Maintenance of anaesthesia

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Abstract

The maintenance phase of general anaesthesia begins immediately following induction of, and ends immediately prior to emergence from, a state of intended unrousable unconsciousness. Maintenance of anaesthesia requires the application of a wide range of knowledge and skills, demanding a solid grounding in basic science, practical abilities and team management. These factors are considered in this article.

Keywords Depth of anaesthesia; general anaesthesia; inhalational; maintenance; non-technical skills; pharmacology; TIVA

Royal College of Anaesthetists CPD Matrix: 2A00

Learning objectives

After reading this article, you should be able to:

- describe the pharmacological factors related to the maintenance of anaesthesia
- formulate a structured outline of the clinical priorities of the anaesthetist during maintenance
- discuss the non-technical skills required of the anaesthetist during maintenance

Maintenance of anaesthesia – agents

General anaesthesia is almost exclusively maintained with inhalational or intravenous agents, but it is possible, when conditions dictate, to provide adequate anaesthesia with repeat intramuscular injections (e.g. ketamine).

Choice of methods and agents will involve decisions based on the patient, anaesthetic preference and experience, surgical requirements, local policy and the availability of equipment. A thorough understanding of each technique will allow the anaesthetist to make appropriate decisions on an individual patient basis and to have confidence when their use is mandated.

Inhalational agents

Inhalational agents are used in the maintenance phase of 92% of general anaesthetics.[1] A typical general anaesthetic usually sees a transition from intravenous induction to inhalational maintenance. Coupled with the transfer of a patient from the anaesthetic room to theatre, this period represents a potential for unintended patient awareness. Knowledge of the pharmacokinetics of the agents employed and skill in their use will help to minimize this risk (Figure 1).

The transition to inhalational maintenance described above can be thought of as a secondary induction phase. The time taken for a vapour to reach adequate effect site partial pressure is affected by numerous patient and pharmacological factors.

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In order for molecules of an inhalational agent to travel from the anaesthetic machine to the effect site (‘wash-in’), a concentration gradient is required. High fresh gas flows and a high dialled vapourizer setting (‘overpressure’) encourage an increase in volatile concentration in the breathing system. A breathing circuit of higher volume (e.g. Circle) will take longer to reach a given concentration than a lower volume circuit (e.g. Bain). Adequate ventilation, matched pulmonary perfusion and favourable conditions at the alveolar:capillary interface promote transfer from airway to circulation. High cardiac output states (sepsis, thyrotoxicosis, anaemia, anxiety) cause a high pulmonary blood flow leading to slow equilibration of agent partial pressure in the alveolus and the blood. Rapidity of equilibration is also affected by agent solubility.

The blood:gas partition coefficient particular to each inhalational agent relates proportionally to its solubility. A more soluble agent will reach a higher concentration in blood more rapidly. This may intuitively suggest a rapidly acting agent. However, it is not the absolute quantity of the agent in blood that governs clinical effect, it is the partial pressure. A higher partial pressure in blood will cause a higher partial pressure at the effect site – the brain. A less soluble agent allows more rapid equilibration of partial pressures at the alveolus and the pulmonary capillary and thence the brain. It is, therefore, the less soluble agents – those with lower blood:gas partition coefficients – that wash-in and act more rapidly.

The problem is that overpressure of certain agents (isoflurane, desflurane) can cause airway irritability. A slower introduction of these agents is better tolerated and both can be used in spontaneously breathing subjects if presented carefully. In fact, because of desflurane’s insolubility and rapid onset, an overpressure technique is unnecessary in any case. Conversely, the greater solubility and more gradual wash-in of isoflurane means that caution should be afforded to potential awareness during slow introduction.

With the use of nitrous oxide, a phenomenon termed the ‘second gas effect’ causes more rapid uptake of other agents. Capillary uptake of nitrous oxide from the alveolus exceeds the speed of molecules travelling in the opposite direction. This leads to the concentration of remaining molecules in the alveolus and a more rapid increase in agent partial pressure than is seen in oxygen/air use. This swift movement of nitrous oxide is also thought to increase tracheal gas flow towards the alveolus, accentuating the effect. Furthermore, the high inspired concentrations of nitrous oxide used produce more rapid equilibration of inspired and alveolar concentrations of the agent – the

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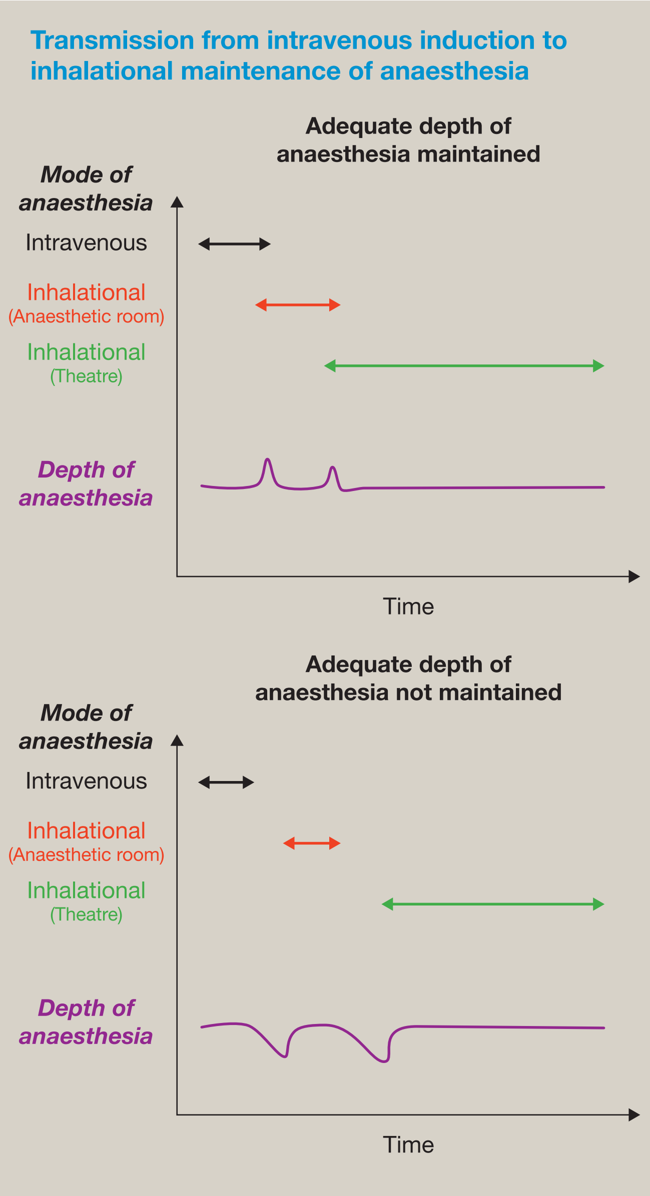

Figure 1 During transmission from intravenous induction to inhalational maintenance and the transfer from anaesthetic room to theatre, the risk of inadequate depth of anaesthesia is high. The coloured arrows represent the time during which the corresponding mode of anaesthesia is of adequate depth. There should be overlap of each arrow/mode in order to avoid unintended awareness, as in the upper graph. When there is a gap between the arrows/modes, as in the lower graph, lightening of anaesthesia and potential awareness can occur. Depth of anaesthesia, represented by the purple graph, increases up the Y-axis.

'concentration effect'. This accounts for a wash-in curve disproportionately rapid to nitrous oxide's blood:gas partition coefficient. High inspired concentrations of nitrous oxide are required due to its low potency.

Potency of an inhalational agent — the dose required to produce a desired effect — is described in terms of MAC. The minimum alveolar concentration (MAC) of an anaesthetic agent is the concentration at steady state and sea level required to prevent physical response to a standard surgical stimulus in 50% of patients aged 40 years who are unpremedicated and unparalysed. MAC can be thought of as the ED_{50} of a volatile agent for the prevention of movement. It should be noted that the addition of opioids, benzodiazepines or other hypnotics to the anaesthetic regimen will decrease MAC, meaning lower concentrations of volatile agents may be employed. The large number of factors affecting MAC (Table 1) shows that a simple number should not be the sole method of determining adequacy of anaesthesia. The oil:gas partition coefficient is a figure particular to each inhalational agent which is inversely proportional to MAC — it relates to the Meyer—Overton theory of anaesthetic action: that highly lipid soluble agents are more potent.

Having taken account of the wash-in characteristics and MAC of the chosen agent, a period of maintenance of anaesthesia can follow by presenting an adequate concentration in the breathing circuit. The use of circle systems permits rebreathing, allowing recycling of exhaled gases and anaesthetic agents. Given that the vast majority of modern agents remain unmetabolized and are simply exhaled, there is no need for large quantities of agent to be added to the breathing system during maintenance. The addition of only basal requirements of oxygen is needed to maintain a suitable FiO_2; flow rates may therefore be reduced. Movement of agent into the third compartment is offset by continual addition via the vapourizer. Low-flow anaesthesia reduces cost and air pollution and unnecessary wastage of anaesthetic agents is minimized. Managing the concentration in the circuit is not a simple matter. Any change of dialled vapourizer settings with such little flow through the vapourizer will only cause a slow change in concentration within the breathing system. A rapid change requires an increase in flow rates for a short period. Similarly, dialled concentrations at low flows do not correspond to inspired concentrations in the same way as at high flows; dialled settings are often much higher to counteract this.

A simple analogy is that of a bath. To ensure that the bath remains at a constant temperature the occupant has two options: either a fast flow of comfortably warm water from the mixer tap, or a trickle of very hot water. To change the overall bath temperature quickly will require a fast flow of either hot or cold water. The temperature marked on the tap is therefore not related to the temperature of the water in the bath.

Some factors which affect MAC

Factors which decrease MAC	Factors which increase MAC
• Increasing age	• Young
• Hypothyroidism	• Hyperthyroidism
• Hypothermia	• Hyperthermia
• Acute alcohol intake	• Chronic alcohol intake
• Pregnancy	• Anxiety/stress
• Hypoxia	• Stimulant use
• Hypercarbia	
• Concurrent drugs:	
○ Opioids	
○ Benzodiazepines	
○ α_2-Adrenergic agonists	

Table 1

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