Sixth Edition, with 115 illustrations, crown 8vo, 3s. 6d. *nett.*

SIR RICHARD DOUGLAS POWELL, BART., M.D. LOND., F.R.C.P.

Physician In Ordinary to H.M. the King; Consulting Physician to the Middlesex Hospital, &c.

THE LUMLEIAN LECTURES ON THE PRINCIPLES WHICH GOVERN TREATMENT IN DISEASES AND DISORDERS OF THE HEART. Coloured Diagrams, demy 8vo, 6s.

LOUIS BATHE RAWLING, M.B., B.C. CANTAB., F.R.C.S. ENG.

Surgeon, with charge of Out-Patients, and Demonstrator of Practical and Operative Surgery, St. Bartholomew's Hospital; late Senior Demonstrator of Anatomy and Assistant Surgeon to the German Hospital, Dalston.

LANDMARKS AND SURFACE MARKINGS OF THE HUMAN BODY. Fourth Edition, demy 8vo, 29 plates (3 in colour), 5s. *nett.* [*Just issued.*

LOUIS STARR, M.D.

Physician to the Children's Hospital, Philadelphia, &c.

HYGIENE OF THE NURSERY. Including the General Regimen and Feeding of Infants and Children; Massage, and the Domestic Management of the Ordinary Emergencies of Early Life. Seventh Edition, with Illustrations, cr. 8vo, 3s. 6d.

E. R. STITT, A.M., PH.G., M.D.

Surgeon U.S. Navy; Graduate London School of Tropical Medicine, &c.

PRACTICAL BACTERIOLOGY, BLOOD WORK, and Animal Parasitology, &c. Second Edition, 91 Illustrations, post 8vo, 6s. 6d. *net.* [*Just issued.*

J. BLAND-SUTTON, F.R.C.S.

Assistant Surgeon to the Middlesex Hospital.

LIGAMENTS: THEIR NATURE AND MORPHOLOGY. Third Edition, wood engravings, post 8vo, 4s. 6d.

SIR HENRY R. SWANZY, A.M., M.D., (CAUSA HON.), PRES.R.C.S.I.

Surgeon to the Royal Victoria Eye and Ear Hospital, and Ophthalmic Surgeon to the Adelaide Hospital, Dublin.

AND LOUIS WERNER, F.R.C.S.I., M.B., B.CH. DUB.

Ophthalmic Surgeon, Mater Miser Hospital, Dublin, &c.

A HANDBOOK OF DISEASES OF THE EYE AND THEIR TREATMENT. Tenth Edition, with new Illustrations, including Coloured Plates, Colour Tests, &c., demy 8vo. [*In the press.*

ALBERT TAYLOR.

Member Royal Sanitary Institute; Sanitary Inspector, City of Westminster; late Chief Sanitary Inspector to the Vestry of St. George, Hanover Square, etc.

THE SANITARY INSPECTOR'S HANDBOOK. Fourth Edition, with Illustrations, cr. 8vo, 6s.

HUGH THURSFIELD, M.D., F.R.C.P.

Senior Demonstrator of Medical Pathology, St. Bartholomew's Hospital; Assistant Physician to the Hospital for Sick Children, Great Ormond Street, &c.

AND WILLIAM P. S. BRANSON, M.D., M.R.C.P.

Junior Curator of the Museum, St. Bartholomew's Hospital; Assistant Physician to the Royal Free Hospital, &c.

MEDICAL MORBID ANATOMY AND PATHOLOGY. Crown 8vo, 6s. *nett.*

E. W. AINLEY WALKER, M.A., D.M. OXON.,
Fellow and Praelector of University College, Oxford; late Gordon Lecturer in Experimental Pathology at Guy's Hospital, &c.

THE GENERAL PATHOLOGY OF INFLAMMATION, INFECTION, AND FEVER. Being the Gordon Lectures for 1902, crown 8vo, 4s. 6d. net.

HUGH WALSHAM, M.A., M.D. CANTAB.
Fellow of the Royal College of Physicians; Chief Assistant in the Electrical Department of St. Bartholomew's Hospital; Senior Assistant Physician to the City of London Hospital for Diseases of the Chest.

AND GEORGE HARRISON ORTON, M.A., M.D. CANTAB.
Medical Officer in charge of the X-Ray Department St. Mary's Hospital, and the Cheyne Hospital for Sick Children, &c.

THE X-RAYS IN THE DIAGNOSIS OF DISEASES OF THE CHEST. With 18 specially prepared plates from selected negatives, and other illustrations, demy 8vo, 6s. net.

R. PROSSER WHITE, M.D. EDIN., M.R.C.S. ENG.
Life Vice-President and Honorary Medical Officer, Royal Albert Edward Infirmary, Wigan.

CATARRHAL FEVERS, COMMONLY CALLED COLDS: their Causes, Consequences, Control, and Cure. With 3 plates, extra demy 8vo, 4s.

E. T. WILSON, M.B. OXON., F.R.C.P. LOND.
Physician to the Cheltenham General Hospital, &c.

DISINFECTANTS AND ANTISEPTICS: HOW TO USE THEM. In Packets of one doz. price 1s., by post 1s. 1d. [*Thoroughly revised.*

BERTRAM C. A. WINDLE, D.SC., M.D., M.A. DUBL.
President, Queen's College, Cork; Examiner in Anatomy, Royal College of Physicians, London, &c.

A HANDBOOK OF SURFACE ANATOMY AND LANDMARKS. Third Edition, with Illustrations, post 8vo, 4s. *nett.*

JOHN WYLLIE, M.D. GLASGOW.

I.

MENINGITIS, SINUS THROMBOSIS AND ABSCESS OF THE BRAIN. Post 8vo, 6s. 6d. *nett.* [*Just published.*

II.

TUMOURS OF THE CEREBELLUM. Post 8vo. With illustrations, 4s. *net.*

All Charts sent post free. Specimen of any Chart free.

LEWIS'S DIET CHARTS. A Suggestive set of Diet Tables for the use of Physicians, for handing to Patients after Consultation, modified to suit Individual Requirements; for Albuminuria, Anæmia and Debility, Constipation, Diabetes, Diarrhœa, Dyspepsia, Eczema, Fevers, Gall Stones, Gout and Gravel, Heart Disease (chronic), Nervous Diseases, Obesity, Phthisis, Rheumatism (chronic); and Blank Chart for other diseases. 5s. per packet of 100 charts, post free.

A special leaflet on the Diet and Management of Infants is sold separately. 12, 1s.; 100, 7s. 6d., post free.

CHART FOR RECORDING THE EXAMINATION OF URINE. Designed for the use of medical men, analysts and others making examinations of the urine of patients. 10, 1s.; 100, 7s. 6d.; 250, 15s.; 500, 25s.; 1000, 40s.

CLINICAL CHARTS FOR TEMPERATURE OBSERVATIONS, ETC. Arranged by W. Rigden, M.R.C.S. 12, 1s.; 100, 7s.; 250, 15s.; 500, 28s.; 1000, 50s.

LEWIS'S HÆMATOLOGICAL CHART. A new Chart designed for recording Counts, &c., designed by Dr. E. R. Turton. 1000, 50s.; 500, 28s.; 250, 15s.; 100, 7s.; 12, 1s.

LEWIS'S CLINICAL CHART, SPECIALLY DESIGNED FOR USE WITH THE VISITING LIST. Arranged for four weeks, and measures 6 × 3 inches. 12, 6d.; 25, 1s.; 100, 2s. 6d.; 500, 11s. 6d.; 1000, 20s.

LEWIS'S "HANDY" TEMPERATURE CHART. Arranged for three weeks, with space for notes of case as to diet, &c., and ruled on back for recording observations on urine. 20, 1s.; 50, 2s.; 100, 3s. 6d.; 500, 14s.; 1000, 25s.

Uniform in size and price with the "Handy" Chart :—

LEWIS'S FOUR-HOUR TEMPERATURE CHART. Meets the requirements of a chart on which the temperature and other observations can be recorded at intervals of four hours. Each chart will last a week.

LEWIS'S NURSING CHART. Printed on both sides.

LEWIS'S BLOOD-PRESSURE AND PULSE CHART. An entirely new Chart.

LEWIS'S SMALL FOUR-HOUR TEMPERATURE CHART. Designed by G. C. Coles, M.R.C.S. Each chart lasts two weeks and gives space for noting Pulse, Respiration and Urine, and Remarks.

LEWIS'S MORNING AND EVENING TEMPERATURE CHART. Designed by G. C. Coles, M.R.C.S. Each chart lasts three weeks, and provides space for noting also the Pulse, Respiration, and Urine, and general Remarks.