GENERAL ANAESTHESIA

Edited by

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ABBREVIATIONS

The following abbreviations have been used in this work and are listed here for the convenience of readers.

Å	– Ångstrom
C.	– Centigrade
cc.	– cubic centimetre
cm.	– centimetre
F.	– Fahrenheit
g.	– gramme
gr.	– grain
kg.	– kilogram
l.	– litre
lb.	– pound
LH	– luteinizing hormone
μ	– micron
μg.	– microgram
m.	– metre
m–equiv.	– milliequivalent
mg.	– milligram
mg./lb.	– milligrams per pound
min.	– minute
ml.	– millilitre
mm.	– millimetre
mM	– millimol
msec.	– millisecond
mV	– millivolt
sec.	– second
sq. cm.	– square centimetre
sq. m.	– square metre
S.W.G.	– standard wire gauge
V.	– volts
v/v	– volume in volume
v/w	– volume in weight
w/v	– weight in volume
w/w	– weight in weight

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BASIC PRINCIPLES

CHAPTER 1

SOME BASIC TECHNIQUES IN ANAESTHESIA

R. BLAIR GOULD

DIETHYL ETHER ($(C_2H_5)_2O$)

IN SPITE of much prejudice and of the severe competition of more recently introduced drugs, ether still remains the routine general purpose anaesthetic agent. The words of the late John Challis in 1946 are even more true today than when he made the pertinent observation: "The consumption of ether in the average London teaching hospital has shown no tendency to fall in recent years. . . . This fact may help to disillusion those ultra-modernists who believe that cyclopropane, thiopentone and curare are the last words in anaesthesia". The chief role of ether in modern practice is as a supplement to nitrous oxide-oxygen, with or without relaxant or other supplementary drugs, to assist in the production of a smooth light anaesthesia without hypoxia; yet the open drop method, which is one of the earliest methods of administering the drug, is still a useful method where a modern anaesthetic machine is not available, or where the administrator is unskilled in the use of such a machine, or in the case of a child where a machine, unless adapted for the purpose, tends to produce hypercapnia due to excessive dead space.

Since the ether vapour is highly inflammable, it must not be used in a room where there is an open fire, a gas or electric fire, or similar dangers, or where sparking in electrical apparatus is a possibility. The usual precautions against the accumulation of a static electrical charge must be observed.

Methods of administration

Open drop method

Since liquid ether, in contact with skin or mucous membranes, may cause burns, the tissues must be protected. As a rule, it is sufficient to drop castor oil or liquid paraffin into the eyes, but in cases of, for example, exophthalmos, in which the eyelids do not easily remain closed, it may be necessary to pull them together with adhesive strapping or even to sew them together. The face must be covered with a pad of Gamgee tissue with a hole cut in the centre to give access to the nose and mouth. If, in spite of this, liquid ether should be spilt into the conjunctival sacs, the latter must immediately be washed out with saline solution from an undine, and castor oil instilled in order to dissolve out any ether remaining. "Ether eye"—conjunctivitis with or without corneal ulceration—is a very painful condition, and must be treated with cocaine and atropine drops. Cold packs applied to the eyes are soothing and helpful.

The Schimmelbusch mask, or one of similar type, is covered with 12–16 layers of gauze, which are cut flush with the mask to prevent liquid ether from dripping

on to the face. A few drops of essence of orange sprinkled on the mask disguises the unpleasant smell to some extent.

It is essential that the patient should be able to inhale the vapour freely. The concentration of ether dropped upon the mask should be as strong as the patient can inhale without breath-holding or coughing. The ether should be dropped upon the mask as regularly and evenly as possible, for irregular dropping allows the anaesthesia to become lighter and it is then tempting to flood the mask, in which case too concentrated a vapour will cause coughing and interrupt the smooth development of induction. The Bellamy Gardner dropper allows a good control over the rate of dropping, but two grooves cut in the cork, one to act as an air inlet and the other fitted with a little ribbon of gauze as a wick, is satisfactory. Great patience is necessary in order to achieve a perfectly smooth induction. It must never be hurried, but at the same time the concentration of ether on the mask must be kept as high as will be tolerated by the patient.

The hot expirations of the patient vaporize the ether ready for the next inhalation and although the ether vapour does not move far from the mask between breaths, some must be blown away when the anaesthesia is light and the breathing is vigorous. The concentration which is inhaled is therefore decreased. On the other hand, when the patient is deeply anaesthetized, the volume of breathing is less, and the tendency is for a more concentrated vapour to be inhaled. The rate at which ether is dropped upon the mask must then be decreased. When the patient is excited or is struggling, it is often difficult to achieve a sufficient concentration of vapour, for the vigorous breathing volatilizes the ether as it is dropped upon the mask, and the more liquid that is poured on the mask the more it becomes chilled and frosted. By such recurring periods of excitement the vitality of the patient is depleted, and post-operative prostration and slow recovery are rendered inevitable.

Thus induction of anaesthesia by means of the drop method requires considerable skill and practice. Apart from struggling and excitement, laryngeal stridor may develop from the inhalation of too concentrated a vapour in the later stages of induction, or may result from surgical stimulation in light anaesthesia. This stridor is due to adductor spasm, and may be very resistant and difficult to eradicate. Forcible respiration with oxygen and carbon dioxide may overcome it, but often very deep anaesthesia is necessary. If anaesthesia is carried to a deep level until the adductor muscles of the cord are paralysed, the vocal cords will often remain relaxed and spasm does not recur subsequently even under strong stimulation in light anaesthesia. Similarly, surgical stimulation in light anaesthesia may cause muscular rigidity, due to reflex stimulation.

These reactions are difficult to overcome when once they have been elicited. Their avoidance depends upon good management by the anaesthetist. Induction should be as speedy as possible without being too hurried, with the object of producing slightly deeper anaesthesia than is necessary for the type of surgery under contemplation. Thus there is a small margin of anaesthesia in hand so that the emergencies of inadequate anaesthesia are not encountered.

The whole volume of respired air must pass through the mask; the drops should fall on the whole surface of the mask, and not only on a part of it. If the patient objects to the vapour concentration, the mask can be lifted from the face for a few inspirations and then gently lowered again. A flow of carbon dioxide under the mask hastens induction.

As induction progresses, the patient's head may be turned to one side to maintain a good airway and to prevent mucus and saliva from gaining entrance into the larynx. Respiratory obstruction may arise from closure of the lips, especially in edentulous patients, or from falling back of the tongue due either to relaxation of the muscles in the floor of the mouth or to spasm of the muscles of the jaws. In the latter case the airway may be restored by strong forward pressure applied at the angle of the jaws, and in strong spasm it may be necessary to lift the patient's head from the pillow by this means. In case of difficulty, an artificial airway should be inserted as soon as the patient will tolerate it, since a good airway favours early and more complete muscular relaxation.

The maximum vapour concentration achieved by this method is about 14 per cent. This is sufficient for maintenance of anaesthesia but not for induction in resistant cases which may require concentrations of up to 18 or 20 per cent.

Semi-open methods

Various devices are employed to hasten induction by increasing rebreathing and thus the concentration of ether vapour obtainable with the open method. A flow of carbon dioxide underneath the mask increases the tidal air and hastens induction. A pad of Gamgee tissue with a hole in the centre is often placed over the mask to conserve the expired carbon dioxide. Towels may be draped around the mask for the same purpose. The Ogston mask consists of a Schimmelbusch mask, attached to the base of which are vertical supports around which towels may be wrapped. The Denis Browne inhaler consists of a light metal cylinder, with a rubber cushion for the face; within the cylinder there is a removable metal frame over which gauze is stretched and on to which the ether is dropped. The volume of rebreathing is controlled by the opening or closing of a shutter fitted across the cylinder.

With all these open or semi-open methods there would appear to be a continuous deprivation of heat, since the patient is inhaling a cold vapour, the temperature of which is much below that of the atmosphere. However, the specific heat of the air and anaesthetic vapour is so low that the gases probably reach body temperature by the time they arrive at the alveoli.

E.M.O. inhaler

The Oxford vaporizer which was designed at the Department of Anaesthetics at Oxford, and delivered ether-air vapour of adjustable and known concentration, has been replaced by the E.M.O. Inhaler (Epstein and Macintosh, 1956). This delivers any desired concentration of ether vapour with air, an automatic thermo-compensator maintains a constant vapour concentration. This apparatus probably affords the most accurate method we possess of giving an air-ether concentration and is particularly useful in providing an air-ether mixture in circumstances where more complicated apparatus or a supply of nitrous oxide is not available. In hot climates crushed ice may be packed into the apparatus and this renders it possible to use ether in tropical conditions.

Ether vaporized by means of a gas machine

Ether may be used with any of the gaseous anaesthetic agents such as nitrous oxide or cyclopropane, in any machine equipped with a suitable vaporizing bottle

and with either an open or closed circuit. As a rule a much smoother induction and anaesthesia may be obtained by vaporizing ether in this way rather than on an open mask. The administration of a small concentration of carbon dioxide facilitates induction by stimulating the subject's respirations particularly if they have been depressed by premedication or an induction dose of thiopentone. The concentration of ether vapour in the inhaled gases depends upon the type of vaporizing bottle, the rate of flow of the gases, the amount of ether in the bottle and the temperature of the environment.

Ether bottles are of two types. The ordinary "bubble-through" bottle has a device by which the gases may be passed either through or over the surface of the liquid. To ensure maximal vaporization, the gas bubbles should be very small so that their surface area is large in proportion to their volume, and the depth of ether through which the bubbles have to pass should be as great as possible. Morris (1952) has described a "bubble-through" vaporizer in which the bubbles are made very small by passing the gases through a sintered bronze disc. This, however, is not available in Great Britain. A second type of vaporizer is provided with a wick, which is kept moist by the liquid ether into which it dips and through the meshes of which the patient breathes. The vaporization from such a bottle is very good, as the whole volume of the patient's respirations can be passed through it, and it is particularly useful in closed-circuit machines, in which the small volume of basic flow gases is hardly sufficient to produce much vaporization from the "bubble-through" type of bottle. The wick, however, rapidly becomes saturated with water vapour and should be dried after each administration.

CHLOROFORM ($CHCl_3$)

Methods of administration

Preliminary remarks

Certain principles are common to all the various methods of administration. Premedication should be sparing so as to avoid respiratory depression. It is best, therefore, to avoid using morphine and similar drugs, although some anaesthetists permit morphine in small dosage. Drugs which do not appreciably depress respiration, such as chloral hydrate, are satisfactory in small dosage. Atropine is usually given as it is thought to be of use in preventing vagal stimulation, although in therapeutic doses this is unlikely. Gillies (1948) has expressed doubts as to the value of atropine before chloroform anaesthesia—in an investigation of 138 fatalities from chloroform anaesthesia the death roll was found to be at least twice as high in the group in which atropine was used as that in which it was omitted.

Throughout the administration particular attention should be paid to the maintenance of a good airway, and oxygen should be given, but not in such a way as to mask a defective airway. An artificial airway should always be provided in order to prevent obstruction due to falling back of the tongue.

The concentration of the vapour should be weak at first, and then increased in an even, steady manner, but not too quickly. Should apnoea occur, due to spasm or to holding of the breath, the mask should be removed from the face until breathing is resumed. On the other hand, if the induction is too prolonged, struggling may

ensue. With a chloroform-sensitized heart there is always a danger of cardiac failure if struggling becomes violent. Further, with slow administration, chloroform "sleep" may develop. This is a state which resembles third-stage anaesthesia, but in which the eyelash reflex still persists. Any attempt to commence the operation in this state may cause intense excitement.

Particular care must be taken to observe the pulse and respiration. Any weakening of the pulse indicates the necessity of lightening the anaesthesia, and the respiration, although depressed, should always be audible and perceptible. Should breathing cease at any stage, the chloroform must be withdrawn immediately and pure oxygen given by some method of artificial respiration. Overdosage causes cessation of respiration before the heart ceases to beat, but the myocardium is usually so depressed by that time that cessation of the heart follows immediately. Immediate cardiac massage is, of course, the treatment of cardiac arrest. Since the apparatus and the dead space in the lungs are full of chloroform vapour and absorption from the alveoli continues for a time after respiration has ceased, apnoea from whatever cause must be taken seriously.

Dilatation of the pupil must also be taken as a sign of an impending overdose. Whereas with ethyl ether a dilated pupil causes little concern, with chloroform the pupil must be kept small.

Open drop method

Since chloroform may cause a burn of the skin or mucous membrane if it is in contact with them, care must be taken to avoid this. A layer of Vaseline smeared over the skin of the face and on the lips is a good protection; some anaesthetists drop castor oil into the conjunctivae on beginning to administer the anaesthetic. Since castor oil, however, may absorb chloroform vapour during the period of anaesthesia, it is better practice to reserve this for the end of the operation in order to lubricate the eyeball after removing the vapour. Liquid paraffin is a good protection and does not absorb the chloroform.

Two layers of lint are stretched over an open-wire skeleton face mask of the Schimmelbusch type. A drop-bottle, with a cork which cannot easily become detached and which allows of easy regulation of a slow rate of dropping, is essential. To avoid restriction of air, it is better not to use Gamgee tissue under the mask. During induction the edge of the mask is lifted from the face to allow ample intake of air. The lint should never be allowed to become wet through with chloroform. The rate of dropping should be as uniform and as steady as possible: 1 drop during the first minute, 6 during the second, 12 during the third, and so on. An oxygen tube may be attached to the mask under the lint to ensure adequate oxygenation, but this should never be allowed to disguise the presence of a defective airway.

Anaesthesia usually develops fairly quickly. With the onset of automatic breathing depression of respiration is obvious, and as the depth of anaesthesia is increased the respiration becomes more shallow and slow. With an overdose, breathing may cease quite suddenly. Anoxia must therefore be watched for carefully, and remedied immediately.

The pupils remain quite small in moderate anaesthesia, but become dilated in deep anaesthesia. In dangerously deep anaesthesia the pupils become widely dilated, and the corneal reflex disappears.

Chloroform vapour with nitrous oxide and oxygen

The development of modern gas machines of a high degree of efficiency has made it possible to use chloroform as a supplement to nitrous oxide anaesthesia, rather than as the sole anaesthetic. Unfortunately, the dangers of chloroform do not depend upon the amount administered. Since a high proportion of deaths under chloroform occur either during induction or in light anaesthesia, probably the use of nitrous oxide, with or without ether, for induction, followed by a nitrous oxide and chloroform mixture for maintenance, does to some extent reduce, although it does not completely eliminate, its dangers. There must, however, be no restriction of the oxygen supply.

Whatever type of machine is to be used, the anaesthetist should be familiar with the control valve on the chloroform bottle, particularly with the position of the valve which opens the bottle and the strength of vapour which is thereby allowed to enter the machine. If care is not taken too concentrated a vapour may suddenly be allowed into the breathing bag, with disastrous consequences. The gases should never be allowed to bubble through the liquid, but should merely be passed over its surface.

Chloroform should not be used in a closed circuit machine, as there is great danger of overdosage with this technique.

ETHYL CHLORIDE (C_2H_5Cl)

Ethyl chloride is a very potent anaesthetic agent; 5 ml. sprayed into a closed bag is sufficient to induce anaesthesia in the average adult. This method is not recommended, both on account of the accompanying hypoxia and because intravenous methods are more convenient in adults. For children, however, where a high degree of muscular relaxation is required for not more than 2 to 3 minutes, or for rapid induction to be followed by "drop ether", the drug may be administered by spraying on to a Schimmelbusch mask as has already been described for ether (*see* page 1). Prolonged or continuous administration must be condemned owing to the high toxicity of the drug, and to the high mortality which may result.

The margin of safety of the drug is small, there being little difference in the quantities required to achieve surgical anaesthesia and to produce overdosage. The toxicity is due mainly to the direct depressant action of the drug upon the heart; this becomes dilated, and the cardiac output is greatly reduced. The blood pressure falls, owing to these cardiac effects and also to the direct action of the drug on the vasomotor system. For these reasons, when respiration ceases as a result of an overdose of the drug as with chloroform, resuscitation by artificial respiration alone is often impossible.

Respiration is stimulated at first, but depressed later. The vapour is not irritating to inhale, although it is often regarded as being disagreeable, and eau-de-Cologne is usually added to disguise the unpleasant smell. Too strong a concentration of vapour during the induction stage may cause respiratory arrest by effecting vagal stimulation.

As has been mentioned above, muscular relaxation is usually very good, even though it is of short duration. Involuntary micturition and even defaecation may occur. Nausea and vomiting are usual during recovery.