# Ministry of Higher Education and Scientific Research

# Middle Technical University, College of Health and Medical Technique, Anaesthesia Technique Department, 4th stage.


# Teaching package for anaesthesia technique


**By**

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# Pregnancy-Related Physiological and Anatomical Changes

Numerous changes occur in a woman's body during pregnancy. These changes affect almost every organ system. Changes early in pregnancy are largely due to increases in hormones (i.e., progesterone and estrogen) and increased metabolic demands of the fetus, placenta, and uterus. Later changes are due to the expanding uterus and growing fetus. All of these changes impact anesthetic care.

## I. Cardiovascular System changes

### 1. *Blood Volume*

Blood volume will increase progressively starting at 6-8 weeks. At the time of delivery, the average blood volume is increased by 1-1.5 liters. There is a greater increase in plasma volume compared to red blood cell mass, resulting in relative anemia. The clotting components of the patient's blood also increase to enhance clotting, reducing excessive bleeding during delivery. These components include fibrinogen, and factors VII, X, and XI. Increased blood volume meets the mother and fetus's metabolic demands, allowing the mother to tolerate blood loss during delivery. The average blood loss associated with vaginal delivery is 400-500 ml. With a cesarean section, it is 800-1000 ml.

### 2. *Cardiac Output*

Cardiac output will increase up to 40% at term. Most of the increase occurs in the 1st and 2nd trimesters. The exception is during labor when cardiac output peaks secondary to increased heart rate and *stroke volume* (the volume of blood ejected from the heart with each contraction). To handle the increased blood volume, the myocardium and chambers enlarge. Cardiac output will return to normal 2 weeks after delivery. Cardiac output can decrease after 28 weeks of pregnancy due to mechanical changes.

### 3. *Blood Pressure*

Despite increases in the patient's cardiac output and blood volume, the patient's blood pressure does not normally increase from pre-pregnancy levels unless there is an abnormality such as pregnancy-induced hypertension. A decrease in blood pressure occurs by about 8 weeks of gestation. By mid-pregnancy, the diastolic blood pressure and mean arterial pressure reach their lowest point (16-20mmHg below pre-pregnancy values), returning to pre-pregnancy levels by term. The overall decrease in diastolic blood pressure and mean arterial pressure is 5-10 mmHg.

### 4. Venous *System*

The venous system has an increased capacity for distension and dilation (up to 150%). This can reduce blood flow, delaying the absorption of subcutaneous or intramuscular medications. Distention of the vessels within the epidural space may increase the risk of vascular damage and bleeding during neuraxial blockade. This, along with hormonal changes, reduces the required amount of local anesthetics by 30%. Using the same dose in the pregnant patient as normally would in the non-pregnant patient results in a high neural block.

*Anesthetic considerations due to Cardiovascular Changes in pregnancy*:

a) *Never lay the patient supine. Always place a wedge or roll under the right hip so the patient is "tipped" to the left. This maneuver will* *prevent a decrease in cardiac output, maternal hypotension, fetal distress, or asphyxia that can result from supine hypotension syndrome/aortocaval compression.*

b) *The pregnant patient is dependent upon sympathetic outflow to maintain systolic blood pressure. Always pre-load the patient with 1-2 liters of crystalloid fluids before the neuraxial blockade.*

c) *Vessel distention in the epidural space may increase the risk of vessel damage during the neuraxial blockade.*

d) *Vessel distention also decreases the intrathecal and epidural spaces. Decrease the dose of local anesthetics by 30% to avoid a high neuraxial block.*

e) *Delayed absorption of subcutaneous and/or intramuscular medication.*

## II. Respiratory System changes

1. **Lung Volumes**

   As the gravid uterus grows in size, it places pressure on the abdomen. At term, the pregnant patient favors thoracic breathing over abdominal breathing. The most important is the change in functional residual capacity (FRC- the volume of air that is in the lungs at the end of a normal breath).

   FRC decreases 20% by term, returning to normal 48 hours after delivery. A decrease in FRC reduces the patient's reserve. In the event of apnea, the patient can become hypoxic quickly. In addition, the pregnant patient will increase her tidal volume (normal volume with each breath) by 40%.

2. **Respiratory Gas Exchange**

Minute ventilation (amount of air breathed in one minute) increases by 50% by the second trimester. The respiratory rate will increase by 15% (2-3 breaths per minute). These changes speed the uptake of inhaled anesthetics. Alveolar ventilation (air that participates in gas exchange) will increase by 70% at term. Oxygen consumption increases by 20-50%. The combination of a decreased FRC and increased oxygen consumption can result in hypoxia.

3. **Respiratory Tract**

As mentioned earlier, the pregnant patient has venous vascular engorgement, which results in a swollen respiratory tract and a diminished view during laryngoscopy. The obstetric population is more difficult to intubate compared to the non-pregnant population. A smaller-than-usual endotracheal tube may be required. Manipulation during laryngoscopy can result in bleeding, obscuring the view of the glottic opening.

*Anesthetic considerations due to Respiratory changes in pregnancy*:
*Patients undergoing regional anesthesia should have supplemental oxygen.*

a) *Patients undergoing general anesthesia should be pre-oxygenated with 100% O2 before induction.*

b) *Patients may desaturate despite pre-oxygenation due to increased oxygen consumption and decreased FRC.*

c) *Be prepared for difficult intubation. Swollen mucous membranes may decrease visualization. Ensure the patient is positioned optimally for laryngoscopy.*

d) *Have smaller endotracheal tubes available for intubation. A smaller endotracheal tube may be required for intubation due to swollen tissue.*

e) *Be very gentle during laryngoscopy as bleeding may obstruct the view.*

## III. Renal system changes

The pregnant patient's renal plasma flow and glomerular filtration rate will increase by 50-60% at term. This correlates with increased cardiac output and blood volume. Increases in renal plasma flow and glomerular filtration rate result in increased clearance of blood urea nitrogen and serum creatinine, which may be reduced by 40%. Obstructive changes to the renal system can occur due to the enlarging uterus. This may result in increased urinary tract infections and decreased blood flow to the kidneys.

## IV. Gastrointestinal system changes

Mechanical and hormonal alterations result in several changes within the gastrointestinal system. As the uterus enlarges, pressure is placed on the stomach resulting in an incompetent lower esophageal sphincter. In addition, progesterone will reduce the competence of the lower esophageal sphincter. Placental gastrin causes an increased secretion of gastric acid. These changes lead to the reflux of gastric acid into the esophagus and delayed gastric emptying and place the pregnant patient at risk for aspiration during anesthesia.

*Anesthetic considerations due to gastrointestinal changes in pregnancy:* *Pregnant patients should be considered to have "full stomachs", regardless of fasting.*

a) *If available, medications should be administered before anesthesia to reduce gastric acidity and volume. A non-particulate antacid (i.e., sodium citrate), Metoclopramide (Plasil) 10 mg IV should be administered 30-60 minutes before anesthesia to stimulate gastric emptying and increase lower esophageal sphincter tone. The use of histamine H2 blockers 30-60 minutes before surgical intervention may help to reduce the acidity of stomach contents.*

b) *Position the patient with a roll under the right hip. A slight reverse Trendelenburg position may help prevent passive reflux.*

c) *Cricoid pressure should be applied and held until the patient is intubated. Cricoid pressure should not be released until it is confirmed that the endotracheal tube has been placed in the trachea.*

d) *Do not routinely administer positive pressure ventilation, with a mask, before intubation. Positive pressure ventilation should occur if the patient's pulse oximetry reading starts to decline or a difficult airway is encountered. Unnecessary positive pressure ventilation before intubation may result in gastric distention, placing the patient at risk for aspiration.*

## Hepatic system changes

The overall function and blood flow to the liver are unchanged during pregnancy. There is a 25-30% decrease in pseudocholinesterase function at term. In the immediate delivery period, this should not produce a clinically significant prolongation of succinylcholine, mivacurium, or ester local anesthetics.

## VI. Central nervous system changes

Changes in hormones result in a decrease of up to 40% in minimal alveolar concentration (MAC). By the 3rd-day post-delivery MAC levels return to normal. Hormonal changes and venous dilatation contribute to a 30% decrease in local anesthetic requirements for spinal and epidural anesthesia. Anatomical changes may create an epidural space that has positive pressure instead of negative pressure.

*Anesthetic considerations due to Central nervous system Changes in pregnancy:*

a) *Reduces the dose of inhaled anesthetics by up to 40%.*

b) *Reduces the dose of local anesthetics for spinal and epidural anesthesia by up to 30%.*

c) *Positive pressure in the epidural space may make it slightly more difficult to identify the epidural space.*

MCQ test

1- The average blood loss associated with vaginal delivery is:
   a) 200-250ml.
   b) 250-400ml.
   c) 400-500ml.
   d) 500-1000ml.
   e) 800-1000ml.

2- The dose of local anesthetics for spinal anesthesia in pregnancy reduced by up to:
   a) 30%.

b) 20%.
c) 40%.
d) 60%.
e) 5%.

3- Regarding anesthesia for pregnant lady(all true except one)
a) Pregnantlady should be considered to have “full stomachs”, regardless of fasting.
b) Reduces the dose of inhaled anesthetics by up to 40%.
c) Cricoid pressure should not be released until it is confirmed that the endotracheal tube has been placed in the trachea.
d) Always administer positive pressure ventilation, with a mask, before intubation.
e) A non-particulate antacid and Metoclopramide given before anesthesia to increase lower esophageal sphincter tone.

4- All the following parameters are increase in pregnancy except one
a) FRC.
b) Blood volume.
c) GFR.
d) Minute ventilation.
e) Cardiac output.

5- Which one is true regarding physiological changes in pregnancy
a) the pregnant patient has venous vascular engorgement, which results in a swollen respiratory tract.
b) The overall function and blood flow to the liver are huge changes during pregnancy.
c) Patients may desaturate despite pre-oxygenation due to decreased oxygen consumption and increased FRC.
d) Cardiac output will return to normal 20 weeks after delivery.
e) increase in plasma volume compared to red blood cell mass, resulting in polycythemia.

# Pediatric anatomical and physiological differences

Several anatomical and physiological differences impact the effects and techniques of anesthesia administration. Pediatric patients can be divided into four groups based on age.

I. *Newborn: from birth to the first 24 hours.*

II. *Neonate: from 1 to 30 days of life.*

III. *Infant: from 1 month to 12 months of age.*

IV. *Child: from 1 year to the onset of puberty.*

**Cardiovascular Physiology**

Cardiac output for a neonate is 30-60% greater than an adult. This helps meet the increased oxygen consumption requirements. Cardiac output in the pediatric patient is dependent on heart rate. Monitoring of the pediatric patient's heart rate can be accomplished with a precordial stethoscope, ECG, and pulse oximetry. Prompt recognition and treatment of bradycardia are critical. Bradycardia is less than 80 in children 1-8 years, less than 100 beats per minute in infants aged 1-12 months, and less than 120 beats per minute in neonates. It is the most common rhythm before cardiac arrest in the pediatric patient.

*The most common cause of bradycardia in pediatrics is:*

1. ***Hypoxia.***

   ***And then:***

2. *Vagal stimulation (suctioning, surgical traction, etc.).*
3. *An overdose of anesthetic medications.*
4. *Hypothermia.*
5. *Increased intracranial pressure.*

The ***blood volume*** of the pediatric patient is highest as a neonate and declines with age. Knowledge of the approximate blood volume is important when calculating total blood volume and estimated blood loss. e.g., a 4 kg neonate's total blood volume would be calculated as follows:

4(kg) X 85 (ml/kg) = 340 ml total blood volume.

| | Premature | Neonate | Infant | 5 year old | Adult |
|---|---|---|---|---|---|
| **Blood Volume (ml/kg)** | 90-100 | 85 | 80 | 75 | 65 |

**Pulmonary Physiology and Airway Anatomy**

The **functional reserve capacity** is much smaller in infants and neonates, during anesthesia, airway obstruction can result in hypoxia very quickly. For this reason, pulse oximetry is essential. Induction and emergence are especially critical periods to monitor for these complications. **Oxygen consumption** for a neonate is two times greater than that of an adult.

*The anatomy of the pediatric airway is different compared to an adult*:

The pediatric patient is prone to airway obstruction related to a proportionally larger head, short neck, and large tongue. Positioning of the patient's airway is an important consideration. Overextension can result in airway obstruction in the neonate. Infants and neonates exchange air primarily through their nasal airways. The larynx is higher in the infant and child (cervical vertebrae 3-4) than in the adult (cervical vertebrae 5-6). The epiglottis is large, stiff, and U-shaped. The trachea is short, and the right main bronchus is less angled. This increases the risk of a right mainstem intubation. **Choosing the correct-size endotracheal tube and approximate length of insertion is important.** This can also be accomplished by a simple calculation. The equation that can be used (age/4+ 4) will approximate the correct size of the endotracheal tube. Regardless of the calculations, an endotracheal tube should slide easily into the trachea, and never be pushed or forced. The calculation for the correct endotracheal tube depth insertion is to multiply the diameter of the endotracheal tube by 3. For example, an endotracheal tube that is a size of 3.0 would be multiplied by 3 to equal a depth insertion of 9 cm. Auscultation of equal, bilateral lung sounds (including the axilla) after endotracheal tube placement should always be performed.

**Renal System and Extracellular Fluid Volume**

At birth, the kidneys have a decreased glomerular filtration rate, decreased sodium excretion, and decreased concentrating ability. The glomerular filtration rate will increase and reach adult levels by 12-24 months of age. Neonates and infants up to 24 months are not able to compensate for alterations in fluid balance as well as adults. This makes fluid replacement very important.

The extracellular fluid volume in an infant is twice that of an adult. Approximately 40% of the body weight in infants is extracellular fluid compared to 20% of adults' body weight. Neonates, infants, and children fasting for anesthesia can become dehydrated more quickly than an adult. Careful fluid calculation includes NPO deficit, maintenance fluids, 3rd space fluid loss, and estimated blood loss replacement. For a pediatric patient that is dehydrated, it is important to correct pre-existing deficits before anesthesia to avoid hypotension.

## Temperature Regulation

Neonates and infants can rapidly lose heat, even in warm environments. They are at greater risk for hypothermia than adults due to:

a) Relatively high surface-to-volume ratio.

b) High metabolic rate.

c) Insufficient body fat for insulation.

Infants less than 3 months do not shiver to generate heat. It is important to take steps to minimize heat loss including a warm operating room, warm blankets, or a heating blanket. Monitoring the patients' temperature before, during, and after the anesthesia is important to detect abnormal drops or increases in temperature.

## Pharmacology in Pediatrics

Pediatric patients respond differently to anesthetic medications when compared to adults. This is due to physiological differences that include:

a. Increase extracellular fluid.

b. Decrease skeletal mass.

c. Increase metabolic rate.

d. Decrease renal function.

e. Receptor maturity.

**Inhaled Anesthetics**

Uptake, distribution, and potency of volatile anesthetics are different in neonates and infants than in adults. Induction of general anesthesia occurs faster in neonates and infants. Emergence also occurs faster. The differences between adult and pediatric patients during induction and emergence are:

1. Smaller functional residual capacity (smaller lung volume).
2. Greater blood flow to the vessel-rich tissues such as the brain, heart, liver, and kidneys.

In infants and neonates, the vessel-rich tissues comprise about 22% of total body weight. In adults, the vessel-rich tissues compose about 10% of the total body weight.

MAC varies according to the age of the patient. In general, MAC is lower in neonates than in infants. MAC increases until about 2-3 months of age, peaks during infancy, and then steadily declines. During puberty, there is a brief increase in MAC. After puberty, MAC will continue to decline. Lower MAC requirements for volatile anesthetics in neonates are due to an immature central nervous system.

**Intravenous Anesthetic Agents**

Neonates are sensitive to intravenous anesthetic agents. They have an immature blood-brain barrier and a decreased ability to metabolize medications such as opioids and barbiturates. In general, lower doses of intravenous anesthetic medications are required to produce the desired effects. There are some generalized exceptions. For example, to induce general anesthesia higher doses of propofol (on an mg/kg basis) are required when compared to an adult. Pediatric patients less than 6 months old may be more sensitive to respiratory depression resulting from opioid administration. Caution should be used when administering opioids to this age group. The pediatric patient should be carefully monitored during the postoperative period.

**Nondepolarizing Muscle Relaxants**

Neonates and infants may be more sensitive to the effects of nondepolarizing muscle relaxants. The neuromuscular junction of the infant is immature. The duration of action of nondepolarizing muscle relaxants may be prolonged due to immature renal and hepatic systems.

**Depolarizing Muscle Relaxants**

Neonates and infants require higher doses, on an mg/kg basis, of succinylcholine than the adult patient. This is due to an increased extracellular volume and volume of distribution. The dose of succinylcholine in pediatrics is 1.5-2 mg/kg IVP compared to 1 mg/kg IVP in adults. Routine use of succinylcholine in pediatric anesthesia is not recommended. The use of succinylcholine in pediatrics should be reserved for emergency intubation, rapid sequence induction, and laryngospasm.

MCQ test

1- Pediatric anesthesia (**all true except one)**
   a) Pediatric patient is small adult
   b) Oxygen consumption for neonate is two time greater than adult.
   c) Alveolar ventilation in neonate is twice the adult rate.
   d) Overextension of neonate can cause airway obstruction.
   e) Neonate means 1-30 days of extra uterine life

2- Pharmacology in pediatrics (**which one is true)**
   a) Neonates are resistant to intravenous anesthetic agents.
   b) The routine use of succinylcholine is recommended.
   c) MAC of inhalational agents is lower in infants than neonates.
   d) Duration of action of non-depolarizing agents may be shorter.
   e) Neonates and infants may be more sensitive to nondepolarizing relaxants.

3- Temperature regulation in infant and neonate (all true except one)
   a) Neonates and infants can rapidly lose heat.
   b) They are at greater risk for hypothermia.
   c) Infants less than 3 months do not shiver to generate heat.
   d) Monitoring the patients' temperature before anesthesia only.
   e) Hypothermia is treated by warm operating room or warm blanket.

4- The most common cause of bradycardia in pediatrics is:
   a) Vagal stimulation.
   b) Hypothermia.
   c) Hypoxia.
   d) Traction.
   e) Atropine.

5- The total blood volume for 4 kg. neonate is approximately

a) 100ml.
b) 120ml.
c) 220ml.
d) 340ml.
e) 440ml.

# Geriatric Anesthesia

The geriatric population (The elderly) experiences significant alterations of many organ systems as a result of the aging process. They also have several co-morbidities including hypertension, cardiac disease, diabetes, cerebrovascular disease, and renal dysfunction. Geriatric patients are considered vulnerable and especially sensitive to the stress of trauma, surgery, and anesthesia.

## GERIATRIC ANESTHESIA STRATEGIES

### A. Preoperative Evaluation

Tests should be directed toward the type of surgery, known co-existing disease, and history and physical examination findings. Electrocardiogram (ECG), hematocrit (Hct), and hemoglobin (Hgb) are often the most useful tests.

1. Cardiac

Major indicators of cardiovascular risk are unstable coronary syndrome, decompensated heart failure, significant or unstable dysrhythmias, and severe or critical valvular disease, especially aortic stenosis. Cardiac testing should be reserved for patients undergoing intermediate- or high-risk surgery.

2. Pulmonary

Referral to a pulmonologist may be indicated if the patient has signs and symptoms of undiagnosed or decompensated lung dysfunction. Risk factors for postoperative pneumonia include the inability to carry out the activities of daily living, weight loss of 10% or more in the previous 6 months, history of stroke, long-term steroid use, smoking, and underlying lung disease.

3. <u>Renal</u>

It is wise to obtain serum electrolyte levels and creatinine concentration before procedures that carry a significant risk of renal failure (e.g., cardiopulmonary bypass, aortic aneurysm resection, or surgeries in which large fluid shifts or significant blood loss are anticipated).

4. <u>Hepatic</u>

Baseline liver function tests may be reasonable before surgeries that involve significant liver manipulation.

5. <u>Diabetes Mellitus</u>

Poor glucose control (blood sugar higher than 200 mg/dL) is associated with a risk of aspiration, poor wound healing, infection, cardiac and cerebral events, and autonomic dysfunction. Whenever possible, control of serum glucose to levels of 120 to 180 mg/dL is desirable before surgery.

6. <u>Malnutrition</u>

Serum albumin below 3 g/dL with hypocholesterolemia and low body mass index is indicative of malnutrition.

**B. Pharmacokinetics and Pharmacodynamics**

There is no evidence that any specific inhaled or injected anesthetic agent is preferable in elderly patients. Changes in body composition can affect the distribution, metabolism, and clearance of drugs.

1. Total Body Water:

Total body water is decreased, leading to a higher plasma concentration of hydrophilic drugs for a given dose.

2. Adipose to Lean Muscle Ratio:

The ratio is increased, and the volume of distribution of lipophilic drugs is greater, facilitating the accumulation of drugs and prolongation of effects. This is even more pronounced in the face of impaired hepatic or renal function.

3. Circulation Levels of Drug-Binding Proteins:

Levels decrease, leading to increased free drug and drug effects.

4. Decreased Cardiac Output.

   This may prolong circulation time and may result in more rapid uptake of volatile agents.

5. Muscle Relaxant Effects

   Decreased muscle blood flow delays the onset of action. Reduced clearance by the liver and kidneys may prolong the action of some relaxants.

6. Multiple Drug Prescriptions

   Commonly, elderly patients are taking multiple medications, which may lead to undesirable drug effects or drug interactions.

7. Minimum Alveolar Concentration (MAC) of Volatile Agents

   MAC decreases with age, about 4% per decade after 40 years of age.

**C. Anesthetic Plan: Anesthetic management for elderly**

Patients require consideration of many details

1. Anesthetic Technique

   Retrospective and prospective studies have failed to show the benefit of regional versus general anesthesia. The technique should be based on patient choice, the anesthesiologist's experience with the technique, the American Society of Anesthesiologists (ASA) status of the patient, and the planned operation.

2. Monitoring

   Monitoring should be based on potential risks and benefits, the potential for large blood loss or fluid shifts, the ASA status and comorbidities, and the planned surgery.

3. Optimal Analgesia

   Treatment of analgesia may be challenging due to pharmacokinetic and pharmacodynamics changes and the side effects of analgesic drugs. Dementia, delirium, and problems with hearing and vision can complicate pain assessment. The physiologic consequence of inadequate analgesia (tachycardia, hypertension, agitation) may be poorly tolerated.

## Postoperative Delirium

Delirium is defined as an acute alteration in cognitive function n that progresses over a brief period lasting for a few days to a few weeks.

### Risk Factors

1. Advanced age (>70)
2. Underlying dementia .
3. Various comorbidities
4. Drugs (narcotics and benzodiazepines).
5. Alcohol abuse.
6. Previous episodes of delirium.
7. Visual impairment.
8. Certain types of injuries (e.g., hip fractures).
9. Elevated blood urea nitrogen (BUN).

### Treatment

Treating underlying disorders, 0.25 to 2 mg of oral haloperidol for acute control of delirium is the preferred treatment, but diazepam, droperidol, and chlorpromazine are also often used with good results.

MCQ test

1- All the following are decreased in elderly except one
   a) Cardiac output.
   b) Total body water.
   c) Circulation level of drugs binding proteins.
   d) Adipose to lean muscle ratio.
   e) Muscle blood flow.

2- The physiologic consequence of inadequate analgesia in elderly is
   a) Hypotension.
   b) Tachycardia.
   c) Sedation.
   d) Fever.

e) Bradycardia

3- Risk factors for postoperative pneumonia in elderly include (all true except one)

a) history of stroke.
b) Smoking.
c) underlying lung disease.
d) short-term steroid use
e) inability to carry out the activities of daily living

4- anesthetic plan for elderly patient (all true except one)

a) anesthetic technique is based on patient choice and anesthesiologist experiencing
b) analgesia may be challenging due to pharmacokinetic and pharmacodynamics changes.
c) MAC for inhalational agents is increases with age, about 4% per decade after 40 years of age.
d) Risk of post operative delirium.
e) prolong the action of some relaxants.

5- All the following are risk factors for delirium postoperatively in elderly except one

a) Visual impairment.
b) Underlying dementia,
c) Alcohol
d) Rib fracture.
e) Advance age.

# Anesthesia effects on the respiratory system

The primary functions of the respiratory system are:

1. Ventilation; the movement of air into and out of the lungs.
2. Gas exchange; is the transfer of oxygen into the blood and carbon dioxide removal.

General anesthesia has several effects on both of these key functions. The passage of gas into the lungs may be impaired by obstruction of the airway; the distribution of gas within the lungs may change and the transfer of oxygen (and anesthetic gases) into the blood may be impaired. Most of these adverse effects can be seen during anesthesia and in many patients, these extend into the postoperative period.

## HOW ANAESTHESIA AFFECTS VENTILATION

### 1. Airway obstruction

General anesthesia, with or without the use of neuromuscular blocking drugs, results in the loss of airway patency due to the relaxation of the pharyngeal muscles and posterior displacement of the tongue. The ability to manage secretions is lost, and saliva and mucous can obstruct the oropharynx. The loss of the cough reflex allows secretions (or refluxed gastric contents) onto the vocal cords, causing laryngospasm, or to enter the trachea and lungs causing bronchospasm. These effects result in airway obstruction and prevent the passage of gases into and out of the lungs resulting in hypoxia and hypercapnia.

### 2. Reduced ventilation

All anesthetic drugs (except ketamine, ether, and nitrous oxide) cause a dose-dependent reduction in minute ventilation. This can be due to either a reduction in the respiratory rate (e.g., opioids), a reduction in the tidal volume (e.g., volatile anesthetics), or both (e.g., propofol). The ventilatory response to carbon dioxide is reduced by all anesthetic drugs, as a result, anesthetized patients become hypercapnic.

## HOW ANAESTHESIA AFFECTS GAS EXCHANGE

Oxygen is the gas of primary importance, but the exchange of anesthetic gases will also be influenced.

Oxygenation is dependent upon

1. The inspired oxygen content.
2. The presence of a patent airway.
3. Adequate alveolar ventilation.
4. Appropriate matching between ventilation and perfusion in the lung.
5. The transfer of oxygen across the alveolar and endothelial membranes.

Anesthesia affects gas exchange by

1. Changes in functional residual capacity (FRC)
2. Changes in ventilation and perfusion.
3. Hypoxic pulmonary vasoconstriction (HPV)

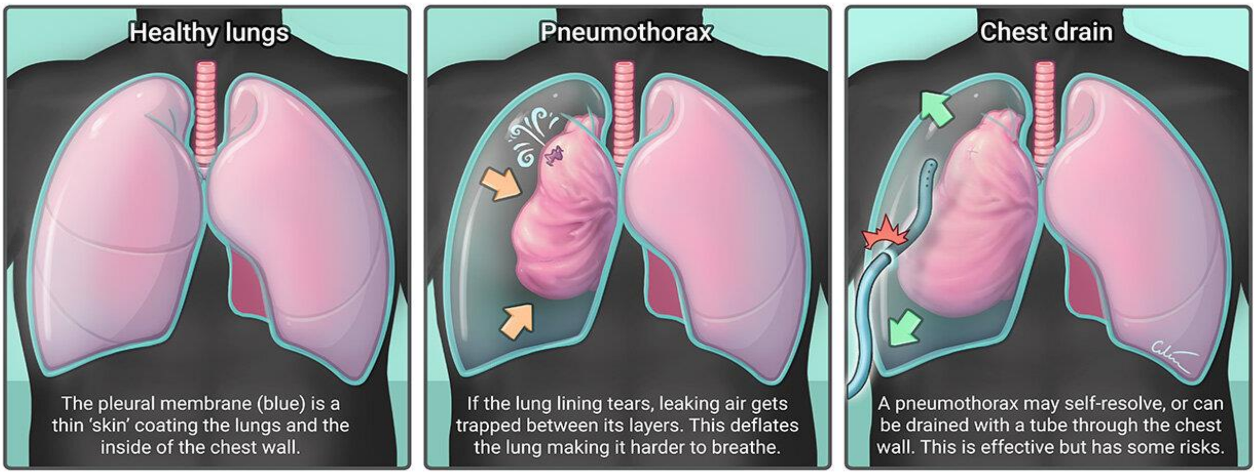
## HOW MECHANICAL VENTILATION CAN DAMAGE LUNG TISSUE

### 1. Acute Respiratory Distress Syndrome ARDS

Mechanical ventilation can directly damage lung parenchyma. Large tidal volumes (>12ml/kg) cause alveoli shearing stress, releasing inflammatory substances. These inflammatory mediators result in edema in the interstitial wall of the alveoli, which reduces lung compliance and gas transfer causing hypoxia. This is termed acute respiratory distress syndrome (ARDS) and results in prolonged stays in the intensive care unit (ICU) with a mortality of up to 40%.

## 2. Pneumothorax (Barotrauma)

Pneumothorax occurs when air is trapped between the two pleural layers of the lungs with a loss of negative pressure that causes the lung to collapse. High inspiratory pressures or large tidal volumes can cause pneumothorax, which is more likely in the stiff, noncompliant lungs caused by ARDS or in the non-elastic lungs of chronic obstructive airway disease. The pressure required to keep one group of alveoli open may rupture another group causing a pneumothorax.




## THE PHARMACOLOGICAL EFFECTS OF ANAESTHESIA

**Table 1.** Summary of the effects of the main anesthetic drugs on the respiratory system.

| ***Inhalational agents*** | ***Positive effects*** | ***Negative effects*** |
|---|---|---|
| **Isoflurane** | Bronchodilation | Reduced MV<br>Reduced response to hypoxia & hypercarbia<br>Pungent – causes coughing<br>Increased secretions |
| **Sevoflurane** | MV stable<br>Bronchodilation<br>Non-irritant | Hypercarbia<br>Depressed response to CO2 |

| | | |
|---|---|---|
| **Halothane** | Bronchodilation<br>Non- irritant<br>Reduced bronchial secretions | Reduced MV, Blunted response to hypoxia and hypercarbia |
| ***Iv Induction agents*** | ***Positive effects*** | ***Negative effects*** |
| **Thiopentone** | | Dose dependent respiratory depression<br>Increased bronchial smooth muscle tone with increased bronchospasm & laryngospasm |
| **Propofol** | Laryngeal relaxation – ease of<br>LMA insertion<br>Bronchodilation | Respiratory depression<br>Reduced response to hypoxia & hypercarbia |
| **Ketamine** | Preserved laryngeal reflexes<br>Maintain patent airway<br>Less respiratory depression<br>Reduction in bronchial smooth muscle tone | Increased saliva and mucous production |
| **Opiates** | Anti-tussive | Respiratory depression<br>Chest wall rigidity<br>Bronchospasm |

MV = Minute Ventilation
TV = Tidal Volume
RR = Respiratory Rate
HPV = Hypoxic Pulmonary Vasoconstriction
LMA = Laryngeal Mask Airway

## MANAGING THE EFFECTS OF ANAESTHESIA ON THE RESPIRATORY SYSTEM

I. ***Pre-operatively***

a. Positioning patients at a 45° angle before induction helps to reduce the fall in the FRC.
b. Pre-oxygenation to maximize the oxygen content of the FRC can significantly increase the time from apnea to hypoxia.
c. Antimuscarinic drugs (atropine, glycopyrrolate) given before induction reduce the quantity of saliva in the airway.

II. ***Intra-operatively***

a. Mechanical ventilation, in particular for obese patients, reduces airway collapse and atelectasis. Positive end-expiratory pressure (PEEP) helps to maintain alveolar patency and prevent hypoxia. If the patient is breathing spontaneously, continuous positive airway pressure (CPAP) will have the same effect.
b. PEEP and recruitment maneuvers can be used to open collapsed portions of the lung. Recruitment is achieved by prolonged periods of high PEEP, Lung protective strategies that are used to treat ARDS can also be used safely for obese patients, bariatric and laparoscopic surgery, and the elderly during anesthesia to reduce atelectasis and increase oxygenation. This effect is not continued after extubating.

***III. Post-operatively***

Oxygen can be continued into the postoperative period in patients at risk of hypoxia. Head-up tilt increases the FRC and helps prevent atelectasis. In obese patients, extubation onto a CPAP mask may help prevent airway collapse and atelectasis and maintain arterial oxygenation. Similarly, extubating ICU patients onto bi-level noninvasive ventilation has been shown to reduce the rate of re-intubation. Make sure the patient has good postoperative analgesia. Patients should be able to take deep breaths and cough.

MCQ test

1- All the following are positive effects of ketamine on respiratory system except one
   a) Reduction in bronchial smooth muscle tone
   b) Maintain patent airway.
   c) Less respiratory depression
   d) Anti-tussive.
   e) Preserved laryngeal reflexes.

2- All the following methods used to decrease the effect of anesthesia on respiratory system except one
   a) Oxygen can be continued into the postoperative period in patients at risk of hypoxia.
   b) atropine, glycopyrrolate) given before induction reduce the quantity of saliva in the airway.
   c) Head down position before induction helps to reduce the fall in the FRC.
   d) Positive end-expiratory pressure (PEEP) helps to maintain alveolar patency and prevent hypoxia.
   e) In obese patients, extubation onto a CPAP mask may help prevent airway collapse and atelectasis.

3- Negative effects of Isoflurane on respiratory system (all true except one
   a) Increased secretions
   b) Reduced minute ventilation.
   c) Sweet odor.
   d) Reduced response to hypoxia.
   e) Reduced response to hypercarbia.

4- All the following anesthetic drugs cause a dose-dependent reduction in minute ventilation except one
   a) Ketamine.
   b) Propofol
   c) Thiopental
   d) etomidate.
   e) Isoflurane.

5- Anesthesia affects gas exchange by (all true except one)
   a) Change in FRC,
   b) Change in ventilation.
   c) Change in perfusion.
   d) Hypoxic pulmonary vasoconstriction.
   e) Change in tidal volume.

# Inhalational anesthetics

**Definition:** An inhalational anesthetic is a chemical compound possessing general anesthetic properties that can be delivered via inhalation. They are administered through a face mask, laryngeal mask airway or tracheal tube connected to an anesthetic vaporizer and an anesthetic delivery system.

The main use of inhalational was to maintain anesthesia, some of them can be used as induction

The dose of inhalational anesthetic was mentioned as MAC

**MAC:** The minimum alveolar concentration (MAC) of an inhaled anesthetic is the alveolar concentration that prevents movement in 50% of patients in response to a standardized stimulus (eg, surgical incision). e.g : Halothane MAC 0.75%

**Factors Increasing MAC (need more volatile to maintain anesthesia)**

- Hyperthermia
- Hypernatraemia
- Sympatho-adrenal stimulation
- Chronic alcohol abuse
- Chronic opioid abuse
- Increases in ambient pressure
- Hypercapnia
- Decreasing age
- Thyrotoxicosis

**Factors decreasing MAC (need less volatile to maintain anesthesia)**

- Nitrous oxide
- Hypothyroid/myxedema

- Hypocapnia
- Hypothermia-decrease is roughly linear
- Hyponatraemia
- Increasing age
- Hypoxaemia
- Hypotension
- Anemia
- Pregnancy
- CNS depressant drugs
- Other drugs: lithium, lidocaine, magnesium, Acute alcohol abuse

HINT: Sex, Weight and Duration of anesthesia does not affect MAC

Nitrous oxide MAC105% , Halothane (Fluothane) 0.75% ,Isoflurane 1.2% ,Desflurane 6.0% ,Sevoflurane 2.0 %

**Characteristic of IDEAL inhalational:**

- Non-flammable, non-explosive at room temperature
- Stable in light.
- Liquid and vaporizable at room temperature
- Stable at room temperature, with a long shelf life
- Stable with soda lime, as well as plastics and metals
- Environmentally friendly - no ozone depletion
- Cheap and easy to manufacture
- Non toxic
- Rapid induction and rapid recovery
- Safe with no toxic side effect

There was no ideal inhalation till now

**Pharmacokinetic of inhalational anesthetics**

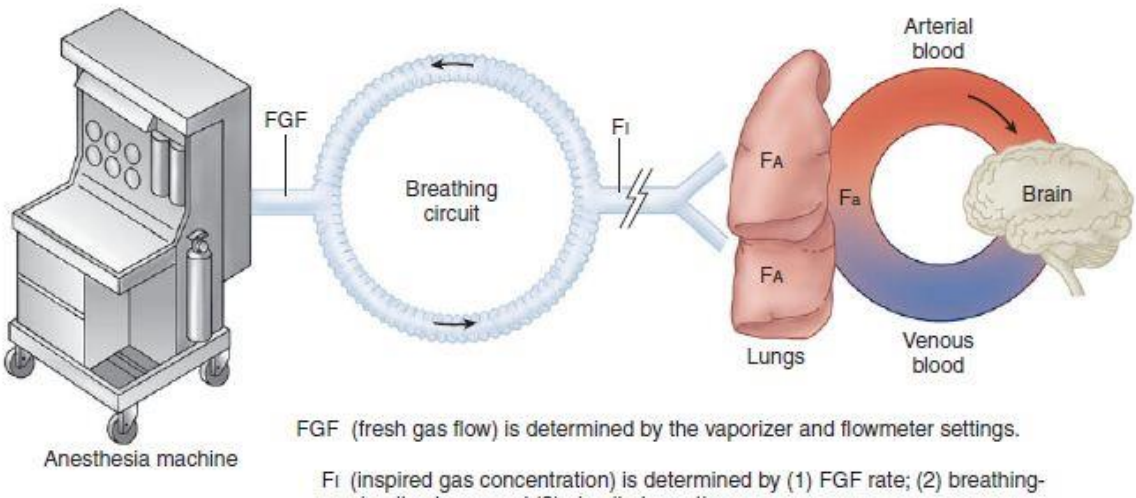
The forward movement of inhalational agent is determined by a series of partial pressure gradients, beginning at the vaporizer of the anesthetic machine, continuing in the breathing circuit, the alveolar tree, blood, and then tissue.

The principal objective of that movement is to achieve equal partial pressures on both sides of each single barrier.

The alveolar partial pressure governs the partial pressure of the anesthetic in all body tissues; they all will ultimately equal the alveolar partial pressure of the gas. After a short period of equilibration the alveolar partial pressure of the gas equals the brain partial pressure.

So there was an **uptake , ventilation and concentration** that effect the induction rate and awaking time

Partial pressure is the ratio of the amount of substance in one phase to the amount in another phase




FGF (fresh gas flow) is determined by the vaporizer and flowmeter settings.

FI (inspired gas concentration) is determined by (1) FGF rate; (2) breathing-circuit volume; and (3) circuit absorption.

FA (aveolar gas concentration) is determined by (1) uptake (uptake = λb/g x C(A-V) x Q); (2) ventilation; and (3) the concentration effect and second gas effect:
a) concentrating effect
b) augmented inflow effect

Fa (arterial gas concentration) is affected by ventilation/perfusion mismatching.

Recovery from anesthesia depends on lowering the concentration of anesthetic in brain tissue. Anesthetics can be eliminated by biotransformation, transcutaneous loss, or exhalation.

Biotransformation usually accounts for a minimal increase in the rate of decline of alveolar partial pressure.

Diffusion of anesthetic through the skin is insignificant. So The most important route for elimination of inhalation anesthetics is the alveolus.

**Mechanism of Action**

The exact mechanism of action for inhaled anesthetics remains mostly unknown. they work within the central nervous system by **augmenting** signals to (GABA receptors) while **depressing** neurotransmission pathways of acetylcholine to muscarinic and nicotinic receptors

**Nitrous oxide (N2O):** Inhalational anesthetic agent, being a useful analgesic for dental extraction



<u>Properties:</u>

- Colorless
- Slightly sweet-smelling gas
- MAC 105%.
- Non-flammable but supports combustion
- Breaking down to $O_2$ and nitrogen at high temperatures.
- Supplied as a **liquid/gas** in French blue cylinders
- Ice often forms on the cylinder during use

CNS effect:

- Fast onset and recovery; strongly analgesic but weakly anaesthetic.

Increases cerebral metabolism, cerebral blood flow and ICP slightly.

Respiratory System:

- Non-irritant. Depresses respiration slightly.
- May cause diffusion hypoxia at the end of surgery.

Cardiovascular system:

- Little effect on heart rate and BP usually

Other:

- Post operative nausea and vomiting
- Does not affect hepatic or renal function, nor uterine or skeletal muscle tone.
- Prolonged use may cause bone marrow depression, megaloblastic anaemia and peripheral neuropathy.
- Generally considered as being safe during pregnancy

**Halothane:** Halothane is a halogenated alkane ,it was nonflammable and no explosive. Sensitive to light so thymol preservative and amber-colored bottles retard spontaneous oxidative decomposition. Its use rapidly spread because of its greater potency, ease of use, non-irritability and non inflammability , Risks of arrhythmias and liver damage on repeated administration (halothane hepatitis)


Properties:

- Colorless liquid
- Pleasant smell
- MAC 0.75%.
- Non-flammable.
- Supplied in liquid form with thymol 0.01%
- Decomposes slightly in light.

Central nervous system Effects:

- Smooth rapid induction, with rapid recovery.
- Anticonvulsant action.
- Increases cerebral blood flow but reduces intraocular pressure.

Respiratory system:

- Non-irritant. Pharyngeal, laryngeal and cough reflexes are abolished early
- Respiratory depressant, with increased respiratory rate and reduced tidal volume.
- Bronchodilatation and inhibition of secretions.

Cardiovascular system:

- Myocardial depression and bradycardia.
- Hypotension is common.
- Myocardial O2 demand decreases.
- Arrhythmias are common, e.g. Bradycardia ,ectopic
- Sensitizes the myocardium to catecholamines, e.g. Endogenous or injected adrenaline.

Other:

- Dose-dependent uterine relaxation.
- Nausea/vomiting is uncommon.
- May precipitate Malignant Hyperthermia.
- Up to 20% is metabolized in the liver.
- Repeat administration after recent use may result in hepatitis.

**Isoflurane:**


Properties:

- Colorless liquid
- Pungent odor
- MAC 1.20
- Non-flammable, non-corrosive.
- With no additive.

Central nervous system Effects:

- Smooth, rapid induction, but speed of uptake is limited by respiratory irritation.
- Recovery is slower than with sevoflurane and desflurane.
- Anticonvulsant properties
- Reduces Cerebral Metabolic Rate of O2.
- Increases cerebral blood flow and ICP.
- Decreases intraocular pressure.
- Has poor analgesic properties.

Respiratory System:

- Irritant; more likely to cause coughing and laryngospasm
- Respiratory depressant, with increased rate and decreased tidal volume.
- Causes bronchodilatation.

Cardiovascular system:

- Myocardial depression is less than with halothane
- Vasodilatation and hypotension commonly occur
- Compensatory tachycardia is common
- Myocardial O2 demand decreases, but tachycardia may reduce myocardial O2 supply.
- Coronary steel may occur

Other:

- Dose-dependent uterine relaxation.
- Nausea/vomiting is uncommon.
- Skeletal muscle relaxation
- May precipitate MH.
- Widely used in neurosurgery

**Sevoflurane**


Properties:

- Colorless liquid
- Pleasant smelling
- MAC 2.
- Non-flammable, non-corrosive.
- Supplied in liquid form with no additive.
- Interacts with soda lime to produce compounds A

Central nervous system Effects:

- Smooth, extremely rapid induction and recovery.
- Early postoperative analgesia may be required as emergence
- Is so rapid.
- Increases the risk of emergence agitation
- Anticonvulsant properties.
- Reduces cerebral metabolic rate of O2
- Decreases intraocular pressure.
- Has poor analgesic properties.

Respiratory System:

- Well-tolerated
- Minimal airway irritation.
- Respiratory depressant, with increased rate and decreased tidal volume.
- Causes bronchodilatation.

Cardiovascular system:

- Vasodilatation and hypotension may occur
- Myocardial O2 demand decreases.
- Arrhythmias uncommon

Other:

- Dose-dependent uterine relaxation.
- Nausea/vomiting occurs.
- Skeletal muscle relaxation
- May precipitate MH.
- Tracheal intubation may be performed easily with spontaneous Respiration.
- Considered the agent of choice for inhalational induction in pediatrics because of its rapid and smooth induction characteristics.
- Has also been used for the difficult airway, including airway obstruction.

## Desflurane

Introduced in the UK in 1994, a colorless liquid with slightly **pungent vapor**, boiling point: 23°C, MAC: 5%–7% in adults; 7.2%–10.7% in children, non-flammable, non-corrosive, supplied in liquid form with no additive, may react with dry soda lime to produce carbon monoxide, **requires the use of an electrically powered vaporizer** due to its low boiling point.

**Effects:**

**On central nervous system:**

1) Rapid induction (although limited by its irritant properties) and recovery.

2) May increase cerebral blood flow, although the response of cerebral vessels to $CO_2$ is preserved.

3) ICP may increase due to imbalance between the production and absorption of CSF.

4) Reduces $CMRO_2$ as for isoflurane.

5) Has poor analgesic properties.

**On respiratory system**:

1) Causes airway irritation; not recommended for induction of anesthesia because respiratory complications (e.g. laryngospasm, breath-holding, cough, apnea) are common and may be severe.

2) Respiratory depressant, with increased rate and decreased tidal volume.

**On cardiovascular system:**

1) Vasodilatation and hypotension may occur, similar to isoflurane, may cause tachycardia and hypertension via sympathetic stimulation, especially if high concentrations are introduced rapidly.

2) Myocardial ischemia may occur if sympathetic stimulation is excessive, but has cardioprotective effects in patients undergoing cardiac surgery.

3) Arrhythmia as uncommon, as for isoflurane, little myocardial sensitization to catecholamines.

4) Renal and hepatic blood flow generally preserved.

**Others:**

1) Dose-dependent uterine relaxation (although less than isoflurane and sevoflurane).

2) Skeletal muscle relaxation; non-depolarising neuromuscular blockade may be potentiated.

MCQ TEST

1- Factors increase MAC(all true except one)

  a) Hyporthermia
  b) Hypernatraemia
  c) Chronic alcohol abuse

d) Chronic opioid abuse
e) Hypercapnia

2- Not affect MAC
a) Hyponatraemia
b) Increasing age
c) Hypoxaemia
d) Hypotension
e) Sex

3- Pungent odor
a) Isoflurane
b) oxygen
c) Halothane
d) Sevoflurane
e) Nitrous oxide

4- Which one is true regarding MAC
a) Halothane=1.2
b) Isoflurane=0.75
c) Sevoflurane=2
d) Desflurane=5
e) Nitrous oxide=105

5- requires the use of an electrically powered vaporizer due to its low boiling point.
a) Desflurane
b) Isoflurane
c) Xenon
d) Halothane
e) Sevoflurane

6- Characteristic of IDEAL inhalational agents

a) flammable at room temperature
b) un stable in light.
c) Un Stable at room temperature
d) short shelf life
e) Rapid induction and rapid recovery

# Anesthesia for pediatrics and geriatrics

## Pediatric anesthesia

### Definitions:

Neonate = less than 28 days old.

Infant = 28 days to 1 year old.

Child = 1 year to 16 years old (dependent on local laws of consent).

### Anatomical differences of pediatrics than the adults:

1) Larger head, shorter neck and larger tongue.
2) Glottic inlet is higher, epiglottis is longer and curved.
3) The narrowest part of the larynx is the cricoid ring.
4) Ribs are more horizontal and breathing is diaphragmatic rather than intercostals.

### Physiological differences in pediatrics than the adults:

1) Functional residual volume (FRC) lies close to the closing volume (CV) in the infants and the reduction in FRC with anesthesia or disease can lead to atelectasia and segmental collapse unless positive end-expiratory pressure (PEEP) is applied.
2) In infants, alveolar ventilation and oxygen demand are much higher than in the adults, but the FRC/$V_A$ (alveolar ventilation) is much lower (half), so the reserves of oxygen in the lung of the infant are lower.
3) Unlike in adults, mild hypoxia in the neonate causes hypoventilation leading to apnea.
4) Basal metabolic rate, caloric requirements and $O_2$ uptake is are higher.
5) Glycogen stores are relatively low, but brain and myocardium are more glucose dependent.

6) Cardiac output average (relative to body weight) and heart rate are greater.
7) The neonate has limited responses to cold (vasoconstriction rather than shivering) and there is an increased propensity to bradycardia.
8) In general, infants have larger volumes of distribution for most drugs, and even susceptible infants may require larger initial doses of drugs to achieve adequate plasma concentrations.

## Normal respiratory rate and heart rate according to age

| Age group | Heart rate<br>Beat/ min | Respiratory rate<br>Breath/ min |
|---|---|---|
| Less than 1 year | 110 - 160 | 30 - 60 |
| 1 to 3 years | 100 - 150 | 24 - 40 |
| 3 to 6 years | 95 - 140 | 22 - 34 |
| 6 to 12 years | 80 - 120 | 18 - 30 |
| 12 to 18 years | 60 - 100 | 12 - 16 |

# Practical conducts for general anesthesia

Fasting guidelines: Neonates and pre-weaned infants will become irritable, dehydrated and hypoglycemic if starved for extended periods. For elective surgery a widely used scheme is:

a) Solids- morning case, no solid food overnight; afternoon case, light food at breakfast; no solid food for 6 hours before surgery.

b) Milk- up to 4 hours before surgery for bottled milk, up to 3 hours before surgery for breast milk.

c) Clear liquids- up to 2 hours before surgery.

Children with major organ dysfunctions, or those actually ill with infection or trauma, should be treated as though they had a full stomach regardless of fasting interval because these conditions are associated with delayed gastric emptying. Small infants should be scheduled first on an operating list to improve planning, but it may still be necessary to commence intravenous fluids.

## Premedication:

The advent of local anesthetic creams prior to venipuncture has reduced the necessity for sedative premedication. Occasionally, a sedative drug required, this is particularly useful for child who, in spite of good preoperative preparation, remains apprehensive. Currently, oral midazolam is a widespread popular, an alternative to midazolam is oral ketamine, in that case, an antisialagogue (e.g. atropine) should be added to prevent excess salivation. If profound degrees of sedation are required, it is possible to combine midazolam and ketamine. The incidences of nausea and vomiting and of excess sedation in the postoperative period are increased. Intramuscular premedication is generally not tolerated well by children. Rectal administration of induction agents has been used (such as thiopental), this form of premedication may be used only under the direct supervision of the anesthetist, as respiratory depression is a distinct possibility.

## Induction of anesthesia:

Unlike adult practice, it is not possible to have all the necessary monitoring devices placed on the child before induction. In most cases, if should be possible to place an appropriately sized pulse oximeter probe on a digit. Most children also allow the placement of precordial stethoscope.


((Precordial stethoscopes))

The appropriate monitoring should be placed as soon as possible after the start of anesthesia.  When inhalational induction is planned, clear scented plastic masks are much more acceptable to little children. Clear masks allow respiration and the presence of vomitus to be observed.

Gas induction has become increasingly preferred since the introduction of sevoflurane. It is usually elected from the outset together with nitrous oxide and oxygen.

Opting for intravenous induction depends on child's preference, suitability of veins, technical expertise and state of the child. Doses should be titrated to effect: neonates and sick infants may require reduced dose, whereas 3–5-year-old need relatively larger doses than adults (e.g., required propofol dose is 2.5-5mg/ kg while it is in adults 1-2.5 mg/ kg). The pain on induction with propofol can be reduced by adding 20 mg lidocaine to 200 mg propofol. Thiopental provides a smooth induction but can delay postoperative recovery.

## Maintenance:

Most simple short procedures require only spontaneous ventilation under a volatile or intravenous anesthetic agent and analgesia that will extend into the postoperative period. Neonates are usually intubated and ventilated for surgical procedures to ensure adequate gas exchange, and are given local anesthetic blockade where possible to limit CNS depressant drug usage. In complex procedures where postoperative ventilation is planned, high-dose opioid techniques are often used to minimize stress responses.

## Regional analgesia:

Regional blocks reduce intraoperative anesthesia requirements and provide a postoperative analgesia and, unlike systemic analgesia, may provide complete analgesia without systemic side-effects.

## I.V fluids:

*Crystalloids:*

Intraoperative hypoglycemia can occur in neonates, but is unusual owing to the effects of the stress response on glycolysis and gluconeogenesis. In contrast, excessive perioperative administration of glucose solutions can lead to hyponatremia, water intoxication and cerebral edema. Hartmann's solution (Ringer's lactate solution) can be given as a sole agent during surgery, but it is wise to measure blood glucose hourly during prolonged cases, alternatively, a fixed maintenance infusion of a glucose-containing solution should be continued throughout, with additional fluid replacement of Hartmann's given independently. A recognized formula for maintenance fluid hourly rates is:

- 1-10 kg = 4 ml/ kg
- 11-20 kg = 40 + 2 ml/ kg
- over 20 kg = 60 + 1 ml/ kg

  It has been shown that a mixture of glucose 2.5% in Ringer's lactate can maintain normal glucose while avoiding hyponatremia. Increased replacement fluids may be required if the gut remain exposed.

*Colloids and blood:*

The threshold for transfusion will vary the child's overall condition and associated pathologies. For otherwise healthy children it is acceptable to let Hb drop to 8-9 g/dl, but neonates and children with cardiac or pulmonary conditions may benefit from a Hb raised to 10-13 g/dl. A volume formula for transfusion is:

- (Hb required – Hb actual) × (body weight in kg) × 5 = volume of red cells required (using resuspended SAGM blood).

  Fresh frozen plasma and platelets may need replacing earlier than in adults to prevent coagulopathy. These colloids contain citrate and will require additional calcium administration to prevent significant hypocalcemia if infused quickly.

## Endotracheal tubes:

For children over 1 year:

- Appropriate tube internal diameter (ID) can be approximately estimated by the formula: age / 4 + 4.
- Appropriate tube length in cm. can be approximately estimated by the formula: age / 2 + 12 oral (+15 for nasal).

In infants:

- Appropriate tube ID sizes for preterm: <1500 g = 2.5 mm, 1500-3000 g = 3 mm, over 3000 g = 3.5 mm.
- Oral length in cm. is given by the formula (6 + weight in kg).

## Laryngeal mask airway (LMA):

They are useful in short procedures with spontaneous ventilation. They have less resistance than endotracheal tubes and are of considerable use for insertion of fiber-optic bronchoscopes. Approximate sizes are:

- 1 for less than 6.5 kg.
- 2 for 6.5-20 kg.
- 2.5 for 20-30 kg.
- 3 for 30 kg and above.

A size 1.5 is also available. The armored versions have reduced risk of kinking and are longer and narrower. The use of the size 1 has not been widespread because of concerns about secure insertion, increased dead space and atelectasis. Although it has been used in neonatal resuscitation, it is not yet recommended for controlled ventilation in small children because of the risk of ventilator impairment from gastric distension.

## Breathing systems:

Common breathing systems used in pediatric practice include Ayre’s T-piece (Mapleson E), Jackson-Rees modification (Mapleson F), Bain systems and circle.

The Mapleson F system remains the mainstay of pediatric anesthesia. It is compact and light, with low dead space and airway resistance. It can function in spontaneous and controlled ventilation with or without manual continuous positive airway pressure (CPAP).

The Bain system behaves like a Mapleson E or F circuit and has been used in all age groups.

The circle system is has become preferred for controlled ventilation in pediatrics because of heat and moisture conversation as well as cost efficiencies.

# Geriatric anesthesia

People above 65 years are defined as old ages, Ageing is characterized by degenerative changes in structure and function of organs and tissues, there is gradual loss of skeletal tissue mass, increase in body fat, reduction in total body water, and reduce in albumin levels. Decreased skin elasticity increases the risk of injury from the use of various adhesive tapes. Adding a thin layer of cotton batting wrap before applying the noninvasive blood pressure cuff may be a simple but effective maneuver for the prevention of neurovascular complication. Thinner layer of subcutaneous fat, which predisposes elderly patients to the potential for pressure sores. Protecting elderly patient's bony prominences, padding with pillows and arm-support devices should be ensured.

## Drugs:

Old aged patients are very sensitive to anesthetic agents. Lower concentration of drug is required to achieve a desired effect and effect is usually prolonged. Gradual titration of drug to dosage effect is usually required, boluses must always be avoided. One must be cautious of hemodynamic surges. Intravenous drugs may have longer circulation time and delayed onset of effect. Elderly patients display a lower dose requirement for propofol, etomidate, barbiturates, opioids, and benzodiazepines. Administration of a given volume of epidural local anesthetic tends to result in more extensive spread in elderly patients. A longer duration of action should be expected from a spinal anesthetic.

Prolonged circulation time delays the onset of intravenous drugs, but speeds induction with inhalational agents.

Elderly requires lesser dosage of opioid agents. Sufentanyl, fentanyl and alfentanil are twice potent in elderly as compared to adult population owing to altered sensitivity of brain to opioids. As the central compartment is reduced in geriatrics infusion rates should be reduced and titrated to effect.

Metabolism of neuromuscular blockade agents (skeletal muscle relaxants) which depend on liver and renal blood flow is reduced, thereby prolonging the duration of effect. Metabolism of atracurium and cis-atracurium is unaffected by age, as they are metabolized by Hoffman degradation (spontaneous degradation in plasma and tissue at normal body PH and temperature).

Aging is associated with a decreasing response to β-adrenergic agents (e.g., adrenaline, dobutamine).

## Airway management:

They have limited neck mobility, because of arthritic changes. They have difficult mask ventilation due to the absence of multiple teeth. Goal of pre-oxygenation may not be reached because of that. They are tending to sleep apnea due to reduction in upper airway consistency that placing them at increased risk of pulmonary complications. Intubation should be rapid, gentle and atraumatic.

## Notable benefits of regional anesthesia in old age:

1) Decreased incidence of deep venous thrombosis.
2) Blood flow improved.
3) Provide adequate pain relief.
4) Maintain spontaneous airway.
5) Pulmonary functions are intact depending on the level of blockade.

## Other physiological notes about old age:

1) Increased vagal tone and decreased sensitivity of adrenergic receptors lead to a decrease in heart rate.
2) Decreased elasticity of lung tissue, allowing over distention of alveoli and collapse of small airways. Residual volume and the functional residual capacity increased. Airway collapse increases residual volume and closing capacity.
3) Impairment of Na+ handling, concentrating ability, and diluting capacity predispose elderly patients to both dehydration and fluid overload.
4) Liver mass and hepatic blood flow reduced with aging. Hepatic function declines in proportion to the decrease in liver mass.
5) Aging produces both pharmacokinetic and pharmacodynamic changes.

MCQ TEST

1- The benefits of regional anesthesia in elderly (all true except one)

a) Maintain spontaneous airway.

b) Risk of deep venous thrombosis.
c) Good pain relief postoperatively.
d) Improves blood flow.
e) No side effects of intubation.

2- Endotracheal intubation in pediatrics (all true except one)
a) internal diameter (ID) can be approximately estimated by the formula: age / 4 + 4.
b) tube length in cm. can be approximately estimated by the formula: age / 2 + 12 for oral tube.
c) For 4th. Month baby, the endotracheal tube ID=6mm.
d) For preterm infant=2.5mm
e) Infants need smaller endotracheal tube than child

3- Airway management in geriatric (which one is true)
a) limited neck mobility because of obesity.
b) difficult mask ventilation due to arthritic joint.
c) Increased elasticity of lung tissue leading to over distention of alveoli
d) Residual volume and the functional residual capacity increased.
e) Loss of teeth have no role in difficult intubation.

4- Aging is associated with all the following except one
a) decreased sensitivity of adrenergic receptors lead to a decrease in heart rate.
b) Metabolism of atracurium and cis-atracurium is unaffected by age.
c) Old aged patients are very sensitive to anesthetic agents.
d) Elderly requires larger dosage of opioid agents
e) speeds induction with inhalational agents.

5- Which of the following system is the mainstay of pediatric anesthesia
a) The Mapleson F system.
b) The Mapleson D system
c) The Mapleson A system
d) The Mapleson B system
e) The Mapleson E system

6- Approximate sizes for Laryngeal mask airway in pediatrics (all true except one)
a) 1 for less than 6.5 kg.
b) 2 for 6.5-20 kg.
c) 2.5 for 20-30 kg.
d) 3 for 30 kg and above.

e) 4 for 30 kg and below.

# ANAESTHESIA FOR THORACIC SURGERY

Thoracic anesthesia is a field requiring mastery of pulmonary anatomy and physiology, as well as technical skills in the stabilization of an adequate airway through various modalities.

**Particular anesthetic challenges of thoracic anesthesia:**

- Control of airway during bronchoscopy.
- Protection of the airway in patients with esophageal disease, lung abscess, bronchopleural fistula or hemoptysis.
- Positioning a double-lumen tracheal tube to maintain anesthesia in the lateral position with the chest opened and one lung collapsed.
- Postoperative care of a patient after lung tissue resection

**One-lung anesthesia:**

In thoracic anesthesia, one-lung ventilation is used, so only a single (non operative) lung is ventilated.

**<u>Principal indications for one-lung anesthesia</u>:**

1) Isolation of the lungs.

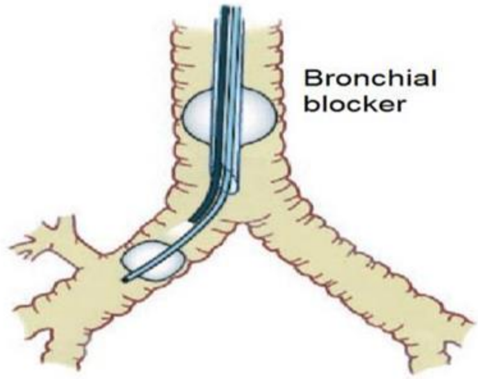
2) Ventilation of one lung alone.

3) Bronchopulmonary alveolar lavage.

4) Collapse of one lung to allow surgical access to other structures

**Ventilation of one lung** alone requires either a double-lumen tracheal tube or a bronchial blocker.

Traditionally, in one-lung ventilation, the same minute volume used in two-lung ventilation is applied to the single lung. However, a smaller tidal volume or pressure controlled ventilation may reduce stretch-related lung injury.





**MANAGEMENT OF HYPOXAEMIA DURING ONE-LUNG VENTILATION**

- Increase inspired oxygen to 100%.
- Check position of tube with fibre-optic bronchoscope.
- Suctioning of secretions may be required.
- Ensure adequate blood pressure and cardiac output.
- PEEP 5–10 $cmH_2O$ to the dependent lung to decrease atelectasis and increase FRC. Excessive PEEP increases pulmonary vascular resistance and may increase shunt.

• CPAP 5–10 cmH2O with 100% oxygen to the non-ventilated lung to facilitate oxygen uptake in this lung whilst not adversely affecting the surgical conditions.

• Abandon one-lung ventilation and intermittently ventilate the collapsed lung after warning the surgeon.

• Early clamping of the appropriate pulmonary artery will stop the shunt

## Thoracotomy:

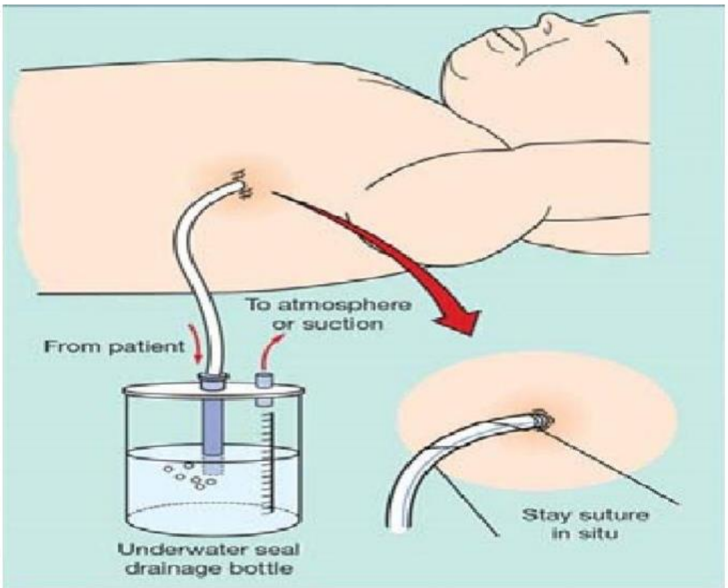
Median sternotomy in supine position is used for access to the thymus, retrosternal goiters and anterior mediastinum; lateral thoracotomy is used for most-other thoracic operations.

Blood loss may be extensive, at least one large-bore cannula is essential. A central venous catheter allows venous pressure monitoring and more rapid drug delivery.

The lungs should be fully expanded before closure. Residual air in the pleural cavity can be removed by an intrapleural drain connected to an underwater seal or a Heimlich flutter valve.

Accidental pneumothorax during thoracotomy can be caused, it is a risk during any operation near the pleura or where local blocks are performed in the region of the thorax. It may be a cause of cardiovascular collapse and be difficult to diagnose. Puncture of the lung itself will usually close spontaneously, but chest drains are usually required as a precaution.

Heimlich flutter valve




Underwater seal drain

**Postoperative considerations:**

1) Postoperative hypoxemia: Patients who have undergone a thoracotomy will require oxygen in the immediate postoperative period for 24 hours and chest physiotherapy, factor may contribute postoperative hypoxemia are:
    a) Pneumothorax: which it should be excluded by routinely postoperative chest radiograph.
    b) Atelectasis.
    c) Sputum retention.
    d) Poor pain relief.
    e) Fluid overload.
2) Cardiac arrhythmia: The most common one after thoracotomy is atrial fibrillation.
3) Torsion of remaining lobe: It is may occur after lobectomy. The presentation may be up to 2 weeks postoperatively. Chest radiology

shows engorgement and increased density of the affected lobe. Resection of the affected lobe is usual.

4) Herniation of the heart: Removal of pericardium together with lung resection, may allow the heart to be displaced from the mediastinum. Cardiovascular collapse is usually profound. Emergency re-exploration is required.

## Pneumonectomy

A lateral approach is usual, but the prone or supine positions may be used, a double-lumen tube is usual, but a single-lumen tube may be adequate (with or without a bronchial blocker).

When the chest is closed at the end of surgery, the remaining lung is fully inflated and the chest drain to the pneumonectomy space is clamped. Clamps are released for 5 minutes every hour to ensure that no air blood or excess fluid accumulates in the pneumonectomy space.

Post-operative pulmonary edema carries a high mortality rate. It appears to be related to the perioperative use of blood products and higher ventilatory inflation pressures.

## Pulmonary lobectomy

There will be a large air leak and difficulty with ventilation unless one-lung anesthesia is used. There will be considerable alveolar air leak afterwards, which decreases when IPPV is stopped. Low-pressure suction (-5 cmH2O) should be applied postoperatively to pleural drains to keep the lungs expanded.

## Lung cyst and bullae

Intermittent positive pressure ventilation (IPPV) and coughing may cause further distension of large cysts compress surrounding tissue or even a tension pneumothorax.

Early isolation of the cyst from ventilation with a double-lumen tube or bronchial clamp is desirable. Nitrous oxide may distend lung cysts because of its much greater solubility than nitrogen and should be avoided. Accidental rupture of a pulmonary hydatid cyst into the bronchi during surgery risks dissemination of the disease. Endobronchial intubation is indicated.

- **Thymectomy for myasthenia gravis**

The approach for thymectomy for myasthenia gravis is trans-cervical or by splitting. A single-lumen endotracheal tube is required. Hemorrhage may be significant and large-bore venous access is essential.

***Implications for anesthesia***:

1) Increased sensitivity to non-depolarizing muscle relaxants.
2) Resistance to depolarizing muscle relaxants.
3) Increased sensitivity to the neuromuscular effects of volatile agents.
4) Risk of aspiration due to bulbar weakness (a weakness due to impairment of function of the lower cranial nerves).
5) Risk of postoperative respiratory failure with respiratory muscle weakness.
6) Risk of cholinergic crisis with excessive doses of anticholinesterases.
7) Effects of immunosuppressant therapy

Maintenance of anesthesia with propofol has the advantages of avoiding the neuromuscular effects of volatile agents. And in combination with thoracic epidural analgesia has been reported to reduce the requirement for postoperative ventilatory support.

Cautious use of other respiratory depressants such as opiates is recommended, non-opioid analgesics and local anesthesia should be used where possible. Neostigmine should be used cautiously because of the risk of precipitating a cholinergic crisis.

- **Rigid bronchoscopy**

It is performed most often to obtain tissue diagnosis and determine if a lesion may be resected. Other indications include removal of foreign bodies and secretions, and control of hemorrhage.

***<u>The principles of anesthesia for rigid bronchoscopy are</u>***:

1) To maintain oxygenation and carbon dioxide removal during the procedure.

2) Hypnosis and reduction of autonomic response.

3) Muscle relaxation to allow passage of the scope and to facilitate the conduct of endotracheal and endobronchial manipulation.

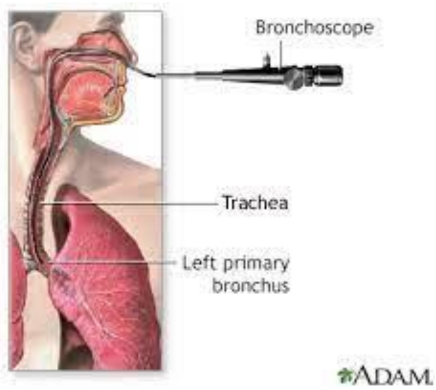
The anesthetist stands beside the patient, intermittently releasing a high pressure gas (ventilation is normally maintained by using a 4 bars gas injector via a cannula attached to the proximal end of the bronchoscope). The chest and abdomen are observed as a monitor of adequate tidal volume.

At the end of the procedure, the bronchoscope is removed and the pharynx sectioned carefully. Ventilation is maintained with a bag and face or laryngeal mask, anesthesia is discontinued and muscle relaxation reversed if a non-depolarizing agent has been used.

The patient is normally recovered in a sitting position. Nebulized adrenaline, I.V dexamethasone and CPAP via a tight-fitting mask may help relieving of the post-procedure laryngeal spasm, which may be an occasional complication.

- **Fiber-optic bronchoscopy**

Commonly, fiber-optic bronchoscopy is performed under topical anesthesia and sedation with midazolam or diazepam. Opioids may be used in addition, but apnea must be avoided. A flexible fiber-optic scope may be passed via an endotracheal tube or laryngeal mask airway under general anesthesia




MCQ TEST

1- Cause of post-operative hypoxemia after thoracotomy (**all true except one**)

a) Sputum retention.

b) Pain.

c) Pneumothorax.

d) Dehydration

e) atelectasis

2- Rigid bronchoscopy (**all true except one**)

a) Laryngeal spasm post operatively treated by IV dexamethasone and CPAP.

b) Recovery of the patient in left lateral position

c) Not performed under local anesthesia.

d) Muscle relaxants to allow passage of scope.

e) For foreign body removal.

3- Thymectomy for myasthenia gravis **(all true except one)**

a) A single lumen endotracheal tube is required.
b) Increased sensitivity to atracurioum.
c) Risk of aspiration due to bulbar weakness.
d) Resistance to succinylcholine.
e) Hemorrhage may be non-significant

4- One lung anesthesia (**all true except one)**

a) One lung is ventilated.
b) Requires either a double lumen tracheal tube or a bronchial blocker.
c) Double minute volume used
d) Indicated for bronchopulmonary alveolar lavage.
e) Not indicated in thymectomy.

5- Management of hypoxemia during one lung ventilation **(which one is <u>true</u>)**

a) Check the position of tube with vediolaryngoscopy.
b) Increase tidal volume to double.
c) Apply PEEP 5-10cmH2O to non-dependent lung.
d) Apply CPAP 5-10cmH2O to the dependent lung.
e) Suctioning of secretions may be required

6- Post-operative complications of thoracotomy

a) Hypoxemia.
b) Atrial fibrillation.
c) Torsion of remaining lobe.
d) Cardiovascular collapse.
e) All the above

7- Fiber-optic bronchoscopy (**all true except one)**

a) Commonly perfumed under general anesthesia
b) Use of opioids with caution to avoid apnea
c) Midazolam good sedative drug.
d) Flexible fiber optic scope may be passed via endotracheal tube under GA.
e) Not need muscle relaxants.