USING VOLATILE ANAESTHETIC AGENTS

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There are a variety of anaesthetic techniques available and various clinical situations demand different techniques of anaesthesia. A trained anaesthetist should be able to decide the most appropriate method for each case as an anaesthetic decision (not a surgical decision) and have the necessary skills to use the technique of choice. Anaesthetists should practise their skills as widely as possible and not give the same anaesthetic to every single patient. This is of particular importance where supplies of drugs and equipment are unreliable.

Volatile anaesthetic agents are commonly used and have an important safety feature in that agents which enter the circulation via the lungs can leave by the same route. Therefore the concentration of anaesthetic at the brain can be rapidly reduced as long as the patient is breathing adequately.

Basic pharmacology of volatile agents

An agent inhaled into the lungs will first enter the circulation and is then carried to all tissues of the body. We are primarily interested in the concentration reaching the brain because this produces the state of anaesthesia. The exact mechanism of anaesthesia is poorly understood but it seems that the nerve cells absorb the agent and in so doing their ability to

conduct impulses to each other is reduced.

The more soluble the agent is in blood the longer it takes to build up an effective concentration in the brain and the slower the onset of unconsciousness. Thus with a very soluble agent such as ether, the induction of anaesthesia is prolonged. On the other hand an agent such as nitrous oxide is relatively insoluble in blood; the blood becomes saturated quickly, the brain concentration rises quickly and the effect is seen rapidly. The degree of solubility of an agent in blood is indicated by its blood gas solubility coefficient (see table 1).

The comparative potency of volatile agents depends on the minimum alveolar concentration (MAC). This has been defined as the concentration of the anaesthetic required in the alveoli to produce in surgical anaesthesia in 50% of patients. Although this is largely a theoretic value it allows us to compare the potencies of different anaesthetic agents. An agent with a low MAC value is more potent than one with a high MAC value. Trichloroethylene, like ether, is very soluble yet it produces its effects at a fraction of the concentration of that needed for ether. This is because the MAC for trichloroethylene is 0.17% and for ether 1.92%. The physical properties of the different agents are listed in table 1.

The inhalation agents that are commonly used in Africa and other places where resources are limited are ether and halothane. When it is available, trichloroethylene is also used.

Patterns of anaesthesia differ from country to country. Halothane, once the mainstay of modern inhalation anaesthesia and an agent that we in Malawi still regard as a "luxury" anaesthetic is now hardly used in the USA. In adult anaesthesia in the UK it has been largely displaced by two newer agents, enflurane ("Ethrane") and Isoflurane ("Forane") both of which are far more costly than halothane. Ether, of course, is never used in the western world and trichloroethylene has a diminishing number of users worldwide as production has now virtually ceased.

ETHER (Diethyl ether)

This is an inexpensive agent made from sugar cane (ethanol). Ether has been known since the 16th century as "sweet vitriol" but only when W.T.G.Morton demonstrated its effects in Boston in 1846 did its anaesthetic properties become known worldwide. This "first anaesthetic" took place on 16th October 1846.

Ether is stored in dark bottles with corks/caps as light may decompose it. If it is taken to high altitude its boiling point is lowered (for example where atmospheric pressure is 425 mmHg ether will boil at 20^{o}C).

Advantages: Ether stimulates respiration and blood flow due to its sympathomimetic effect mediated by adrenaline release. When too much ether is given respiration becomes depressed before the heart. These effects make ether a "safe" anaesthetic agent. It is a bronchodilator and produces analgesia. It may be used as the sole anaesthetic agent and is capable of producing good abdominal muscle relaxation. Ether causes little uterine relaxation.

Disadvantages: Ether is associated with a slow onset and a slow recovery. It stimulates salivation

Table 1. Physical characteristics of the volatile agents.

Characteristics	Ether	Halothane	Trichloroethylene	Nitrous oxide
MAC	1.92%	0.77%	0.17%	101%
Blood/gas coefficients	12.1	2.3	9.15	0.47
Oil/gas coefficient	65	224	960	1.4
Boiling point	35^{o}C	50^{o}C	87^{o}C	-89^{o}C

and is best used with atropine premedication. The vapour is unpleasant to breathe initially and causes irritation of the bronchial tree which may slow down the induction of anaesthesia. The incidence of nausea and vomiting is higher with ether than with other agents. The frequency is related to the concentration of ether used and is lower when ether is given via an endotracheal tube during relaxant anaesthesia.

Indications: Any general anaesthetic. It is especially useful for caesarean section (because the baby tolerates it and the uterus contracts well), major operations requiring intubation and poor risk cases (using a low dose). It is the volatile agent of choice when general anaesthesia is needed but no oxygen is available.

Contraindications: There are no absolute contra-indications to ether. It is better avoided in moderate or severe pre-eclampsia because of its sympathomimetic activity. Likewise, liver or renal failure and phaeochromocytoma are relative contra-indications.

Ether is explosive when mixed with oxygen and is inflammable in air. It may be ignited by a flame or an electrical spark such as those produced by diathermy or static electricity. The ether vapour is inflammable within the patient (lungs, airway or stomach full of vapour) or outside the patient within 25cm of the anaesthetic circuit. Scavenging must always be carried out (where possible) to avoid contact between heavy inflammable ether vapour and diathermy apparatus or other electrical devices that may spark. If the end of the scavenging tube is placed on the floor (away from any possible sources of ignition) then the heavy ether vapour will remain at floor level and the smell of the agent to the surgical and anaesthetic team reduced.

If in doubt about the safety of ether with diathermy, don't use them together.

Dosage and technique: The easiest method is to give ether to the patient after they have been intubated following atropine, thiopentone and suxamethonium. IPPV is commenced initially with 10 - 15% ether and then according to the patient's requirements, the ether is cut back after 2-8 minutes to 4-8% (usually 6-8%). Poor risk, septic or shocked patients can be kept just insensible with 2% ether. Discontinue the ether well before the end of the operation to avoid a prolonged recovery. With skill you can have your patients almost awake as they are moved off the table. If the patient is given a long acting muscle relaxant and the ventilation controlled, then the ether may be reduced to around 3 - 4%.

Vaporisers: The small Ether TEC vaporiser will deliver a lower dose than the EMO for the same setting. When using the EMO vaporiser do not give 15-20% ether for more than a few minutes because it is a very efficient vaporiser and will rapidly overdose the patient.

Practical points: If you are not used to giving ether, you will be surprised at its slow onset of action. Don't let the surgeon start until the patient is really deep. People working in theatre may complain about the smell of ether and nurses may claim that it gives them headaches. Symptoms improve after a while and may be reduced by efficient scavenging.

HALOTHANE (Fluothane)

Halothane contains thymol as a stabilizing agent and is stored in dark bottles as it is decomposed by ultraviolet light. It is more expensive than ether (about US $25.00 per bottle compared to US $3.00 for three times the volume of ether).

Advantages: Halothane is a well tolerated, non-irritant potent agent giving rapid induction, low dose maintenance and rapid recovery. There is a predictable, dose-related depression of respiration and cardiac function.

Disadvantages: As halothane is a very potent agent it is not suitable for use by untrained anaesthetic staff. Its poor analgesic properties necessitate deep planes of anaesthesia before surgery can be tolerated. For this reason it is generally not suitable as a sole agent without an analgesic supplement, eg nitrous oxide, trichloroethylene, local anaesthetic block or other analgesic, especially during spontaneous respiration. It provides no post-operative analgesia, and causes uterine relaxation and haemorrhage particularly if greater than 0.5% halothane is used. The depression of the cardiovascular system may cause bradycardia, hypotension and a reduction in cardiac output. These

effects may be marked in children who should receive atropine either as premedication or i.v. at induction if halothane anaesthesia is planned. The combined depressant effects on the circulation and respiration mean that during anaesthesia and the early recovery phase supplemental oxygen should always be given.

Halothane sensitises the heart to adrenaline and predisposes the patient to developing arrhythmias. These arrhythmias occur most commonly in patients who are retaining CO_2 or who have an inadequate analgesic component in their anaesthetic. They can usually be managed by supporting the ventilation, reducing the amount of halothane in the inspired gases and supplementing with another analgesic e.g. a small dose of i.v. opiate (be sure to support respiration due to the extra respiratory depression that may result). If this is not effective i.v. lignocaine or propranolol (avoid in asthma) are generally effective. Injection of adrenaline by the surgeon during anaesthesia with halothane may be dangerous and the doses need to be carefully monitored. The surgeon should never inject more than 10mls of 1:100,000 in any ten minute period and never exceed 30mls of 1:100,000 in an hour. If possible avoid adrenaline altogether; if it has to be used monitor the pulse closely and support ventilation.

Postoperative shivering may occur which is usually shortlived. "Halothane hepatitis" occurs on very rare occasions, and is almost unheard of in children. In common with all agents being considered in this article halothane causes an increase in intracranial blood flow and therefore pressure.

Indications: almost all general anaesthesia. Inhalation induction especially in upper airway problems such as partial obstruction.

Contraindications: These include simultaneous administration with adrenaline, especially during spontaneous breathing, or a history of hepatitis following a previous anaesthetic. Avoid high doses during caesarean section or evacuation of retained products of conception or placentae as uterine bleeding may result.

Dosage: Induction requires inspired concentrations of up to 3%. Maintenance dose is 1-2% for spontaneously breathing patients and 0.5 - 1% during controlled ventilation. Great care should be taken to avoid an overdose which may occur easily with higher doses.

Vaporisers: Halothane should always be given through a calibrated vaporiser. When using an Oxford Miniature Vaporiser (OMV) the thymol in halothane may cause the pointer to stick. This can be remedied either by washing the vaporiser through with ether or stripping and cleaning if you have the facilities.

Practical points: Halothane alone is not ideal: because it has no analgesic properties and high concentrations are needed to abolish reflex activity. This becomes expensive and may also be unsafe. The combination of high concentrations of halothane, oxygen and air, high levels of carbon dioxide (from respiratory depression) and heart disease is potentially very hazardous for the patient, especially if the pulse is not adequately monitored for arrhythmias. I would never use this method, though many do and get away with it, probably because heart disease is so uncommon in Africa.

Inhalation induction starting with 3% seems to be well tolerated by all patients and stage two effects are minimised with this dose.

A common arrangement is to have two draw-over vaporisers in series containing halothane and trichloroethylene, with the halothane nearest the patient.

Supplementary oxygen is mandatory when using halothane to avoid hypoxia.

In a study recently conducted in Malawi, halothane accounted for one quarter of the entire anaesthetic department budget.

TRICHLOROETHYLENE (Trilene)

Advantages: A non-irritant, safe agent. It provides good analgesia during and after surgery. It maintains cardiac output and is inexpensive.

Disadvantages: Trichloroethylene takes effect slowly. It has weak anaesthetic properties and may

result in a rapid respiratory rate in spontaneously breathing patients. Arrhythmias may occur and adrenaline administration is contraindicated. If high doses are used a prolonged recovery will occur - particularly in elderly patients. Trichloroethylene is stabilised in solution by the addition of 0.01% thymol and should be protected from light.

Indications: Trichloroethylene is mainly used as an analgesic supplement to halothane or used on its own for minor procedures such as fracture manipulation. It has been used as the sole agent for tonsillectomy without intubation and for analgesia in labour.

Contraindications: Never use trichloroethylene in a circle with soda-lime as the toxic compounds phosgene and carbon monoxide are produced.

Dosage: 0.5 - 1% initially, reducing to 0.2 - 0.5%.

Vaporisers: A variety of vaporisers have been used with trichloroethylene, the Oxford Miniature Vaporiser (OMV) is recommended.

Practical points: A very easy agent to give but remember to turn it off well before the end of the operation to avoid prolonged sedative effects. It is most commonly used to give background analgesia for long cases or combined with halothane for short cases using inhalation induction. When combining vaporisers in this way always place the halothane vaporiser closer to the patient. ICI has ceased production of their blue "Trilene", though laboratory grade trichloroethylene from Germany can still be obtained.

NITROUS OXIDE

Advantages: Nitrous oxide has a rapid onset and recovery. It is a good analgesic supplement for halothane and reduces the incidence of awareness. It produces minimal cardiovascular and respiratory effects.

Cylinders containing a 50% mixture of nitrous oxide in oxygen (named Entonox) are produced in some countries. The contents may be breathed by patients via a demand valve for analgesia following trauma, changes of dressings or childbirth.

Disadvantages: In developing countries nitrous oxide is expensive to produce and transport. It is delivered to the patient through a rotameter and is mixed with oxygen to produce an inspired mixture of not less than 30% oxygen. If the rotameters are set incorrectly a hypoxic gas mixture may be given to the patient. (This may be a particular problem if nitrous oxide is mixed with "oxygen" from an oxygen concentrator).

During anaesthesia nitrous oxide diffuses into any body cavity which contains gas. This includes air spaces in the gut, middle ear, endotracheal tube cuff and pneumothorax.

Diffusion hypoxia (Fink principle) may occur at the end of anaesthesia when nitrous oxide rapidly leaves the blood and tissues and passes out through the lungs. This may result in a dilution of the oxygen in the lungs for a few minutes and is prevented by administering extra oxygen at the end of anaesthesia.

In the developing world where resources are scarce and transport costs high, the use of nitrous oxide is an unnecessary extravagance. Before its use was discontinued at the Queen Elizabeth Hospital in 1988 nitrous oxide accounted for a quarter of the total pharmacy budget for the whole hospital (which included 3,000 outpatients a day)!

Contraindications: Nitrous oxide is not used in drawover circuits. It should never be given to a patient with an untreated pneumothorax or a patient who has been scuba diving within the previous 24 hours due to the potential for decompression sickness. Less than 50% nitrous oxide is largely ineffective.

How should volatile agents be used?

One method is to use them for both induction and maintenance of anaesthesia. The patient inhales the agent via a close-fitting facemask and provided the smell is accepted and the stage two excitement effects are not excessive, this is a very satisfactory method of inducing general anaesthesia for short, minor cases.

Another method is to induce anaesthesia intravenously and use the volatile agent for maintenance of anaesthesia. Often the intravenous induction will be followed by tracheal intubation. Most general

anaesthesia for major cases may be done this way. When muscle relaxants are used the concentration of anaesthetic agents may be reduced but care should be taken to avoid the patient becoming too light whilst paralysed.