General anesthesia
(Induction, Maintenance and Complications)

General anesthesia provides hypnosis (unconsciousness), analgesia, amnesia, and skeletal muscle relaxation.

A. All patients who are undergoing general anesthesia require an appropriate **preoperative evaluation** and optimization of any coexisting medical problems.

B. Monitoring. Basic monitoring requirements for general anesthesia are similar to those for regional anesthesia.

C. Induction of general anesthesia. Intravenous agents are most widely used owing to rapid onset and ease of administration.

1. Thiopental, a barbiturate (3–5 mg/kg i.v.), has a rapid onset and redistribution. Often, there is an associated decrease in cardiac output and BP.

2. Propofol, a phenol derivative (1–3 mg/kg i.v.), is used for induction and maintenance of anesthesia. This agent has hemodynamic properties that are similar to those of thiopental but is associated with a low incidence of postoperative nausea and vomiting.

3. Etomidate, an imidazole derivative (0.3 mg/kg i.v.), has only mild direct hemodynamic depressant effects.

4. Ketamine, a phencyclidine derivative (1–4 mg/kg i.v.), increases cardiac output and BP in patients who are not catecholamine depleted. Ketamine raises intracranial pressure and is not used in patients with head trauma. The **use of ketamine is limited** owing to the emergence of delirium and nightmares.

D. Airway management. Ventilation during general anesthesia may be spontaneous, assisted, or controlled.

1. Mask ventilation with spontaneous respiratory effort can be used during limited (usually peripheral) procedures that do not require neuromuscular relaxation. Because the airway is unprotected, this technique is contraindicated in patients at risk for aspiration.

2. Endotracheal intubation secures the airway, allows control of ventilation, and protects against aspiration. Although frequently performed orally with the laryngoscope, intubation can also be accomplished nasally and, in anatomically challenging patients, can be performed with the aid of a fibreoptic bronchoscope via oral or nasal routes.

E. Neuromuscular blockade facilitates tracheal intubation and is required for many surgical procedures. It provides the surgeon with improved working conditions and optimizes ventilatory support. Agents that produce neuromuscular blockade act on postsynaptic receptors in the neuromuscular junction to antagonize the effects of acetylcholine competitively. Agents are categorized as either depolarizing or nondepolarizing.

Table 6-2. Agents producing neuromuscular blockade

1. Succinylcholine is a rapid-acting (60 seconds), rapidly metabolized depolarizing agent that allows return of neuromuscular function in 5–10 minutes. This agent causes a transient mild hyperkalemia that may be exaggerated in patients with severe burns, trauma, or paralysis; patients on

prolonged bed rest; or patients with other neuromuscular disorders. In addition, it can cause increases in intraocular, intracranial, and gastric pressures.

2. Nondepolarizing muscle relaxants can be divided into short-, intermediate, and long-acting agents. Associated hemodynamic effects and elimination pathways vary.

a. These agents are often used in an intensive care setting when paralysis is necessary for adequate ventilation of an intubated patient. Such patients must have adequate sedation and analgesia before and during paralysis. Dosage should be monitored by train-of-four stimulus every 4 hours, with one-quarter twitches the goal. Corticosteroids and aminoglycosides should be avoided to reduce the risk of myopathy.

b. Reversal of neuromuscular blockade for patients who are receiving nondepolarizing muscle relaxants usually is performed before extubation to ensure full return of respiratory muscle function and protective airway reflexes. The diaphragm is less sensitive to muscle relaxants than are the muscles of the head and neck; a spontaneously ventilating patient may be unable to protect the airway. The definitive test to assess the degree of remaining paralysis is to have the patient raise the head from the bed for 5 seconds or more. **Anticholinesterases** (neostigmine, 0.06–0.07 mg/kg, and edrophonium, 0.1 mg/kg) act to increase the availability of acetylcholine at the neuromuscular junction. The binding frequency of the nondepolarizing muscle relaxant (a competitive acetylcholine antagonist) is reduced, and the blockade is reversed.

F. Maintenance of anesthesia

1. The **goal of anesthesia** is to provide unconsciousness, amnesia, analgesia, and, usually, muscle relaxation. Balanced anesthesia involves the combined use of inhalational agents, narcotics, and muscle relaxants to attain this goal.

2. Inhalational agents

a. All inhalational agents provide varying degrees of unconsciousness, amnesia, analgesia, and muscle relaxation.

b. Isoflurane is the most commonly used inhalational agent due to its low rate of metabolism. Enflurane, halothane, sevoflurane, and desflurane are also used.

c. Halothane and nitrous oxide are used extensively as induction agents in pediatric patients owing to the decreased irritating effects of halothane on the airway. Halothane sensitizes the myocardium to catecholamines; thus, another inhalational agent should be used if epinephrine solutions have been injected into the surgical field. Sevoflurane is also used in children because, like halothane, it causes minimal irritation of the airways.

d. Nitrous oxide by itself cannot provide surgical anesthesia. When combined with other inhalational agents, it reduces the required dose and subsequent side effects of the other agents. Nitrous oxide is extremely soluble and readily diffuses into any closed gas space, increasing its pressure. As a result, this agent should not be administered to patients with intestinal obstruction or suspected pneumothorax.

3. Intravenous agents

a. **Narcotics** can be administered continuously or intermittently. These agents provide superior analgesia but unreliable amnesia. Commonly used narcotics include fentanyl, sufentanil, alfentanil, remifentanil, morphine, and meperidine.

b. Hypnotics, benzodiazepines, and propofol. Propofol infusion provides excellent hypnosis (unconsciousness) but insignificant analgesia and unreliable amnesia. Its rapid dissipation of effects and low incidence of postoperative nausea have contributed to its widespread use in outpatient surgery. The maintenance dose is 0.1–0.2 mg/kg per minute.
c. Ketamine by itself can provide total anesthesia. The associated emergence of delirium and nightmares limits its use.

G. Recovery from general anesthesia. The goal at the conclusion of surgery is to provide a smooth, rapid return to consciousness with stable hemodynamics and pulmonary function, protective airway reflexes, and continued analgesia.
1. Preparation for emergence from anesthesia usually begins before surgical closure, and communication between the surgeon and anesthesiologist facilitates prompt emergence of the patient at the procedure's termination.
2. Laryngospasm is a potentially life-threatening complication that may occur after extubation (see section **III.H.2**).
3. Patients recover from the effects of sedation or general or regional anesthesia in the **postanesthesia care unit**. Once they are oriented, comfortable, hemodynamically stable, ventilating adequately, and without signs of anesthetic or surgical complications, patients are discharged to the appropriate ward or to home.

H. Complications of general anesthesia
1. **Malignant hyperthermia** is a hypermetabolic disorder of skeletal muscle characterized by intracellular hypercalcemia and rapid adenosine triphosphate consumption. This condition is initiated by exposure to one or more anesthetic triggering agents, including desflurane, enflurane, halothane, isoflurane, sevoflurane, and succinylcholine.
a. Signs and symptoms may occur in the operating room or more than 24 hours postoperatively and include tachycardia, tachypnea, hypertension, hypercapnia, hyperthermia, acidosis, and skeletal muscle rigidity.
b. Treatment involves immediate administration of dantrolene (1 mg/kg i.v. up to a cumulative dose of 10 mg/kg), which attenuates the rise in intracellular calcium. Repeat doses are given as needed if symptoms persist. Each vial contains 20 mg dantrolene and 3 g mannitol and must be mixed with 50 mL sterile water. Intensive care monitoring for 48–72 hours is indicated after an acute episode of malignant hyperthermia to evaluate for recurrence, acute tubular necrosis, and disseminated intravascular coagulation.
2. Laryngospasm
a. During emergence from anesthesia, noxious stimulation of the vocal cords can occur at light planes of anesthesia. Additionally, blood or other oral secretions can irritate the larynx. As a result, the vocal cords may be brought into forceful apposition, and the flow of gas through the larynx is restricted or prevented completely.
b. Treatment involves the use of positive-pressure ventilation by mask to break the spasm. Such therapy usually is sufficient. Succinylcholine may be required in refractory cases to allow successful ventilation.

3. Nausea and vomiting a. **Cortical** (pain, hypotension, hypoxia), **visceral** (gastric distention, visceral traction), **vestibular**, and **chemoreceptor trigger zone** (narcotics) afferent stimuli all can play a role in postoperative nausea and vomiting. Overall incidence is approximately 30%. It is more common in preadolescents 11–14 years old, women, and obese patients. Narcotics, etomidate, and isoflurane have been implicated.

b. Treatment includes avoiding gastric distention during ventilation as well as administering prochlorperazine (Compazine), an antidopaminergic agent, 10 mg i.v. or p.o. every 4–6 hours as needed. For severe cases of postoperative nausea and vomiting, ondansetron (Zofran), 4 mg i.v., can be given. The dosing can be repeated every 6–8 hours if symptoms persist.

4. Urinary retention

a. Although very common with spinal anesthesia [see section **II.A.2.a.(4)(f)**], **urinary retention occurs in only 1–3% of cases involving general anesthesia**. It most commonly occurs after pelvic operations and in the setting of benign prostatic hypertrophy.

b. Treatment ranges from conservative (early ambulation, having patient sit or stand while attempting to micturate) to aggressive intervention (bladder catheterization).

5. Hypothermia

a. General anesthesia induction causes **peripheral vasodilation**, which leads to internal redistribution of heat, resulting in an increase in peripheral temperature at the expense of the core temperature. Core temperature then decreases in a linear manner until a plateau is reached. Such hypothermia is more pronounced in the elderly.

b. Treatment includes passive warming during an operation by insulation of all exposed surfaces. Additionally, active warming with forced-air convective warmers is effective, but care should be taken in patients with vascular insufficiency (warmers should not be used on unperfused extremities) and to prevent thermal injury.

6. Nerve injury

a. Nerve palsies can occur secondary to improper positioning of the patient on the operating table or insufficient padding of dependent regions. Such palsies can be long-lasting and debilitating.

b. Prophylactic padding of sensitive regions and attention to **proper positioning** remain the most effective therapies.