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Essentials of
Anesthesiology Critical Care and Resuscitation
for Medical Students

As per the Competency-based Medical Education Curriculum (NMC)



Mukul Chandra Kapoor

JAYPEE

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CHAPTER 4

General Anesthesia

Parul Gupta, Rakhee Goyal

Learning Objectives

- Principle of general anesthesia
- Balanced anesthesia
- Process of general anesthesia (induction, intubation, maintenance, recovery, and tracheal extubation)
- Modes of ventilation in general anesthesia

INTRODUCTION

General anesthesia (GA) is the term familiar to most people, but there are more myths than facts, more fear than assurance. GA is a process to render a patient unconscious and still during the period of surgery, with no recall (amnesia) or awareness of this time and no sensory, motor, or autonomic response to any stimulation. GA is a state of controlled unconsciousness. During a GA, drugs send the patient to sleep, become unaware of surgery, become immobile, and have no pain while surgery is carried out. GA is used to make surgery safer or more comfortable for the patient.

Early anesthesia was all about ether and chloroform. Still, modern anesthesia has come a long way not only to facilitate surgeries and interventions and provide analgesia but also to optimize the patient as a whole and vital organ support throughout the surgical procedure.

How does GA work?

It is not clear exactly how GA works, but it is known that anesthetics stop the transmission of neural signals to the brain. The general anesthetics reduce nerve transmission at synapses between nerves, i.e., the sites at which neurotransmitters are released. The exact mechanism of this synaptic neurotransmission inhibition is not yet fully understood. Volatile anesthetic agents are more soluble in lipids than in water. They primarily affect the function of ion channel and neurotransmitter receptor proteins in the membranes of nerve cells, which have high-lipid content.

Balanced Anesthesia

Besides unconsciousness, the other key elements include muscle relaxation, analgesia, and reversibility of the whole process at the termination of surgery. They are commonly referred to as the 'Triad of Balanced Anesthesia' (**Fig. 1**). The synchronization of these elements makes it possible to have balanced anesthesia wherein optimal doses of different drugs that act on different receptors can be used safely to provide suitable conditions to facilitate surgery.

Need for General Anesthesia

General anesthesia can be given to any patient for any surgery except when the patient does

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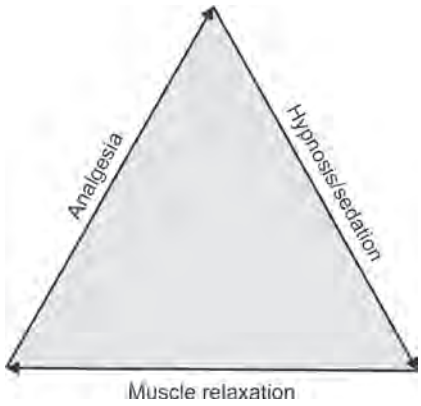

Fig. 1: Balanced anesthesia triad.

not consent or needs to be optimized. The most common site for administration of GA is the operating room (OR). Still, with the latest equipment, monitoring devices, and trained personnel, it can even be administered in nonoperative room settings like radiology suites and outpatient settings. The indications of GA are:

- Procedures requiring muscle relaxation
- Presence of contraindications for regional anesthesia
- Hemodynamic fluctuations anticipated
- Surgeries involving significant blood loss
- Uncooperative patient
- Patient's request for GA.

Before GA

A detailed preanesthetic assessment and written informed consent are mandatory before accepting a patient for GA. The patients are accepted in the American Society of Anesthesiologists (ASA) physical status grades I to VI with or without 'E' depending on their overall health condition and comorbidities, with higher grades being at higher risk than the lower ones, and 'E' denoting emergency scenarios. The details of the preanesthetic assessment are described in Chapter 2.

Once accepted for GA and written informed consent is obtained from the patient, the process of GA is conducted in the designated operating room that is well-equipped and staffed as per national guidelines. This process commonly runs through four phases, namely induction, intubation, maintenance, and reversal.

PROCESS OF GA

The triad of general anesthesia involves the administration of a hypnotic agent, mostly an analgesic, and may or may not include a muscle relaxant depending upon the surgical needs. There is no common recipe for every patient. Rather, the GA is tailored and titrated according to the surgery and patient-related factors and the amount of pain and surgical stimulation anticipated.

Premedication

AS4.3: Observe and describe the principles and the practical aspects of induction and maintenance of anesthesia.

The induction phase may be preceded by a premedication phase in certain cases, but mostly it is synced together. The aim is to allay the patient's anxiety and facilitate a smooth transition to unconsciousness. Benzodiazepines like midazolam are given as premedication because of their anxiolytic properties and the ability to cause anterograde amnesia. With the advent of enhanced recovery from surgery protocols, traditional premedication is generally no longer recommended. Premedication is now restricted to essential drugs, the patient is already being administered (such as anti-hypertensives, anti-epileptics, etc.) or needed to prevent certain adverse effects of anesthetic agents (such as drugs to prevent postoperative nausea and vomiting and hypersensitivity response).

Induction of GA

The induction of anesthesia means transitioning from an awake to an unconscious state. The endpoint of induction can be faintly defined and is associated with multi-system

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and physiological effects. Before initiating the induction of GA, standard ASA monitors are applied, which include noninvasive blood pressure, pulse oximeter, and electrocardiogram. Apart from these, ventilation, temperature, and urine output are also measured for patients under GA.

Preoxygenation

The patient is preoxygenated with 100% oxygen before induction of GA to denitrogenate the lungs and fill the patient's functional residual capacity with oxygen. Preoxygenation provides a safety reserve to prevent oxygen desaturation during periods of inadequate ventilation for laryngoscopy and intubation and difficult facemask holding, especially in patients with compromised respiration and circulation.

Inhalation Induction

General anesthesia can be induced through inhalation of an inhalation agent (like sevoflurane). Inhalation induction is a routine practice in children who do not have intravenous access. The child inhales a high concentration of the volatile agent while breathing spontaneously. Intravenous (IV) access is taken once the patient is asleep.

Intravenous Induction

Intravenous agents are the most commonly used for induction of GA. Propofol, thiopentone, etomidate, and ketamine are the agents used for IV induction. Propofol is the most popular and extensively used IV agent. It has a rapid onset, profound sedation, quick recovery, anti-emetic property, and is easily available. Propofol causes pain on injection, which can be prevented by injecting it into a larger vein, injection in running intravenous fluids or injecting lignocaine IV before propofol injection. A calculated dose of induction agent according to the patient's weight is injected (1–3 mg/kg), and further titrated doses are administered based on the effect.

Etomidate is a cardiostable agent and is ideal for patients with cardiovascular disorders. Its use is restricted to critically balanced cardiac patients because it can cause adrenal insufficiency, pain on injection, and thrombophlebitis.

Many barbiturates have been used for the induction of GA. Thiopentone was the most used barbiturate used and popular barbiturate. Its use has declined recently and is now limited to a certain category of patients like those undergoing electroconvulsive therapy.

Ketamine is also used for induction of GA at a dose of 1 mg/kg in patients with compromised hemodynamics. It also offers an advantage for patients with severe atopic disease, bronchial asthma, and children with congenital cyanotic heart diseases.

Opioids

An opioid dose is given as a part of the induction sequence. Besides being analgesic agents, preinduction opioids reduce the total dose of the induction agent required and reduce the stress response associated with induction and intubation. The most commonly used opioids are morphine and fentanyl. Morphine is a long-acting opioid with the histamine-releasing property. Fentanyl (1–2 mcg/kg) is a faster and short-acting opioid and is currently the opioid of choice. It is more potent than morphine.

Dissociative Anesthesia

Ketamine causes dissociative anesthesia and can be used as a sole agent for GA. It causes analgesia and bronchodilatation as well. Although it is a circulatory stimulant, it should be avoided in catecholamine-depleted patients. Its common side effects include agitation, hallucinations, and delirium. A small dose of benzodiazepine can be given before ketamine to prevent these side effects. Ketamine is usually used in the dose of 2 mg/kg for induction of dissociative anesthesia,

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and repeat titrated boluses are given for the maintenance of anesthesia. Ketamine is also used in a dose of 0.5 mg/kg for analgesia.

Rapid Sequence Induction/Intubation (RSI)

A modified induction/intubation process is used when rapid intubation of the trachea is required to reduce the risk of aspiration as in cases of a full stomach, intestinal obstruction, emergencies, obstetric patients, or if the patient has a history of gastroesophageal reflux disease. After preoxygenation, rapid induction and muscle paralysis are achieved using a rapid-acting neuromuscular blocker. Without a bag and facemask ventilation, the trachea is intubated. This rapid sequence helps secure the airway and reduces the risk of gastric insufflation and regurgitation.

Muscle Relaxation

Muscle relaxants are required to facilitate intubation and to provide surgical relaxation. The details of the neuromuscular blocking agents used as muscle relaxants are described in Chapter 7. Adequate muscle relaxation is required for endotracheal intubation. Laryngoscopy and tracheal intubation is done after muscle relaxation is achieved.

The onset of action of different neuromuscular blocking agents is different. In case neuromuscular monitoring is used, laryngoscopy and intubation are done after all twitches are lost in the 'Train-of-Four' (TOF) monitor.

Airway Management

On induction of GA, airway muscles lose their tone leading to the collapse of the upper airway and loss of airway reflexes. Chin lift, jaw thrust, and airways (oral and nasopharyngeal) can be used to maintain airway patency. Airway maintenance during anesthesia can be done with a supraglottic airway device or an endotracheal tube. Airway management is described in detail in Chapter 3.

Under direct under vision facilitated by direct laryngoscopy, the endotracheal tube (ETT) is inserted. Confirmation of proper tube placement can be done by chest auscultation, chest rise, and condensation on the endotracheal tube lumen. However, the appearance of a capnograph trace is the gold standard for the correct placement of the ETT in the trachea. The ETT can be inserted orally or nasally, depending on the surgical requirement. In patients with thoracic surgery, a double-lumen tube may be used for isolating and ventilating the two lungs separately through different channels (one-lung anesthesia).

Laryngoscopes are available with different shapes and sizes of blades. Macintosh (curved) and Miller (straight) blades are the most commonly used (**Fig. 2**). The portable video-laryngoscope or a fiberoptic bronchoscope can be used for difficult airways. Video laryngoscope use is specially indicated in patients with anterior larynx, limited mouth openings, and in patients with airway lesions as it provides a 30° to 60° anterior view.

Supraglottic airway devices like laryngeal mask airway (LMA) can also be used to ventilate patients under GA. Muscle relaxation may or may not be required for its placement. It seats in the posterior pharynx and seals the supraglottic airway to permit tracheal ventilation. A supraglottic device may not prevent aspiration if it does not provide a definitive seal. Supraglottic airway devices can be used as rescue airway devices

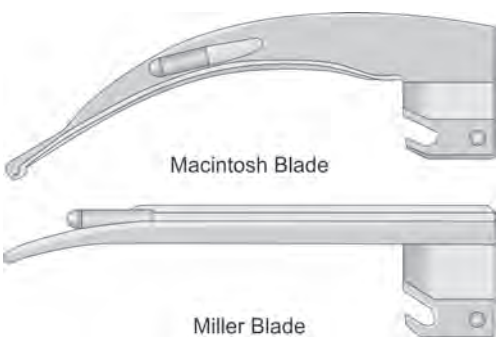

Fig. 2: Types of commonly used Laryngoscope blades.

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in difficult airways, difficult mask ventilation, and difficult intubations.

Maintenance of Anesthesia

Anesthesia is maintained using an inhalation volatile agent or an intravenous agent (continuous infusion). During the maintenance phase, hypnosis, sedation, and muscle relaxation need to be maintained using inhalation agents or intravenous agents. It is also essential to maintain the patient's hemodynamics and blood gas homeostasis (described in Chapter 10). The patient is also exposed to cold operating room temperatures, so body temperature must be maintained. The measures to ensure patient safety are described in Chapter 20.

Inhalation Anesthesia

Volatile agents are more commonly used and are delivered through calibrated vaporizers mounted on the anesthesia machine. Inhalation agents include nitrous oxide (gas at room temperature) and volatile agents (halothane, isoflurane, sevoflurane, and desflurane which are in the form of liquids but delivered as vapors to the patients). The pharmacological properties of inhalation agents currently in use are described in Chapter 5.

The delivered concentrations of the inhaled agents are measured by the gas analyzers in the anesthesia gas monitor. End-tidal concentration of the volatile agents indicates the concentration of volatile agents achieved in the patient's blood and reflects the depth of anesthesia. Depth of anesthesia can also be monitored with a bispectral index (BIS) monitor, which monitors the EEG activity of the patient and by monitors using evoked sensory potentials. Minimal alveolar concentration (MAC) is the alveolar concentration of a volatile agent that prevents movement in 50% of healthy volunteers to a standard surgical stimulus (e.g., skin incision). The MAC varies between different agents and is inversely related to their potency. MAC is also affected by various pharmacological and physiological variables.

Intravenous Anesthesia

Total intravenous anesthesia (TIVA) can also be used to maintain anesthesia. Propofol with or without dexmedetomidine, midazolam, and muscle relaxants can be given through a continuous infusion without using volatile agents. The choice of maintenance agents depends upon the type of surgery and patient-related factors.

Controlled Mechanical Ventilation (CMV)

In case muscle relaxants are used during the maintenance phase, intermittent positive-pressure ventilation (IPPV) supports respiration. Different modes of ventilation which can be used are volume-controlled ventilation (VCV), pressure-controlled ventilation (PCV), and pressure-controlled ventilation - volume guaranteed (PCV-VG). In VCV, the desired tidal volume generated for delivery is set on the machine along with the respiratory rate. The airway pressure is variable (depends on the lung compliance of the patient). In PCV, the airway pressure generated is set and regulated, and the volume delivered by the ventilator is variable. In PCV-VG, the ventilation mode is PCV, but the set volume is guaranteed. Most modern anesthesia workstations have these ventilation modes to facilitate appropriate ventilation for exchanging breathing gases. Usually, the VCV mode is used for healthy adults, and PCV and PCV-VG modes are used in children.

Lung-protective Ventilation

Use of lung-protective ventilation is recommended with appropriate positive end-expiratory pressure (PEEP) and low tidal volumes (6–8 mL/kg) to prevent atelectasis, barotrauma, volutrauma, and postoperative pulmonary infections.

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Opioid-free Anesthesia (OFA)

The opioid addiction epidemic in the western world has triggered a need to restrict the use of opioids in medical therapy. With the availability of potent non-opioid analgesics and multimodal analgesia methods, there is a trend to move towards OFA. Multimodal analgesia includes using non-steroidal anti-inflammatory drugs (NSAIDs), ketamine, paracetamol, and regional anesthetic blocks.

Enhanced Recovery After Surgery (ERAS)

To improve patient outcomes, reduce patient length of stay, and thereby reduce the cost of surgery, ERAS is getting very popular. Anesthesia for ERAS is managed in such a way as to promote early mobilization with the use of short-acting agents to ensure a quick recovery and early discharge from the hospital. Multimodal analgesia is used to reduce the after-effects of drugs. Different ERAS protocols for different surgeries have been defined. The results of these protocols are very promising, and their use has reduced the length of hospital stay and improved patient outcomes.

Monitoring During GA

Throughout the conduct of GA, monitoring of oxygenation, ventilation, vitals, fluid balance, urine output, and blood loss should be done to ensure hemodynamic stability and patient safety. The details of the modes of monitoring are described in Chapter 9.

Emergence from Anesthesia

At the end of the surgery, the maintenance agent should be discontinued. After discontinuation of inhalation agents, their end-tidal concentration must be monitored. The patient will awaken only after most of the agent has been washed out of the body. To wash off inhalation agents, there is a need to administer higher fresh gas flows. A patient will wake up only when the concentration of an agent has fallen to about 0.2 MAC. NSAIDs and anti-emetics should be given before the end of the GA for adequate analgesia and prevention of postoperative nausea and vomiting (PONV).

Reversal of Neuromuscular Blockade

Upon completion of the surgery, the neuromuscular blockade has to be reversed. Reversal of neuromuscular block can be achieved by administration of its competitive antagonist anti-cholinesterase agent. Neostigmine is the most common drug used. Neostigmine must be given with an anticholinergic agent (atropine or glycopyrrolate) to prevent bradycardia and other muscarinic effects of the drug. A new cyclodextrin derivative drug, Sugammadex, has been recently introduced for early reversal of the steroidal neuromuscular blocking agents.

Tracheal Extubation

A safe tracheal extubation requires a lot of skill and experience and is perhaps more challenging than induction and intubation. Several physiological changes occur with the patient transitioning from a deep to the lighter plane of anesthesia. Many potential complications can occur during this period, like bronchospasm, agitation, etc. A quick oral toilet should be done using a suction before extubation to clear any secretions. The trachea should be extubated once the patient meets the extubation criteria, i.e., the patient is awake, breathing spontaneously with adequate tidal volume, and protective reflexes have returned. Tracheal extubation may be done in a deeper plane for a few patients (e.g., reactive airway disease) to reduce the risk of coughing and laryngospasm associated with awake extubation. Deep plane extubation is also favored for certain neurosurgical and cardiac patients to prevent sudden surges in intracranial pressure and systemic blood pressure. Deep plane extubation is, however, associated with the risk of aspiration. It is vital to verify that the patient can maintain a clear airway after tracheal extubation.

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Postoperative Care

The postanesthesia care unit (PACU) is a transition place from the operating room to the ward. The patient is monitored here for any immediate postoperative surgical or anesthetic complications. The potential complications which can occur include hypoxemia, nausea, vomiting, pain, hemodynamic instability, and surgical problems. PONV is the most common complication seen. It can be prevented by avoiding nitrous oxide and volatile agents, using propofol infusion, timely antiemetic prophylaxis, minimizing the use of opioids, and maintaining adequate hydration. All patients should be monitored closely in the PACU and discharged only when fulfilling the discharge criteria. Details of postoperative care are described in Chapter 12.

MULTIPLE CHOICE QUESTIONS

1. **Balanced anesthesia is the triad of:**
   a. Unconsciousness, inhalational anesthetic agents, and benzodiazepines
   b. Unconsciousness, muscle relaxation, and analgesia
   c. Hypnosis, sedation, and muscle relaxation
   d. Sedation, immobility, and unconsciousness
2. **The alphabet 'E' as a suffix to the ASA functional class denotes:**
   a. A grade slightly higher than the numerical class written
   b. Denotes emergency
   c. Denotes extra risk factors
   d. All of the above
3. **The patient is preoxygenated with 100% oxygen before induction of GA to:**
   a. Denitrogenate the lungs
   b. To increase the oxygen saturation of the patient
   c. To ease the anxiety of the patient
   d. To help induction of anesthesia
4. **The following agents are used for induction of anesthesia *except*:**
   a. Dexmedetomidine
   b. Propofol
   c. Thiopentone
   d. Etomidate
5. **All these are common adverse effects of ketamine used for dissociate anesthesia *except*:**
   a. Agitation
   b. Bronchospasm
   c. Hallucinations
   d. Delirium
6. **The gold standard method of confirming the correct placement of an endotracheal tube is:**
   a. Chest auscultation
   b. Chest rise on ventilating the lung
   c. The appearance of a capnography trace
   d. Fogging on the endotracheal tube
7. **In enhanced recovery after surgery (ERAS) involves:**
   a. Use of multimodal analgesia techniques
   b. Use of short-acting anesthetic agents to ensure a quick recovery and early discharge
   c. Reduces cost of surgery
   d. All of the above
8. **The phases of general anesthesia include all *except*:**
   a. Muscle relaxation
   b. Induction
   c. Intubation
   d. Reversal

Answers

1. b	3. a	5. b	7. d
2. b	4. a	6. c	8. a

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