Acknowledgments

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We would like to thank Prof. Sabah Al-Sharkawi the General Coordinator of General Directorate of Technical Health Education, Dr. Azza Dosoky the Head of Central Administration of HR Development, Dr. Seada Farghly the General Director of THE and all share persons working at General Administration of the THE for their time and critical feedback during the development of this course.

Special thanks to the Minister of Health and Population Dr. Hala Zayed and Former Minister of Health Dr. Ahmed Emad Edin Rady for their decision to recognize and professionalize health education by issuing a decree to develop and strengthen the technical health education curriculum for pre-service training within the technical health institutes.
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This course aims at equipping students with necessary and essential knowledge regarding to anesthesia and its basic principles.

**Course Aim**

Intended learning Outcomes

**By the end of this course the students should be able to:**

1. list elements of preoperative screening and assessment
2. Describe airway management technique during anesthesia
3. Identify different anesthesia devices, function and use
4. list the complication of general, inhalation, local and regional anesthesia.
5. Compare between different stages of anesthesia
6. Describe the function of each component of the anesthesia machine
7. Discuss the monitoring and measurement technique during and after anesthesia
8. Explain the discharge criteria and complication in recovery area.
9. discuss pain management during postoperative period

**By the end of this course the students should be able to:**

1. Express one of point of view regarding the topic of the course
2. Evaluate patient’s data all through the operation
3. Analysis and monitoring output data
4. Share surgical team in decision making

- **المعلومات والمفاهيم**
  - A. Knowledge and understanding
    - A.1. list elements of preoperative screening and assessment
    - A.2. Describe airway management technique during anesthesia
    - A.3. Identify different anesthesia devices, function and use
    - A.4. list the complication of general, inhalation, local and regional anesthesia.
    - A.5. Compare between different stages of anesthesia
    - A.6. Describe the function of each component of the anesthesia machine
    - A.7. Discuss the monitoring and measurement technique during and after anesthesia
    - A.8. Explain the discharge criteria and complication in recovery area.
    - A.9. discuss pain management during postoperative period

- **المهارات الذهنية**
  - B. Intellectual skills
    - B.1. Express one of point of view regarding the topic of the course
    - B.2. Evaluate patient’s data all through the operation
    - B.3. Analysis and monitoring output data
    - B.4. Share surgical team in decision making

- **المهارات المهنية الخاصة بالمقرر**
  - C. Professional skills
**D. General and transferable skills**

D.1. Recognize the interpersonal communication skills with surgical team
D.2. Use information technology resources in collecting knowledge related to the course
D.3. Use problem solving skills.
D.4. Communicate with surgical patients and their families, health care team and colleagues in respect for different values, cultures, intellectual levels and emotional state.
D.5. Respect patient rights and promote principles of ethical consideration.

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### Teaching and Learning Methods

- Lecture
- Group discussion
- Quizzes

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**Students Assessment**

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**Total: 100 marks**

1. Final written Exam 80 Mark (at the end of 15th W)
2. Semester work 20 Mark (Quizzes 6th and 12th W)

---

**List of References**

- Ministry of Health essential book
  (Introduction to anesthesia)
- Required Books
  (Text Books)
- Recommended Books
- Periodicals. Web sites... etc.
Course Description

- **The aim of this course**...... This course aims at equipping students with necessary and essential knowledge regarding to anesthesia and its basic principles.

**Core Knowledge**

*By the end of this course, students should be able to understand his role in the Medical Emergency Service as follow:*

By the end of this course the students should be able to:

1. List elements of preoperative screening and assessment
2. Describe airway management technique during anesthesia
3. Identify different anesthesia devices, function and uses
4. List the complication of general, regional and local infiltration anesthesia.
5. Describe the function of each component of the anesthesia machine
6. Discuss the monitoring and measurement technique during and after anesthesia
7. Explain the discharge criteria and complication in recovery area.
8. Discuss pain management during postoperative period

**Core Skills**

*By the end of this course the students should be able to:*

1. Express once of point of view regarding the topic of the course
2. Evaluate patient’s data all through the operation
3. Analysis and monitoring output data
4. Recognize the interpersonal communication skills with surgical team
5. Use information technology resources in collecting knowledge related to the course
6. Use problem solving skills.
7. Communicate with surgical patients and their families, health care team and colleagues in respect for different values, cultures, intellectual levels and emotional state
8. Respect patient rights and promote principles of ethical consideration
## Course Overview

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| 6<sup>th</sup> | Complication of tracheal intubation |
| Hypoxia |  |
| Trauma |  |
| Reflex activity |  |
| Difficult intubation |  |
| Emergency airway techniques |  |

| 7<sup>th</sup> & 8<sup>th</sup> | General and inhalation anesthesia |
| Intravenous induction of anesthesia |  |
| Inhalation induction of anesthesia |  |
| The safe delivery of anesthesia |  |
| Safety measures |  |

- The stages of anesthesia
  - First stage
  - Second stage
  - Third stage
- Maintenance of anesthesia
  - Minimum alveolar concentration
  - Nitrous oxide
  - Systemic effects
  - Assessment of neuro-muscular blockade
  - Peripheral nerve stimulation

| 9<sup>th</sup> | The antiesthetic machine |
| Checking the anesthetic machine |  |
| The circle system |  |
| Components of breathing system |  |
| Mechanical ventilation |  |
| Scavenging systems |  |
| 10th & 11th | Measurement and monitoring
Monitoring the patient
The ECG
Blood pressure
Pulse oximeter
Capnography
Vapor concentration analyzer
Temperature
Central venous pressure
Oxygen supply
Breathing systems |
| --- | --- |
| 12th | The anesthetic record
Intravenous cannulation and fluid administration
Complications
Central venous cannulation
Intravenous fluids
Blood and blood components
Risks of intravenous blood and blood products |
| 13 & 14th | Local and regional anesthesia
Techniques
Local anesthetic toxicity
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Epidural anesthesia
IVRA, bier's block
Spinal anesthesia
Monitoring during local and regional anesthesia
Complication of central neural blockade
Nausea and vomiting
Postural puncture headache
Hypotension and bradycardia |
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Chapter 1
The Anesthesia machine

THE SAFETY FEATURES IN AN ANESTHESIA MACHINE

Safety features can be further sub-divided into the following categories:

1. Gas supplies: From the central pipeline to the machine as well as cylinders.
2. Flowmeters.
3. Vaporizers.
5. Scavenging.

We shall examine in detail the safety features in each of the categories described above apart from patient monitoring, which is not directly related to the anesthesia machine.

Many international standards exist for the Anesthesia machines (or workstations as they are called) specifying the safety features that are absolutely required and those that are relative/desirable.

Most professional associations e.g., Association of Anesthetists of Great Britain and Ireland (AAGBI) and ASA also recommend pre-Anesthesia checkout procedures that check the proper functioning of all the safety features incorporated in the machine.

Newer electronic machines have a computerized check out.

In a review conducted over the years 1962-1991 by ASA, malpractice claims were related to gas delivery equipment. Death and permanent brain damage accounted for a majority of the claims (76%). Misuse of equipment was 3 times more common than equipment failure, highlighting the necessity of proper equipment check and training before use.

This article is only intended to help the reader understand the minimum
safety features needed in an anesthetic machine.

There are many other safety features, which are not discussed here such as electrical safety, monitoring capability, reliability or reproducibility of results/performance under different working conditions.

In most new machines pneumatic systems can be divided into the high, intermediate and low-pressure systems. Safety features are incorporated into every single component of the machine.

*Figure: The high, intermediate and low-pressure systems of the Anesthesia machine*

**1-Gas supplies**

**HIGH-PRESURE SYSTEM**

The high-pressure system consists of cylinders and their yoke assemblies, cylinder pressure indicators, pressure regulators.

Many mishaps have happened because of the wrong cylinder or the wrong gas being filled in the intended cylinder. Hence, the cylinder colour coding and PIN index systems were developed but still accidents do happen.

The hanger yokes of the machine, which support the cylinder, have the Pin Index safety systems, which prevent the attachment of the wrong cylinder to the yokes. The pins are on the yoke assembly and the cylinders have corresponding holes. Presence and integrity of pins should be visually checked before installing cylinders as defects could make the feature useless.

*Figure: The pin*
The other safety features in the cylinders are the colour-coding schemes, which are used on all caps, hoses, connectors, knobs and pressure gauges concerned with the said gas.

Oxygen has a black body with white shoulders, medical grade air is coded grey with white and black shoulders, nitrous oxide is blue, entonox is blue and white in colour. Different countries (for e.g., the US) have different national colour-coding systems, which may lead to confusion for personnel working across different geographic areas.

**Pressure relief device**

Cylinders have exploded because of over-pressure in them either due to over-filling or mis-filling. To prevent this, all cylinders to have pressure relief devices, which vent the contents of the cylinder to the atmosphere.

They are of two types: Rupture disc, where, when a predetermined pressure is reached a disc guarding an orifice ruptures releasing the contents or the fusible plug, which is a thermally operated plug providing protection against high temperatures, but not pressure. A combination of these two is sometimes used as well. Further newer modifications are the pressure relief valves which re-close after the dangerous pressures have been vented, thus saving the contents and not entirely discharging the cylinder.

**Figure:** Safety valves

**Pressure regulators**
Anesthesia standards require that each gas be provided with a separate pressure regulator for providing a constant low pressure suitable for the machine from the variable high-pressure cylinders. Some machines use two regulators e.g., flow meters. This helps in providing a smooth constant flow of gas irrespective of fluctuations in pipeline pressures due to peak/trough demands in the system.

**INTERMEDIATE PRESSURE SYSTEM**

The intermediate pressure system consists of the pipeline inlet connections, master switch (present in newer machines), pipeline pressure indicators, second stage pressure regulators, auxiliary gas outlets for ventilators, oxygen failure devices, oxygen pressure failure devices, oxygen flush and the flow control valves.

Cross over of gas pipelines, filling of cylinders with wrong gases, wrong connectors, incorrect tanks from the central manifolds, accidents during installation or routine maintenance of pipelines, may all compromise patient safety.

Connectors that can be fitted to the wrong gas terminals have caused patient dangers and led to the development of safety features such as non-interchangeable screw thread (NIST), diameter index safety system (DISS), etc.

**Schrader probe**

The probe for each gas supply has a protruding indexing collar with a unique diameter, which fits the Schrader socket assembly for the same gas only.

**Figure:**
Different connectors and their safety mechanisms

**Pipeline attachments**

Each terminal unit that connects to the main pipeline system is equipped with
the DISS. Non-interchangeability of connections is achieved by differing diameters of the shoulders that surround the nipple. Quick connectors are other safety devices, which allow correct attachments by using varying combinations of shapes and spacing of the different portions of the components that couple with each other.

**Machine end of gas pipelines**

Each flexible hose ends in a unique fitting of nut and probe. This ensures a hose connection specific to each gas service. It comprises of a nut and probe. The probe has a unique profile for each gas. While the nut has the same diameter and thread for all gas services. A one-way valve ensures unidirectional flow.

**Figure: Non-interchangeable screw thread**

**Pipeline pressure indicators**

Indicators are required for each gas. They usually have a colour-coded dial and in some indicators satisfactory working pressures zones have a special colour for easier identification.

**Oxygen pressure failure system**

Several catastrophes have resulted when the oxygen supply had depleted allowing the administration of hypoxic gas mixtures. The delivered oxygen concentration at the common gas outlet (CGO) does not fall below 21%.

Anesthesia machine standards also specify that when oxygen pressure falls below a safe threshold an audible alarm be sounded within 5 seconds and that this cannot be muted.
Second stage pressure regulator
Some machines incorporate an additional regulator eg. the flow meters so that flow is constant at the meters even if there are fluctuations in the pipeline pressure. These reduce the pressure to approximately 14 psig for oxygen and 26 psig for N\textsubscript{2}O.

Oxygen flush
Named as flush or emergency oxygen, this switch directs a high pressure flow of oxygen direct to the CGO from the source bypassing all intermediate meters and vaporizers. Barotrauma and awareness may result from inappropriate activation of this switch. To prevent accidental activation these are usually placed in a recessed setting and will deactivate as soon as the finger activating the switch is removed.

LOW-PRESSURE SYSTEM
Flow in this part of the machine is slightly above the atmospheric pressure. This part contains the flow meters, hypoxia prevention devices, vaporizers, unidirectional valves and pressure relief devices.

Flow meter assembly
In the modern machines, oxygen flow meter is always positioned downstream, so that if there is a leakage anywhere still oxygen will be delivered in a sufficient concentration to the CGO. The flow control knob for oxygen is the largest, most protruding and has tactile differentiating features for additional and easy identification.
**Figure:** Potential unsafe and safe arrangements of flow meter tubes

2-Flow meters

Anesthesia workstation standards require that only one flow control be provided for each gas and it be placed near the corresponding flow meter. The various safety features built into the flow meters/control valves are:

1. Providing stops at the full ON or OFF position to avoid damage to the valve seat.
2. Control knob: Oxygen flow control knob is the largest and fluted for easy identification.
3. Tubes, which measure flow, have different lengths and diameters. Some machines have a pin-index system at each end.
4. Tubes are made leak-proof (O-rings) at both ends of the flow meter assembly.
5. The tubes have an antistatic coating on both surfaces, preventing the bobbin from sticking.
6. The bobbin is visible throughout the length of the tube.

3-Hypoxia prevention devices

**Mandatory minimum oxygen flow**

Most modern machines have a minimum pre-set oxygen flow, which will automatically start once the machine is powered on. This flow is variable between 50-250 ml/min depending upon the manufacturer and the machine.

**Minimum oxygen ratio**
Anesthesia workstation standards require that a device that protects against a user selection of a gas mixture with an $O_2$ concentration below 21%. Hypoxic injuries have happened in the past with older machines where it had been possible to set oxygen and nitrous oxide flows independently.

**Mechanical linkage**

Mechanically linking the oxygen and nitrous oxide flow control valves can ensure that at a certain set percentage of concentration (of oxygen) both flows either increase or decrease in proportion to the oxygen. Above the set percentage, the gases can be altered independent of each other.

*Figure: Mechanical linkage of oxygen and nitrous flow meters, to prevent hypoxic mixture delivery*

**Electronic linkage**

An electronic proportioning valve controls the oxygen concentration to a preset minimum.

**Alarms**

Some machines also activate an alarm when a user tries to set a flow with a lower than desired $O_2$ concentration.

**Pressure relief devices**

Modern machines have a pressure relief device between the vaporizer and the CGO which vents to the atmosphere in case dangerous pressures develop downstream due to occlusions, thus protecting the machine.

**Common Gas Outlet (CGO)**

This has a standard 15 mm female slip joint fitting with 22 mm coaxial connector.

4-Vaporizers
Several errors regarding the use of vaporizers have been known;
1. Wrong installation leading to loss of fresh gas flow
2. Wrong agent being filled,
3. Multiple vaporizers being used simultaneously,
4. Gas channels being filled with liquid agent due to inappropriate transport arrangements

All this kind of errors have led to addition of multitude of safety mechanisms for vaporizers.

**These include:**
1. Most vaporizers have a push (release) button to be activated before the dial can be turned on. This push button cannot be used until the vaporizer is seated firmly on the back bar, ensuring that the vapour is not delivered if installation is incorrect.
2. An interlock mechanism, which prevent from more than one vaporizer being put to use at the same time, thus causing an accidental overdose.
3. Newer modern vaporizers have a separate transport setting, which prevents spillage of the liquid agent into the bypass channel.

![Figure: Transport setting in a vaporizer.](image)

All newer vaporizers have keyed/funnel filling systems with unique sizing of the fillers/funnels that are agent specific (filling adaptors)

The colour coding of the anesthetic agent is usually applied to the concentration dial, filling port and in some vaporizers on the front of the body as well. The internationally accepted colours are halothane-red, isoflurane-purple, sevoflurane-yellow, enflurane-orange and desflurane-blue.

![Figure: Keyed and colour coded vaporizer filling systems](image)
Despite all the safety features described, some vaporizers leak gas into the outflow channel even when the vaporizer is in the fully OFF/Lock position. The small amounts do not produce a clinical effect, but may cause problems when patients with malignant hyperthermia are being anaesthetized. Hence, these vaporizers may need to be removed from the machine before use in these cases.

5. Scavenging systems

Due to various reasons such as cost, ignorance, lack of health safety checks etc., scavenging is an ignored item in respect to the anesthesia machine. Nevertheless, we must make an effort to change and be aware of the standards and safety.

All connections in the scavenging system are of 30 mm diameter, which is distinctly different from the airway accessories (15/22 mm) making misconnections improbable. Transfer tubing's in the system are different by colour and configuration to that of breathing gases, resistant to kinking and are occlusion proof.

Scavenging systems also incorporate negative and positive pressure relief valves to make sure no dangerous pressures are transmitted into the breathing system in the event of malfunction of the system. Negative pressure relief valve and a reservoir are needed in active scavenging systems, whereas a positive pressure valve is needed in a passive system.

Monitoring

General Anesthesia should never be administered without an oxygen analyzer in the breathing circuit. This is because, despite all the safety features of the machine, the final confirmation is the percentage of oxygen delivered to the patient as intended.

There are many types of oxygen analyzers, the commonest one used on most of the machines being the galvanic cell type. The other types are paramagnetic analyzers, and the polarographic (Clark's electrode) type. Oxygen analyzers have to be calibrated at regular intervals, most often as part of the machine start-up check procedure. ASTM standards do require that low oxygen alarm level cannot be set below 21%. Gas volume monitoring is performed with spirometers. This monitoring gives us a measure of the tidal volume and minute volume, as well as disconnection.

Airway pressure monitoring in most of the machines is now electronic. Some older machines still use a mechanical pressure gauge. It prevents either high (to prevent barotraumas) or low pressures (leaks or disconnection).
Disconnection monitors are an integral component of newer anesthesia machines. They can be based on the gas flows (volume measurements), pressure in the circuit, or gas detection like capnography.

**Criteria to determine obsolescence of Anesthesia machines**

Anesthesia machines may be considered obsolete (to be discarded) if they do not offer the following mandatory safety features:

**Lack of certain safety features**

1. Minimum oxygen ratio device in a machine, which can provide nitrous oxide as well.
2. Oxygen failure safety device.
3. Oxygen supply pressure failure alarm.
4. Vaporizer interlock device (may be waived off if machine is capable of accepting only one vaporizer).
5. Pin index safety system and Non-interchangeable gas connectors like DISS.

**Presence of unacceptable features**

1. Measured flow (flow meter-controlled) vaporizers. (e.g., Copper Kettle, Vernitrol).
2. More than one flow control knob for a single gas delivered to the CGO of the machine.
3. Vaporizer with rotary concentration dials such that the anesthetic vapour concentration increases when the dial is turned clockwise.
4. Connection (s) in scavenging system of the same (i.e., 15-mm or 22-mm) diameter as a breathing system connection.

**Lack of certain desirable features to be considered**

1. Means to isolate the adjustable pressure-limiting valve during mechanical ventilation.
2. Oxygen flow control knob that is fluted and larger than the other flow control knobs.
3. Oxygen flush control protected from accidental activation.
4. Main on/off switch for electrical power to integral monitors and alarms.
5. Anti-disconnection device at the fresh gas outlet.
6. Airway pressure alarm (for detecting sustained positive pressure, negative pressure and high peak pressure)
Chapter 2
Anesthesia Breathing Systems

1. FUNCTIONS
- Delivery of anesthetic gases and vapours;
- Oxygenation of the patient; and
- CO2 elimination.

2. CLASSIFICATION
- Open - Fresh Gas Flow (FGF) from atmosphere alone (no circuit).
- Semi-open - Fresh gas from atmosphere, gas from T-piece +/- added O2 etc.
- Closed - Closed to atmosphere; FGF = uptake, CO2 removed.
- Semi-Closed - Closed to atmosphere; FGF > uptake; excess scavenged; can be
  o Semi-Closed Non-Rebreathing (typical ICU ventilator) or
  o Semi-Closed Rebreathing (e.g. typical circle circuit); CO2 removal by absorber or FGF
- Alternative classification:
  - Without CO2 absorbers - Mapleson type, Resuscitation Bags.
  - With CO2 absorbers - Circles, Waters (to-and-fro).

3. MAPLESON CIRCUITS
Figure: MAPLESON CIRCUIT

Figure: Schimmelbusch Mask
Figure: Waters To and Fro system
1- MAPLESON A - (Magill) CIRCUIT

FGF enters at the end near the patient, and there is a one-way valve at the mask end. Originally, Magill designed the A circuit to get the bag away from the patient during faciomaxillary surgery.

Tube volume must exceed (Vt-Vd) or alveolar gas could contaminate the bag.

Inadequate FGF causes re-breathing.

In controlled ventilation: FGF must be increased to compensate for gas lost during inspiration - typically 2.5x minute ventilation.

2) The Lack System:

A co-axial Magill, with the expiratory valve brought coaxially back to the Fresh Gas outlet. Not popular due to inefficiency during controlled ventilation.

2. MAPLESON B & C SYSTEMS:

Both are inefficient. Not suited for spontaneous breathing (re-breathing is inevitable) unless FGF exceeds (3xMV).

The C circuit is compact and was used for short transports before self-inflating bags became available.

3. MAPLESON D, E and F SYSTEMS FGF enters at patient end.

- D system has a relief valve proximal to the bag. Bain circuit is a co-axial D introduced in 1972 (Bain and Spoerel).
- E and F are functionally identical.

Spontaneous breathing: inefficient. Inspiration needs FGF > 2.5xMV. CO2 during capnometry inspiration indicates a need for higher flows.
Controlled ventilation: more efficient. CO₂ washout depends on FGF, with normal CO₂’s at an FGF of 70ml/kg. Tubing + bag volume must exceed Vt to prevent air entrainment (unless functionally extended by a scavenging hose).

**Jackson-Rees modification of Ayre’s T-Piece (Mapleson F)**

Original T-piece by Phillip Ayre in 1937 for children; ventilation by occlusion of the open ended tube with fresh gas entering at a right angle to the tube. Modified by Jackson Rees in 1950’s by adding an open-ended 500 ml bag to allow respiratory monitoring and/or assistance, and a parallel entry of the fresh gas line at the patient connection.

Commonly used for pediatrics, especially in neonates:

- Light weight;
- Low resistance - no valves.
- Low dead space
- Good ‘feel’ of the lungs
- Can be used for both spontaneous and controlled ventilation

Dead space is determined by the distance between fresh gas inflow point and the face. Specialized neonatal T-pieces direct FGF directly at the lips.

Disadvantages

- High FGF (especially in adults)
- Much less efficient than a circle system
- Dry gases unless humidified
- Scavenging issues
- Can’t be used for controlled ventilation with some modern machines

**Figure: Bain Circuit**

Outer tube 22 mm diameter. 1.8m long. FGF travels to patient end via thinner ‘coaxial’ inside the expiratory tube.
Advantages:
- Light weight
- compact at ETT end
- no valves to fail

Disadvantages
- checking inner tube isn’t so easy
  - O2 flush should empty reservoir bag by venturi effect
  - Occlude distal end and observe drop in rotameter bobbin/s
- unrecognized detachment of inner tube at machine end causes CO2 rebreathing
- Very uneconomical compared to circle, especially in spontaneous breathing

Table: FGF needed for each circle

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<th>Mapleson</th>
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<th>Uses</th>
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<td>70-100 ml/kg/min</td>
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<td>D</td>
<td>Bain</td>
<td>Spontaneous IPPV, Gen. Anaes</td>
<td>150-200 ml/kg/min</td>
<td>70-100 ml/kg/min</td>
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<tr>
<td>E</td>
<td>Ayres</td>
<td>Very uncommon, not in use today</td>
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<tr>
<td>F</td>
<td>Jackson Rees</td>
<td>Paediatric &lt;25 Kg</td>
<td>2.5 - 3 x MV</td>
<td>Min 4 lpm</td>
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</table>
CO2 ABSORPTION (CIRCLE) CIRCUITS:

Semi-closed and closed operation possible.

1. Absorber and absorbent

Canister containing absorbent may be single or dual, of metal, glass or plastic. Air space typically 50% of total. Larger cross-sectional diameters allow less turbulence with reduced resistance and less dust.

Well packed canisters allow diffuse spread of gas through the absorbent, rather than in a columnar fashion.

Bypass mechanism can isolate absorber from circuit and allow PaCO2 to rise without decreasing minute ventilation.

Advantages of CO2 absorption

- Lower FGF, improved economy;
- Less pollution;
- Heat and moisture are conserved;
- Flammable gases and vapours (historically) contained.
- Inhaled mixture composition is more constant.

There are two types of CO2 Absorbant:

Soda lime and Baralim:

- 80% Ca (OH)₂ plus 4% NaHCO₃, 1% KOH, 14-19% H₂O.

  - Calcium hydroxide free soda lime (Baralime which contains Barium hydroxide instead of Calcium hydroxide) reduces compound A production markedly.
  - Desiccated soda lime can produce carbon monoxide.
  - Silicates prevent powdering.
  - Fresh soda lime has pH = 12; decreases as CO₂ absorbed.

- - white S/L contains ethyl violet, critical pH = 10.3
- - Pink S/L contains phenolphthalein, critical pH = 7.
Granule size 4-8 mesh; irregular surface shape to enhance absorptive area.
450g soda lime absorbs 47 liters of CO2
Heat in the canister is heat of neutralization; liberates water vapour; may indicate high patient VCO2 e.g. Malignant Hyperthermia (MH).

**Signs of exhaustion of CO₂**
- Inspired CO₂ rise on capnometry
- Colour change
- Warm at the top of canister, cool at the bottom
- Signs of hypercapnoea in the patient.

**2. Fresh gas inlet**: Usually between CO₂ absorber and inspiratory valve.

**3. Uni-directional valves**
- At least 2 in each circle system.
- Present on inspiratory and expiratory limbs, typically within the absorber.
- Problems:
  - additional resistance
  - incompetence (sticking at an angle - wetting, electrostatic attraction, poor design)
  - leaks around seals of the domes

**4. APL (adjustable pressure limit) valve**:
- Usually a spring loaded disk occluding flow:
  - During manual ventilation:
    - Adjust so that losses during inspiration = FGF
    - Should open at a specified pressure and be airtight below that
  - During spontaneous respiration:
    - Should be set fully open.
    - Should demonstrate low resistance when open.
    - Perceived resistance to exhalation usually increases markedly once bag is full and all gas must exit the APL.
  - Mechanical IPPV
    - must be closed completely or isolated, either manually or automatically.
- Aneroid gauges typically attached near inspiratory limb in mechanical machines
- Electronic transducers in more recent machines

6. **Reservoir bag:**
- permits manual ventilation, manual assessment of compliance etc
- volume buffer
- Indicator of adequacy of fresh gas over leak
- Sizes from 500 ml (for child) - 3 liters (for adults).
- Small bags on 15mm circle circuits provide excellent feel of the lung when hand-ventilating neonates
- Pressure rises to peak of about 50-70cmH20 but falls late with massive distension

7. **"Y" Piece:**
Standard 22 mm male connections for breathing hoses. Patient connection port is a 15 mm female fitting or a 15 mm female port coaxial within a 22 mm male fitting. Common source of leaks.

8. **O2 Analyzer**
"T" fitting located at the inspiratory limb of the circuit or via gas sample line

9. **Ports**
- "Common gas outlet" coaxial 15/22 mm.
- Inspiratory and Expiratory ports on circle 22 mm male ± 15 mm female; should not point straight down
- Reservoir bag 22 mm male; should point downwards
- ETT connector 15 mm male
- Scavenging system 19 mm conical.
- Ventilator connection
  o Either manually connected to the end of the breathing hose, or
  o Internally located and automatically activated when a ‘vent’ mode is selected
Principles of Anesthesia Institute

Objectives

By the end of this unit the student should be able to:

1. List the 3 phases of preoperative assessment.
2. Discuss the anesthesia assessment.
3. Discuss the examination of each system.
4. Describe the risks associated with surgery.
5. Identify the importance of informed consent.

Introduction

The recent attempts to improve efficiency by admitting patients on the day of their planned surgical procedure further reduces the opportunity for an adequate anesthetic assessment. This has led to significant changes in the way patients undergoing elective surgery. Surgery is managed preoperatively and, more recently, the introduction of clinics specifically for anesthetic assessment.

Stage 1- Screening

Screening is not necessary for all patients in a preoperative assessment clinic by an anesthetist but can be done by the surgical team.

On admission patients will need to be formally checked and examined by a member of the surgical team, especially the patient who scheduled for day case ambulatory surgery. These patients should be seen at the time of admission by the anesthetist, who will

- Confirm the findings of the screening;
• Check the results of any baseline investigations;
• Explain the anesthetic approach appropriate for the procedure.
• Have the ultimate responsibility for deciding it is safe to proceed.

**Stage 2—The preoperative assessment clinic**

The patients seen here are those who have been identified by the screening process as having coexisting medical problems that:-

• Patients with well-controlled concurrent medical conditions.
• Are well controlled with medical treatment;
• Are previously undiscovered, for example diabetes, hypertension.
• Are less than optimally managed, for example hypertension, angina;
• Have abnormal baseline investigations;
• Show a need for further investigations, for example pulmonary function tests, echocardiography.
• Indicate previous history of anesthetic difficulties, for example difficult intubation.
• Suggest potential anesthetic difficulties, for example difficult intubation.
• Patients undergoing complex surgery with or without planned admission to the intensive therapy unit (ITU) postoperatively.

**3-The anesthetic assessment**

Whoever is responsible for the anesthetic assessment must take a full history, examine and ensure that appropriate investigations are carried out for each patient.

**Cardiovascular system**

Patients with a proven history of myocardial infarction (MI) are at a greater risk of perioperative reinfarction, the incidence of which is related to the time interval between infarct and surgery. Untreated or poorly controlled hypertension may lead to exaggerated cardiovascular responses during anesthesia. Both hypertension and hypotension can be precipitated, which
increase the risk of myocardial and cerebral ischemia. The severity of hypertension will determine the action required:

**Mild** systolic blood pressure (SBP) 140-159 mmHg, diastolic blood pressure (DBP) 90-99 mmHg: No evidence that delaying surgery for treatment affects outcome.

- **Moderate** (SBP 160-179 mmHg, DBP 100-109 mmHg): Consider review of treatment. If unchanged, requires close monitoring to avoid swings during anesthesia and surgery.

- **Severe** (SBP 180 mmHg, DBP 109 mmHg): At this level, elective surgery should be postponed due to the significant risk of myocardial ischemia, arrhythmias and intracerebral hemorrhage. In an emergency surgery, will require acute control with invasive monitoring.

**Respiratory system**

Patients with pre-existing lung disease are more prone to postoperative chest infections, particularly if they are also obese, or undergoing upper abdominal or thoracic surgery. If an acute upper respiratory tract infection is present, anesthesia and surgery should be postponed unless it is for a life-threatening condition.

**Assessment of exercise tolerance**

An indication of cardiac and respiratory reserves can be obtained by asking the patient about their ability to perform everyday physical activities before having to stop because of symptoms of chest pain and shortness of breath.

**Previous anesthetics and operations**

Enquire about any complication, for example: nausea, vomiting, dreams, postoperative jaundice. Check the records of previous anesthetics to rule out or clarify problems such as difficulties with intubation, allergy to drugs or
adverse reaction such as malignant hyperpyrexia. Details of previous surgery may reveal potential anesthetic problems, for example cardiac, pulmonary or cervical spine surgery.

**Family history**

All patients should be asked whether there are any known inherited conditions in the family (e.g. Sickle-cell disease, porphyria). Have any family members experienced problems with anesthesia (e.g: history of prolonged apnea suggests pseudo-cholinesterase deficiency and an unexplained death, malignant hyperpyrexia. Elective surgery should be postponed if any conditions are identified, and the patient investigated to diagnose the problem.

**Drug history and allergies**

Identify all medications, both prescribed and self-administered, including herbal preparations. Patients will often forget about the oral contraceptive pill (OCP) and hormone replacement therapy (HRT). The incidence of use of medications rises with age and many of these drugs have important interactions with anesthetics.

**Social history**

Smoking: Ascertain the number of cigarettes or tobacco smoked per day.

Alcohol: This is measured as units consumed per week.

Drugs: Specifically, about the use of drug for recreational purposes.

Pregnancy: The date of the last menstrual period should be noted in all women of childbearing age and history of previous complicated pregnancy.

**Examination**

**Cardiovascular system**

Look specifically for signs of:
• Arrhythmias (irregular pulse).
• Heart failure (Congested neck veins, lower limb oedema orthopnea).
• Hypertension.
• Valvular heart disease (murmur by auscultation).
• Peripheral vascular disease (cold extremities).

**Respiratory system**

Look specifically for signs of:

• Respiratory failure:
  o impaired ventilation;
  o collapse, consolidation, pleural effusion.
  o additional or absent breath sounds.

**Nervous system**

Chronic disease of the peripheral and central nervous systems should be identified and any evidence of motor or sensory impairment recorded.

**Musculoskeletal system**

Patients with connective tissue disorders should have any restriction of movement and deformities noted. Patients suffering from chronic rheumatoid disease frequently have a reduced muscle mass.

**Assessment of the airway**

All patients must have an assessment made of their airway, the aim being to try and predict those patients who may be difficult to intubate and what is the degree of difficulties.

Observation of the patient’s anatomy:

Look for:

• limitation of mouth opening;
• a receding mandible;
• position, number and health of teeth;
• size of the tongue;
• soft tissue swelling at the front of the neck;
• deviation of the larynx or trachea;
• limitations in flexion and extension of the cervical spine.
Finding any of these suggests that intubation may be more difficult.

**Risk associated with anesthesia and surgery**

Anesthesia risks can be divided into two main groups:

**Minor**

These are not life threatening and can occur even when anesthesia has apparently been uneventful they include:

1. Failed IV access;
2. Cut lip, damage to teeth, caps, crowns;
3. Sore throat
4. Headache
5. Postoperative nausea and vomiting
6. Retention of urine

**Major**

These may be life-threatening events:

They include:

• Aspiration of gastric contents.
• Hypoxic brain injury; myocardial infarction.
• Cerebrovascular accident.
• Nerve injury.
• Chest infection.

Anesthesia itself is safe, particularly in those patients who are otherwise well prepared. The most likely risk is unavoidable (adverse drug reaction or drug interaction or embolization). When the risks of the surgical procedure
(emergency, bloody or long procedure) and those due to pre-existing disease are combined, the risks of morbidity and mortality are increased.

**Risk indicators:**

The most widely used scale for estimating risk is the American Society of Anesthesiologists (ASA) classification of the patient’s physical status.

The patient (according to ASA classification) is assigned to one of five categories depending on any physical disturbance caused by either pre-existing disease or the process for which surgery is being performed.

**Multifactorial risk indicators**

The leading cause of death after surgery is myocardial infarction. Attempts have been made to identify factors that will predict those at risk.

One system is the Goldman Cardiac Risk Index, that used in patients with pre-existing cardiac disease undergoing non-cardiac surgery. The points total is used to assign the patient to one of four classes. The risks of a perioperative cardiac event including myocardial infarction, pulmonary edema, significant arrhythmia and death are:

- **Class I** (0-5 points) 1%
- **Class II** (6-12 points) 5%
- **Class III** (13-25 points) 16%
- **Class IV** (=26 points) 56%

<table>
<thead>
<tr>
<th>Patient risk index score</th>
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</thead>
<tbody>
<tr>
<td>Grade of surgery</td>
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<tr>
<td>Class I</td>
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</tbody>
</table>
Table 1: Overall Approximate risk (%) of major cardiac complication based on type of surgery and patient’s cardiac risk index

<table>
<thead>
<tr>
<th>Classification of operation</th>
<th>Minor surgery</th>
<th>0.3%</th>
<th>1%</th>
<th>3%</th>
<th>19%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elective: Operation at a time to suit both patient surgeon and anesthetist; for example, hip replacement, varicose veins.....</td>
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<td>Scheduled: An early operation but not immediately lifesaving; operation usually within 3 weeks; for example, surgery for malignancy.</td>
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<td>Urgent: Operation as soon as possible after resuscitation and within 24 h; for example, intestinal obstruction, major fractures.</td>
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<tr>
<td>Emergency: Immediate life-saving operation, resuscitation was done simultaneous with surgical treatment; operation usually within 1h; for example, major trauma with uncontrolled hemorrhage, extradural hematoma.</td>
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Informing the patient and consent.
Consent is an agreement by the patient to undergo a specific procedure, only the patient can make the decision to undergo the procedure.

What information the patient needs to know?

In obtaining consent, it is essential that the patient is given an adequate amount of information in a form that they can understand. This will vary depending on the procedure, but may include:

- The environment of the anesthetic room.
- Establishing intravenous access and IV infusion.
- The need for, and type of any invasive monitoring.
- What to expect during the establishment of a regional technique.
- Being conscious throughout surgery if a regional technique alone is used.
- Induction of anesthesia (although most commonly intravenous, occasionally it may be by inhalation).
- Numbness and loss of movement after regional anesthesia.
- The possibility of drains, catheters and drips.
- The possibility of a need for blood transfusion.
- Postoperative pain control, particularly if it requires their cooperation.

Investigation:

All routine and special investigation should be done

Routine investigation: Complete blood picture (CBC), Coagulation profile, liver function, kidney function, fasting and postprandial blood sugar and viral markers.

Special investigation: According to general condition of the patients and type of operation, e. ECHO cardiography chest x ray, respiratory function test.....
Chapter 4
Anesthesia

Objectives:

By the end of this chapter the student should be able to

1. Identify the term of premedication.
2. List most common type of premedication.
3. Discuss the proper technique of using facemask.
4. Discuss the proper technique of using simple adjuncts.
5. Discuss the indication and proper technique of endotracheal intubation.

Introduction

Anesthesia is a medical treatment that prevents patients from feeling pain during surgery. It defined as reversible stat of loss of conscious, analgesia and muscle relaxation. To produce anesthesia, doctors use drugs called anesthetics. These drugs include general, regional, and local anesthetics. General anesthetics put patients to sleep during the procedure. Local and regional anesthetics just numb a part of the body and allow patients to remain awake during the procedure. Anesthetist deliver anesthetics by injection, inhalation, infiltration, topical lotion, spray, eye drops, or skin patch according to the type of surgery, age of the patient, coexisting diseases and type of pain relief needed.

General anesthesia affects the whole body, making patients unconscious and unable to move. Anesthetist use it when they operate on internal organs and for other invasive or time-consuming procedures such as back surgery. Without general anesthesia, many major, life-saving procedures would not be possible, including open-heart surgery, brain surgery, and organ transplants.

Still, as with any medical procedure, some risks exist. To minimize these
risks, specialized anesthetist carefully monitor unconscious patients and can adjust the amount of anesthetic they receive. Serious side effects—such as dangerously low blood pressure—are much less common than they once were.

**Premedication:** Premedication originally referred to drugs administered to facilitate the induction and maintenance of anesthesia. The premedication administered to produce Anxiolysis, amnesia, anti-emetic, antacid and analgesia.

### Anxiolysis
- They produce a degree of sedation and amnesia. The anxiolytic drugs are well absorbed from the gastrointestinal tract and are usually given orally, 45-90 mins preoperatively.

### Amnesia
- Some patients specifically request that they not have any recall of the events leading up to anesthesia and surgery. This may be accomplished by Amnesia

### Anti-emetic (Drugs that reduce the nausea and vomiting)
- Nausea and vomiting may follow the administration of opioids, either pre- or intraoperatively. Certain types of surgery are associated with a higher incidence of postoperative nausea and vomiting (PONV)

### Antacid: (Drugs that modify pH and volume of gastric contents)
- Patients are starved preoperatively to reduce the risk of regurgitation and aspiration of gastric acid at the induction of anesthesia. The antacids were administered to help this purpose.

### Analgesia: (Drugs that relieve pain)
- Although the oldest form of premedication, analgesic drugs are now generally reserved for patients who are in pain preoperatively. The most commonly analgesics are morphine, pethidine and fentanyl. Opiates have a range of unwanted side-effects, including nausea, vomiting, respiratory depression and delayed gastric emptying.
Miscellaneous: A variety of other drugs are commonly given prophylactically before Anesthesia and surgery; for example:

- Steroids: to patients on long-term treatment with steroids or who have received them within the past 3 months.
- Antibiotics: to patients with prosthetic or diseased heart valves or undergoing valves, or undergoing joint replacement.
- Anticoagulants: as prophylaxis against deep venous thrombosis.
- Transdermal glyceryl trinitrate (GTN): as patches inpatients with ischemic heart disease to reduce the risk of coronary ischemia.
- Eutectic mixture of local anesthetics (EMLA): a topically applied local anesthetic cream to reduce the pain of inserting an IV cannula.

Preoperative fasting.

Traditionally, patients were fasted of both food and fluids for a certain period preoperatively.

Guidelines for normal healthy patients undergoing elective surgery:

- No solid food for 6 h preoperatively.
- Clear fluids can be taken up to 2h preoperatively; these include water, black tea or coffee, pulpless fruit juice.
- Milk is not allowed as it flocculates in gastric acid and the fat delays gastric emptying.
- Chewing gum does not increase gastric volume and is best treated as for clear fluids.
- Normal medications can be taken with a small volume of water.
- Breast feeding child fasted for 4 hours preoperative.

Basic techniques:
Anesthesia frequently results in airway obstruction, and this is most easily restored by a combination of the head tilt and a jaw thrust. When holding a facemask in position with the index finger and thumb, the jaw thrust is achieved by lifting the angle of the mandible with the remaining fingers of one or both hands. The overall effect desired is that the patient’s mandible is ‘lifted’ into the mask rather than that the mask is being pushed into the face.

Figure: Facemask

Facemasks

- A commonly used type in adults is the BOC anatomical facemask designed to fit the contours of the face with the minimum of pressure.
- Leakage of anesthetic gases is minimized by an air-filled cuff around the edge.
- Masks are made in a variety of sizes, and the smallest one that provides a good seal should be used.
- The transparent body facemask preferred because it allow identification of vomit, making them popular for resuscitation.
• All masks must be disinfected between each patient use. Alternatively, single use masks are available.

**Simple adjuncts**

The oropharyngeal (Guedel) airway, and to a lesser extent the nasopharyngeal airway, are used in conjunction with the techniques described above to help maintain the airway after the induction of anesthesia.

**Oropharyngeal airway.**

- Curved plastic tubes flattened in cross-section and flanged at the oral end. They lie over the tongue, preventing it from falling back into the pharynx.
- Available in a variety of sizes suitable for all patients, from neonates to large adults. The commonest sizes are 2–4, for small to large adults.
- An estimate of the size required is given by comparing the airway length with the vertical distance between the patient’s incisor teeth and the angle of the jaw.
- Initially inserted ‘upside down’ as far as the back of the hard palate rotated 180° and fully inserted until the flange lies in front of the teeth, or gums.

**Nasopharyngeal airway.**

- Round, malleable plastic tubes beveled at the pharyngeal end and flanged at the nasal end.
- Sized on their internal diameter in millimeters, length increasing with diameter. The common sizes in adults are 6–8 mm, for small to large adults.
- A guide to the correct size is made by comparing the diameter to the external nares.
• Prior to insertion, the patency of the nostril should be checked, and the airway lubricated.

• The airway is inserted along the floor of the nose, with the bevel facing medially to avoid catching the lubricates.

• A safety pin may be inserted through the flange to prevent inhalation of the airway.

Figure 4: Nasopharyngeal airway

Figure 5: Oropharyngeal airway

Figure): Mechanism of action of oral and nasopharyngeal airway
The laryngeal mask airway (LMA).

Originally designed for use in spontaneously breathing patients, it consists of a ‘mask’ that sits over the laryngeal opening, attached to which is a tube that protrudes from the mouth and connects directly to the anesthetic breathing system. On the perimeter of the mask is an inflatable cuff that creates a seal and helps to stabilize it. The LMA is produced in a variety of sizes suitable for all patients, from neonates to adults, with sizes 3, 4 and 5 being the most commonly used in female and male adults. The LMA is reusable, provided that it is sterilized between each patient.

The intubating LMA.

The use of the laryngeal mask overcomes some of the problems of the previous techniques:

- It is not affected by the shape of the patient’s face or the absence of teeth.
- The anesthetist is not required to hold it in position, avoiding fatigue and allowing any other problems to be dealt with.
- It significantly reduces the risk of aspiration of regurgitated gastric contents but does not eliminate it completely especially if it contains a port for gastric tube insertion.
- The LMA has proved to be a valuable aid in those patients who are difficult to intubate.

Technique for insertion of the Standard LMA.
• The cuff is deflated and the mask lightly lubricated at the back of the laryngeal part.

• The patient should be sleep by intravenous or inhalational anesthesia.

• A head tilt is performed, the patient’s mouth opened fully, and the tip of the mask inserted along the hard palate with the open side facing but not touching the tongue. The mask is further inserted, using the index finger to provide support for the tube.

• The cuff is now inflated according to the volume labeled on the pilot balloon using an air-fill syringe attached to the valve at the end of the pilot tube.

• The laryngeal mask is secured either by a length of bandage or adhesive strapping attached to the protruding tube.

• A ‘bite block’ may be inserted to reduce the risk of damage to the LMA at recovery.

**Figure: the insertion of LMA**

**Tracheal intubation:**

This is the proper method of providing and securing a clear airway in patients during anesthesia and resuscitation. During anesthesia, this is usually achieved by the administration of intravenous hypnotics and muscle relaxant.

**Indications for tracheal intubation.**
• Where muscle relaxants are used to facilitate surgery.
• In patients with a full stomach, to protect against aspiration.
• Where the position of the patient would make airway maintenance difficult.
• In those patients in whom the airway cannot be satisfactorily maintained by any other technique.
• During cardiopulmonary resuscitation.
• To secure the airway in comatose patients on mechanical ventilation in ICU.

**Equipment for tracheal intubation.**

The equipment used will be determined by the circumstances and by the preferences of the anesthetist.

• Laryngoscope: with a curved (Macintosh) blade and functioning light.
• Tracheal tubes (cuffed): in a variety of sizes. The internal diameter is expressed in millimeters and the length in centimeters. They may be lightly lubricated if used for nasal intubation.
• For adult males: 7.5-8.5mm internal diameter, 22-24cm length.
• For adult females: 7.0-8.0mm internal diameter, 20-22cm length.
• Syringe: to inflate the cuff once the tube is in place.
• Suction: switched on and immediately to hand in case the patient vomits or regurgitates.
• Stethoscope: to check correct placement of the tube by listening for breath sounds during ventilation.
• Extras: a semi-rigid introducer (Stylet) to help mould the tube to a particular shape.
• Magill’s forceps, designed to reach into the pharynx to help in nasal intubation and remove debrisor direct the tip of a tube; bandage or tape to secure the tube.
Tracheal tubes.

- Mostly manufactured from plastic (PVC), and for single use to eliminate cross-infection. They are available in 0.5mm diameter intervals (The smallest size is 2.5mm while the largest size 9.0mm), and long enough to be used orally or nasally. A standard 15mm connector is provided to allow connection to the breathing system.

The technique of oral intubation.

Preoxygenation.

- All patients who are to be intubated are asked to breathe 100% oxygen via a close-fitting face mask for 2-3 mins (‘preoxygenation’). The patient’s head is placed on a small pillow with the neck flexed and the head extended.

Laryngoscopy:

- The laryngoscope is held in the left hand and the blade introduced into the mouth along the righthand side of the tongue, displacing it to the left.
- The blade is advanced until the tip lies in the gap between the base of the tongue and the epiglottis, the vallecula.

Intubation

- The tracheal tube is introduced into the right side of the mouth, advanced and seen to pass through the cords until the cuff lies just below the cords. The tube
is then held firmly, and the laryngoscope is carefully removed, and the cuff is inflated sufficiently to prevent any leak during ventilation. Finally, the position of the tube is confirmed and secured in place.

**Figure 6: Endo tracheal intubation**

**The intubating LMA (ILM).**

This device is used as a conduit to perform tracheal intubation without the need for laryngoscopy. This is a modification of the LMA in which the mask part is almost unchanged, but a shorter, wider metal tube with a 90° bend in it replaces the flexible tube. A handle is attached to the tube. It is inserted by holding the handle rather than using one’s index finger as a guide and sits opposite the laryngeal opening. A specially designed reinforced, cuffed, tracheal tube can then be inserted, and, due to the shape and position of the ILM, will almost always pass into the trachea. Once it has been confirmed that the tube lies in the trachea, the ILM can either be left in place or removed.

**Confirming the position of the tracheal tube.**

This can be achieved using several techniques:

- Measuring the carbon dioxide in expired gas (capnography): less than 0.2% indicates oesophageal intubation.
- Auscultation of equal breath sound on both sides of the chest.
- Oesophageal detector: a 50 mL syringe is attached to the tracheal tube and the plunger rapidly withdrawn. If the tracheal tube is in the oesophagus, resistance is felt, and air cannot be aspirated; if it is in the trachea, air is easily aspirated.
- Direct visualization: of the tracheal tube passing between the vocal cords.
• Fogging: on clear plastic tube connectors during expiration.

**Complications of tracheal intubation.**

• Hypoxia due to improper position.
• Trauma to the teeth or larynx.
• Reflex activity to the upper airway.
• Hypertension and arrhythmias occur in response to laryngoscopy and intubation.
• Vomiting.
• Laryngeal spasm: Reflex adduction of the vocal cords due to stimulation of the epiglottis or larynx.

**Cricoid pressure (Sellick's manoeuvre).**
Regurgitation and aspiration of gastric contents are life-threatening complications of anesthesia and every effort must be made to minimize the risk. Preoperatively, patients are starved to reduce gastric volume and drugs may be given to increase pH. At induction of anesthesia, cricoid pressure provides a physical barrier to regurgitation. As the cricoid cartilage is the only complete ring of cartilage in the larynx, pressure on it, anteroposteriorly, forces the whole ring posteriorly, compressing the oesophagus against the body of the sixth cervical vertebra, thereby preventing regurgitation. An assistant, using the thumb and index finger, applies pressure whilst the other hand is behind the patient’s neck to stabilize it. Pressure is applied as the patient loses consciousness and maintained until the tube has been inserted, the cuff inflated, and correct position confirmed. It should be maintained even if the patient starts to actively vomit, as the risk of aspiration is greater than the theoretical risk of oesophageal rupture. If vomiting does occur, the patient should be turned on to his or her side to minimize aspiration.

**Difficult Airway**

**Can’t intubate, can’t ventilate.**

In most patients who are difficult to intubate, a patent airway and ventilation can be maintained using one or more of the techniques. Rarely, a patient may be both difficult to intubate and ventilate. This is a life-threatening emergency and may require the anesthetist to resort to one of the emergency techniques.
Emergency airway techniques.

- **Needle cricothyroidotomy**: The cricothyroid membrane is identified and punctured using a large bore cannula attached to a syringe. Aspiration of air confirms that the tip of the cannula lies within the trachea. The cannula is angled to about 45° caudally and advanced off the needle into the trachea. A high-flow oxygen supply is attached to the cannula and insufflate for 1 s, followed by a 4 s rest. Expiration occurs via the upper airway as normal. This technique oxygenates the patient but only results in minimal carbon-dioxide elimination and is therefore limited to about 30mins use while a definitive airway is created.

- **Surgical cricothyroidotomy**: This involves making an incision through the cricothyroid membrane to allow the introduction of a 5.0-6.0mm diameter tracheostomy tube or tracheal tube. It is more difficult to perform, and results in significantly more bleeding than the above. However, once a tube has been inserted the patient can be ventilated, ensuring oxygenation, elimination of carbon dioxide and suction of the airway to remove any blood or debris.
General Anesthesia Concept: Induction, Mechanism and Agents

Consciousness and Unconsciousness

General anesthesia is an essential component of modern medicine. It’s a drug-induced, reversible unconsciousness, amnesia, analgesia, and akinesia with concomitant stability of the autonomic, cardiovascular, respiratory, and thermoregulatory systems. Defining unconsciousness and exploring its relationship to general anesthesia, sleep, and coma, gives us a better explanation of how these agents work and could also lead to the development of better drugs with fewer side effects. William James defined consciousness as the "awareness of oneself and the environment".

Sleep Cycles

Normal human sleep cycles between two states: rapid-eye-movement (REM) sleep and non-REM sleep, at approximately 90-minute intervals.

In contrast, coma is a state of profound unresponsiveness, usually the result of a severe brain injury. Comatose patients cannot respond appropriately to vigorous stimulation. General anesthesia is, in fact, a reversible drug-induced coma. It was previously believed that general anesthetics are drugs without receptors, but significant progress in the understanding of their mechanisms of action at the molecular, cellular, and neural levels have been made.

Induction to Emergence

After insertion of a large bore intravenous canula, according to the administered dose, general anesthetic agents first produce amnesia, then sedation then unconsciousness, and finally, immobility and areflexia. The clinical signs induced unconsciousness appear over three periods: induction, maintenance, and emergence.

Induction

The induction period begins with the administration of a hypnotic drug, a barbiturate or propofol that act on GABA receptors and induce sedation. The dose is then slowly increased to produce a state of paradoxical excitation
(purposeless or defensive movements, incoherent speech, euphoria or dysphoria). With increasing dose (over a period of 10 to 15 seconds) progresses to apnea. This is where bag-mask ventilation is initiated to support breathing. Simultaneously, loss of response to oral commands and skeletal muscle tone occurs. As unconsciousness takes place, eye tracking stops, blinking increases, corneal reflexes are lost, but the pupillary light reflex remains. There can be either an increase or a decrease in blood pressure, but the heart rate typically increases. An opioid or a benzodiazepine before or during induction can be administered as well to decrease the effects on the heart rate, and a vasopressor can be given to maintain blood pressure. At the end of induction, a muscle relaxant is administered, followed by endotracheal intubation.

**Maintenance**
A combination of hypnotics and inhalational agents, opioids, muscle relaxants, sedatives, and cardiovascular drugs, along with ventilatory and thermoregulatory support are used in the maintenance period until the end of operation. During this period, it is critical to monitor the adequacy of anesthesia and the patient’s vital signs. If the level of anesthesia is inadequate, the heart rate and blood pressure can increase dramatically, along with perspiration, tearing, changes in pupil size, return of muscle tone and movement.

**Emergence (Recovery from anesthetics)**
During phase 1 of the emergence period, decreasing and stopping the anesthetic agents, regular breathing with good tidal volume returns and reversing neuromuscular blockers using reversal agents (neostigmine and atropine) and brain stimulants take place. Additionally, alpha and beta activity on EEG are increased.

In phase 2, heart rate and blood pressure increase, autonomic responsiveness returns which includes responsiveness to painful stimulation, salivation, tearing, grimacing, swallowing, gagging, and coughing also return. Furthermore, return of muscle tone, defensive posturing, a further increase in alpha and beta activity on EEG, a tracheal extubation may occur in this stage.

During phase 3, the patient will open his eyes and respond to some oral commands, and extubation definitely happens here. The early clinical signs of emergence from general anesthesia such as the return of regular breathing, salivation, tearing, and swallowing, indicate
return in brain stem function, while the late signs such as response to oral commands, indicate the return of cortical function. The patient should be able to answer simple questions and convey any discomfort, before he can discharge from the post-anesthesia care unit (PACU).

**General Anesthetics**
The balanced anestheia is commonly used today. In the past, the patient was given a high dose of an inhaled anesthetic to achieve all the desired effects (unconsciousness, analgesia and muscle relaxation). Today, many drugs are given in low doses to achieve equilibrium and to avoid side effects: sedatives-hypnotics, neuromuscular blockers, anticholinergics, IV and inhaled anesthetics, opiates can all be given.

The general anesthetics can be classified into three groups based on the different clinical endpoints: **Group 1** consists of the IV drugs etomidate, propofol, and barbiturates, which are more potent, rapid onset and are commonly used in the induction phase.

**Group 2** includes the gaseous anesthetics nitrous oxide (N2O), and cyclopropane, along with ketamine (intravenous) agent. In contrast to group 1 and group 3 drugs, these drugs produce significant analgesia while their potency as hypnotics and muscle relaxation is relatively weak. These drugs are usually used in the maintenance phase of anesthesia. Cardiovascular stability and a high frequency of reported dreamlike experiences are also features associated with Group 2 drugs. Unlike the drugs in group 1, the Group 2 drugs N2O, cyclopropane, and ketamine have little to no effect on GABAA receptors. These drugs inhibit N-methyl-D-aspartate (NMDA) receptors which are excitatory cation channels activated by the amino acid glutamate. Glutamate receptors are the major excitatory neurotransmitter-gated ion channels in the brain. Additionally, group 2 general anesthetics also accomplish analgesia through their primary inhibitory action of NMDA receptors which plays a role in nociception, which results in analgesia.

**Group 3** drugs consist of volatile liquids anesthetics: halothane, enflurane, isoflurane, sevoflurane, and desflurane.
These drugs induce amnesia, hypnosis and immobility. They produce amnesia at doses lower than those that produce unconsciousness. These drugs positively modulate GABAA receptors and its subunits, K+ channels and Acetylcholine receptors. It also inhibits NMDA receptors. In addition, it can affect the neuronal nicotinic Ach receptors, serotonin type 3 receptors, Na+ channels, mitochondrial ATP-sensitive K+ channels, and cyclic nucleotide-gated HCN channels that mediate neuronal pacemaker currents.

General anesthetics are in fact quite selective for important CNS targets and structures that are critical for modulating the processes associated with consciousness.

Understanding the mechanisms of action of these three groups have led to a better clinical application of general anesthetics; this explains why today, a combination of drugs is used in order to achieve different results, as opposed to just one drug.

Pharmacologic properties and action of anesthetic drugs

(A) Intravenous Anesthetics

1- Barbiturates (Thiopental sodium)

Mechanisms of Action Barbiturates depress the reticular activating system in the brainstem, which controls multiple vital functions, including consciousness.

Primary mechanism of action is believed to be through binding to the γ- aminobutyric acid type A (GABA A) receptor. Increasing the duration of openings of a chloride specific ion channel.

Effects on Organ Systems

A. Cardiovascular

1. Intravenous bolus induction doses of barbiturates cause a decrease in blood pressure and an increase in heart rate due to a central vagolytic effect. Hemodynamic responses to barbiturates are reduced by slower rates of induction.

2. Cardiac output is often maintained

B. Respiratory

Deep barbiturate sedation often leads to upper airway obstruction; apnea often follows an induction dose. It can precipitate bronchospasm in asthmatic patients.
C. Cerebral Constrict the cerebral vasculature, causing a decrease in cerebral blood flow, cerebral blood volume, and intracranial pressure, cerebral perfusion pressure (CPP) usually increases.

D. Renal reduce renal blood flow and glomerular filtration rate in proportion to the fall in blood pressure.

E. Hepatic Hepatic blood flow is decreased.

F. Immunological Anaphylactic reactions are rare. +histamine release

Drug Interactions Ethanol, opioids, antihistamines, and other central nervous system depressants potentiate the sedative effects of barbiturates.

The common clinical impression that chronic alcohol abuse is associated with increased thiopental requirements during induction lacks scientific proof.

2-BENZODIAZEPINES: (Midazolam=Dormicum, diazepam=Valium)
Mechanism: binding to the GABA A receptor increases the frequency of openings of the associated chloride ion channel.

Antidote = Flumazenil (Anxit) is a specific benzodiazepine-receptor antagonist that effectively reverses most of the central nervous system effects of benzodiazepines.

Midazolam Dose intranasal (0.2–0.3 mg/kg), buccal (0.07 mg/kg), and sublingual (0.1 mg/kg) provide effective preoperative sedation.

Effects on Organ Systems

A. Cardiovascular Intravenous midazolam tends to reduce blood pressure and peripheral vascular resistance more than diazepam. Changes in heart rate variability during midazolam sedation suggest decreased vagal tone (ie, drug-induced vagolysis).

B. Respiratory Benzodiazepines depress the ventilatory response to CO₂ especially if used with other respiratory depressants.

C. Cerebral
-Reduce cerebral oxygen consumption, cerebral blood flow, and intracranial pressure.

-Prevent and controlling grand mal seizures.

-Antegrade amnesia

-No direct analgesic properties.

3-KETAMINE:
Mechanisms of Action

1. Inhibiting polysynaptic reflexes in the spinal cord as well as excitatory neurotransmitter effects in selected areas of the brain.

2. Ketamine functionally “dissociates” the thalamus from the limbic cortex. Clinically, this state of dissociative anesthesia may cause the patient to appear conscious (e.g., eye opening, swallowing, muscle contracture) but unable to process or respond to sensory input.

3. Ketamine has been demonstrated to be an (NMDA) antagonist.

Effects on Organ Systems

A. Cardiovascular

Ketamine increases arterial blood pressure, heart rate, and cardiac output after rapid bolus injections. It increases pulmonary artery pressure and myocardial work. Administered cautiously in patients with coronary artery disease, uncontrolled hypertension, congestive heart failure, or arterial aneurysms.

On the other hand, ketamine’s indirect stimulatory effects may be beneficial to patients with acute shock.

B. Respiratory

- Upper airway reflexes remain largely intact, but partial airway obstruction may occur
- Increased salivation associated with ketamine can be attenuated by premedication with an anticholinergic agent such as atropine sulphate.

C. Cerebral

- Increases cerebral oxygen consumption, cerebral blood flow, and intracranial pressure so it is not preferred in head injury.
- Undesirable psychotomimetic side effects (e.g., disturbing dreams and delirium) during emergence and recovery are less common in children and in patients premedicated with benzodiazepines.

4. PROPOFOL:

Mechanisms of Action General anesthesia may involve facilitation of inhibitory neurotransmission mediated by GABA A receptor binding. Propofol actions are not reversed by the specific benzodiazepine antagonist flumazenil.

A. Cardiovascular
Decrease in arterial blood pressure due to a drop in systemic vascular resistance, preload, and cardiac contractility. Hypotension following induction is usually reversed by the stimulation accompanying laryngoscopy and intubation.

Factors associated with propofol-induced hypotension include large doses, rapid injection, and old age.

B. Respiratory profound respiratory depressant that usually causes apnea following an induction dose. Propofol-induced depression of upper airway reflexes exceeds that of thiopental, allowing intubation, endoscopy, or laryngeal mask placement in the absence of neuromuscular blockade.

C. Cerebral
- Decreases cerebral blood flow and intracranial pressure. -Propofol and thiopental probably provide a similar degree of cerebral protection during experimental focal ischemia.

Propofol has anticonvulsant properties and has been used successfully to terminate status epilepticus.

Drug Interactions: Fentanyl and alfentanil concentrations may be increased with concomitant administration of propofol.

(B)-Inhalational anesthesia

Nitrous oxide is believed to inhibit NMDA receptors. NMDA receptors are excitatory receptors in the brain.

Other inhalational agents may interact at other receptors (eg, GABA receptors).

Unconsciousness and amnesia are probably mediated by cortical anesthetic action.

Minimum alveolar concentration (MAC)

Defined as (concentration of a volatile Anesthesia agent that produces immobility in 50% of experimental animals subjected to a standardized noxious stimulus).
Potency of inhalational Anesthesia agents is usually directly proportional to their lipid solubility, although MAC is indirectly related to lipid solubility (the more potent a drug, the lower its MAC).

**Effects of inhalational drugs on Organ Systems**

1. **Nitrous oxide**:
   
   **A. Cardiovascular**: Nitrous oxide has a tendency to stimulate the sympathetic nervous system. Constriction of pulmonary vascular smooth muscle increases pulmonary vascular resistance. Despite vasoconstriction of cutaneous vessels, peripheral vascular resistance is not significantly altered.

   **B. Respiratory**: Nitrous oxide increases respiratory rate (tachypnea) and decreases tidal volume.

   Hypoxic drive, the ventilatory response to arterial hypoxia that is mediated by peripheral chemoreceptors in the carotid bodies, is markedly depressed by even small amounts of nitrous oxide. This is a concern in the recovery room.

   **C. Cerebral**: By increasing CBF and cerebral blood volume, nitrous oxide produces a mild elevation of intracranial pressure. Nitrous oxide also increases cerebral oxygen consumption (CMRO 2). These two effects make nitrous oxide theoretically less attractive than other agents for neuroanesthesia. Concentrations of nitrous oxide below MAC may provide analgesia in dental surgery, labor, traumatic injury, and minor surgical procedures.

   **D. Neuromuscular**: In contrast to other inhalation agents, nitrous oxide does not provide significant muscle relaxation. Nitrous oxide is not a triggering agent of malignant hyperthermia.

   **E. Renal**: Nitrous oxide seems to decrease renal blood flow by increasing renal vascular resistance.

   **F. Hepatic**

   Hepatic blood flow probably falls during nitrous oxide anesthesia, but to a lesser extent than with the volatile agents.

   **G. Gastrointestinal**: Nitrous oxide in adults increases the risk of postoperative nausea and vomiting.
**Contraindications**  
N2o tends to diffuse into air-containing cavities. Hazardous include venous or arterial air embolism, pneumothorax, acute intestinal obstruction with bowel distention, intracranial air (pneumocephalus following dural closure or pneumoencephalography), pulmonary air cysts, intraocular air bubbles, and tympanic membrane grafting.

- **DIFFUSION HYPOXIA**
  - High concentrations of relatively insoluble gasses (N2O) diffuse out of the blood and enter the alveolus, displacing and reducing alveolar concentration of O2 and CO2
  - Dilution of alveolar O2 can lead to hypoxia, dilution of CO2 can ↓ ventilatory drive and worsen hypoxia
  - Administer high-flow 100% O2 for 5 to 10 min after discontinuation of N2O

**SYSTEMIC EFFECTS OF INHALED AGENTS (Halothane, Isoflurane, Sevoflurane)**

**Cardiovascular:**
- All volatile agents are dose-dependent CV depressants, though mechanism of ↓ BP differs
- Heart rate effects vary with MAC and inspired concentration rate of change

**Pulmonary:**
- All agents cause ↑ RR with ↓ TV, overall volatile agents cause ↓ in minute ventilation.
- All decrease response to hypercarbia.
- Volatile agents are potent bronchodilators.

**Neurologic:**
- All agents ↑ cerebral blood flow causing ↑ ICP (especially halothane) and impair autoregulation of vascular tone (least with sevoflurane at <1 MAC)
- Volatile agent’s ↓ cerebral metabolic rate
- Hepatic: Halothane causes hypoxic hepatic injury

**Renal:** All cause ↓ renal blood flow, ↓ GFR, ↓ urine output without lasting dysfunction; untreated hypotension can cause acute kidney injury

Isoflurane
• Key features: Inexpensive; slower onset/offset of action, pungent. Versatile use

• Disadvantages: Coronary vasodilator, potential for coronary “steal” effect (flow diverted away from vessels with fixed lesions) of uncertain clinical significance

Desflurane
• Key features: Most rapid onset/offset of action among volatiles; very pungent
• Disadvantages: High vapor pressure requires an electrically heated vaporizer

Sevoflurane
• Key features: Least pungent (best choice for inhalational induction); fast onset/offset of action; causes ↓ tachycardia than desflurane or isoflurane; does not sensitize myocardium to catecholamine's
• Disadvantages: Compound A production ↑ with low flows, high concentrations of sevoflurane

Halothane
• Key features: Low pungency (ideal for gas induction), inexpensive, ↑ cerebral blood flow > other volatiles, especially potent bronchodilator.
• Disadvantages: Its use decreased due to rare but fulminant postoperative auto-immune hepatitis, myocardial depression and myocardial sensitization to catecholamine's (↑ ventricular dysrhythmias).

(D) Neuromuscular blockers

Classification of Muscle Relaxants

• Depolarizing blockers: (Non-competitive)
  - Succinylcholine (Suxamethonium)

• Non-depolarizing (competitive)
  - Long acting: Pancuronium, Pipecuronium,
  - Intermediate: Vecuronium, Rocuronium, Atracur
  - Short acting: Mivacurium
Figure: NMJ and neuromuscular blockers action sites

Features of non-depolarizing agents

Table 1: Features of non-depolarizing agents

<table>
<thead>
<tr>
<th>Agent</th>
<th>Onset/duration of action</th>
<th>Ganglion blockade</th>
<th>Histamine release</th>
<th>Cardiac effects</th>
<th>Elimination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tubocurarine</td>
<td>Slow/long</td>
<td>Yes +++</td>
<td>Yes +++</td>
<td>Hypotension</td>
<td>Renal</td>
</tr>
<tr>
<td>Gallamine</td>
<td>Slow/long</td>
<td>No</td>
<td>No</td>
<td>Tachycardia</td>
<td>Renal</td>
</tr>
<tr>
<td>Pancuronium</td>
<td>Slow/long</td>
<td>No</td>
<td>No</td>
<td>Tachycardia</td>
<td>Renal/hepatic</td>
</tr>
<tr>
<td>Vecuronium</td>
<td>Slow/intermediate</td>
<td>No</td>
<td>No</td>
<td>Nil</td>
<td>Hepatic/renal</td>
</tr>
<tr>
<td>Atracurium</td>
<td>Slow/intermediate</td>
<td>No</td>
<td>Yes +</td>
<td>No</td>
<td>Hofmann</td>
</tr>
<tr>
<td>Mivacurium</td>
<td>Slow/short</td>
<td>No</td>
<td>Yes +</td>
<td>No</td>
<td>Plasma cholinesterase</td>
</tr>
<tr>
<td>Rocuronium</td>
<td>Rapid/intermediate</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Hepatic/renal</td>
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</table>
# Prolonged neuromuscular blockade

<table>
<thead>
<tr>
<th>Drugs</th>
<th>Excess neuromuscular blockade</th>
<th>Echolothiophate eye drops</th>
<th>Aminoglycosides (inhibit acetylcholine formation)</th>
<th>Magnesium / Lithium (inhibit acetylcholine release)</th>
<th>Furosemide (inhibit acetylcholine release)</th>
<th>Local anesthetics (decrease propagation action potentials)</th>
<th>Antidysrhythmics / calcium-blockers</th>
<th>Steroids</th>
<th>Dantrolene</th>
<th>Beta-blockers</th>
<th>MAOIs</th>
<th>Inhaled agents</th>
<th>Alkylating chemotherapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid-base</td>
<td>Metabolic alkalosis (from respiratory acidosis)</td>
<td>Pseudocholinesterase deficiency:</td>
<td>• liver disease / uremia</td>
<td>• pregnancy (last trimester)</td>
<td>• malignancy</td>
<td>• malnutrition</td>
<td>• collagen vascular disease</td>
<td>• hypothyroidism</td>
<td>• neostigmine / pyridostigmine</td>
<td>• phenceline</td>
<td>• cyclophosphamide</td>
<td>Liver disease (decreased metabolism)</td>
<td>Renal failure (decreased excretion)</td>
</tr>
<tr>
<td>Metabolic</td>
<td>Amyotrophic lateral sclerosis</td>
<td>Malignant hyperthermia / muscular dystrophy</td>
<td>Familial periodic paralysis</td>
<td>Hereditary hepatic porphyria</td>
<td>Myasthenia gravis / Eaton-Lambert</td>
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<tr>
<td>Neuro</td>
<td>Hypokalemia / hypocalcemia</td>
<td>Hypermagnesemia / hypernatremia</td>
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**E(O)pioids**

Opium is an extract of the juice of the poppy Papaver somniferum which is the most common plant used socially & medically.

## Opioid Classification

- **Morphine Analogues**
  - \textbf{Agonists:} Morphine, diamorphine (heroin), Codeine, Levorphanol
  - \textbf{Partial agonists:} Nalorphine, Levallorphan
  - \textbf{Antagonists:} Naloxone, Naltrexone, Nalmefene

- **Synthetic Derivatives Unrelated to Morphine**
  - \textbf{Agonists:} Pethidine (meperidine), Fentanyl, Sufentanil, Methadone, Etorphine, Dextropropoxyphene
- Partial Agonists: Pentazocine, Cyclazocine, Buprenorphine
- \(\mu\) - receptor agonist with other mode of action: Tramadol
- Those lacking analgesic activity & having other uses: Loperamide, Noscapine, Diphenoxylate, Dextromethorphan

**Opioid Actions (figure 5)**

**Opioid Receptors**

- Mainly 3 (three) types of receptors - \(\mu\) (mu), \(\kappa\) (kappa) and \(\delta\) (delta)
- Subtypes: \(\mu_1, \mu_2, \kappa_1, \kappa_2, \kappa_3, \delta_1\) and \(\delta_2\)
- Location: Peripheral Nerve endings, SG in spinal cord, Periaqueductal gray (PAG) in midbrain and Brain stem (medulla, hypothalamus and also amygdala)
- Opioids are - agonists, partial agonist or competitive antagonists of these receptors
- Overall effect depends on nature of interaction and affinity to these
- Morphine is agonist of all but affinity is higher for mu
Opioid side effects

- Sedation
- Slowed breathing
- Dependence
- Tolerance
- Addiction
- Constipation
- Nausea
- Vomiting

Acute (over-dose) Poisoning
- It may be accidental or suicidal or in drug addicts due to over dosing
- 50 mg IM produces acute toxicity presented by coma, severe respiratory depression, pinpoint pupils, occasional jerks, convulsions, cyanosis
- Respiratory failure leads to death

Treatment
- Supportive measures like maintenance of blood pressure and respiratory support
- Gastric lavage with potassium permanganate to remove unabsorbed drug and that coming through enterohepatic circulation
- Use of specific antidote, Naloxone 0.4 - 0.8 mg IV repeatedly after every 5 minutes till respiration recovers and repeated every 1 - 3 hrs later till morphine is cleared out of the body

Contraindications
- Hypotension (itself causes postural hypotension)
- Hepatic damage (itself metabolized in liver)
- Hypertrophy of prostate (due to urinary retention)
- Head injury (elevated pCO2 lead to cerebral vasodilatation associated with a decrease in cerebral vascular resistance an increase in cerebral blood flow an increase in intracranial pressure and pinpoint pupil will also mask the prognosis)
- Hypothyroidism (prolonged and exaggerated response to opioids)
- Bronchial Asthma (worsening due to histamine release and also builds up mucus in lungs due to antitussive action)
- Biliary colic (itself causes spasm of sphincter of Oddi)
Babies (infants are more susceptible to respiratory depression due to morphine)

(C)-Local Anesthetics

**Local Anesthesia**

Local anesthetics are drugs that block nerve conduction when applied locally to nerve tissue in appropriate concentrations. They act on any part of the nervous system and on every type of nerve fiber without affecting the degree of consciousness.

**Chemistry of local anesthetics**

All the useful local anesthetics consist of three parts-
1) Hydrophilic amino group
2) Intermediate chain (including an ester or amide)
3) Lipophilic aromatic group

- Local anesthetics produce a transient and reversible loss of sensation (analgesia) in a without loss of consciousness.

**Mechanism of action:**

- Local anesthetics block generation, propagation, and oscillations of electrical impulses in electrically excitable tissue. Mainly by acting on Sodium channels as Sodium chneel blockers.

**Classification of LA**

Local anesthetics: esters or amides

<table>
<thead>
<tr>
<th>AMIDE GROUP</th>
<th>ESTER GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lidocaine</td>
<td>Cocaine</td>
</tr>
<tr>
<td>Mepivacaine</td>
<td>Procaine</td>
</tr>
<tr>
<td>Bupivacaine</td>
<td>Chloroprocaine</td>
</tr>
<tr>
<td>Etidocaine</td>
<td>Tetracaine</td>
</tr>
<tr>
<td>Prilocaine</td>
<td></td>
</tr>
</tbody>
</table>
Local Anesthetic drugs

Cinchocaine (Nupercaine, Dibucaine, Procaine, Sovcaine). 0.5% hyperbaric (heavy) solution is similar to bupivacaine.

Amethocaine (Tetracaine, Pantocaine, Pontocaine, Decicain, Butethanol, Anethaine, Dikain). A 1% solution can be prepared with dextrose, saline or water for injection.

Mepivacaine (Scandicaine, Carbocaine, Meaverin). A 4% hyperbaric (heavy) solution is similar to lignocaine.

Bupivacaine (Marcaine). 0.5% hyperbaric (heavy) bupivacaine is the best and more common agent to use. 0.5% plain bupivacaine is also popular. Bupivacaine lasts longer than most other spinal anaesthetics: usually 2-3 hours.

Lignocaine (Lidocaine/Xylocaine). Best results are obtained with 5% hyperbaric (heavy) lignocaine which lasts 45-90 minutes.

Table: LA Dosing

<table>
<thead>
<tr>
<th>Drug</th>
<th>Onset</th>
<th>Maximum Dose (with Epinephrine)</th>
<th>Duration (with Epinephrine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lidocaine</td>
<td>10-20 min</td>
<td>4.5 mg/kg (7 mg/kg)</td>
<td>120 min (240 min)</td>
</tr>
<tr>
<td>Mepivacaine</td>
<td>10-20 min</td>
<td>5 mg/kg (7 mg/kg)</td>
<td>180 min (300 min)</td>
</tr>
<tr>
<td>Bupivacaine</td>
<td>15-30 min</td>
<td>2.5 mg/kg (3 mg/kg)</td>
<td>360-720 hours (8 h)</td>
</tr>
<tr>
<td>Procaine</td>
<td>Rapid</td>
<td>8 mg/kg (10 mg/kg)</td>
<td>45 min (90 min)</td>
</tr>
<tr>
<td>Chlorprocaine</td>
<td>Rapid</td>
<td>10 mg/kg (15 mg/kg)</td>
<td>30 min (90 min)</td>
</tr>
<tr>
<td>Etidocaine</td>
<td>10-20 min</td>
<td>2.5 mg/kg (4 mg/kg)</td>
<td>360-720 min (8 h)</td>
</tr>
<tr>
<td>Prilocaine</td>
<td>10-20 min</td>
<td>5 mg/kg (7.5 mg/kg)</td>
<td>180-300 min (360 min)</td>
</tr>
<tr>
<td>Tetracaine</td>
<td>20-30 min</td>
<td>1.5 mg/kg (2.5 mg/kg)</td>
<td>300-600 min (10 h)</td>
</tr>
</tbody>
</table>

Pharmacokinetics

• Effective within 5 min
- Duration of action - 1-1.5 h
- Activity is pH dependent
- Increased action in acidic pH

**Prolongation of action:** Action of local anesthetics can be prolonged by:-
- Add vasoconstrictor - adrenaline (Not to - fingers, toes, nose, penis)
- Can use a larger dose
- By adding an additive as Sodium bicarbonate, opioids

Adverse effects
- LA’s cause some vasodilatation at site
- LA toxicity related to rate of absorption via blood flow (systemic toxicity).

**Systemic Toxicity**
- Blockage of voltaged-gated Na channel affects action potential propagation throughout the body which is potential for systemic toxicity
- Excitation - anxiety, agitation, restlessness
- Convulsions
- Reduced myocardial contractility
- Arrhythmias
- Vasodilatation (hypotension with bradycardia which is dangerous)

**Management of LA Toxicity**

*Figure: ALS Guidelines for LA Toxicity*
Recognition of Potential Systemic Toxicity

Advanced Life Support Guidelines

**INTRALIPID ADMINISTRATION**
- Initial bolus 1.5 ml / kg
- Continuous infusion 0.25 ml / kg / min
- Repeat bolus twice at 3-5 min intervals up to 3 ml / kg

**Immediate Airway Management**
- O₂ administration
- Mask ventilation / tracheal intubation

**Arrhythmia Suppression**
- Amiodarone
  - 300 mg IV push
  - May repeat once at 150 mg in 3-5 min

**Circulatory Support**
- Epinephrine / Norepinephrine

**SEIZURE CONTROL**
- Propofol
  - 0.5 - 1.5 mg / kg
- Midazolam
  - 0.05 - 0.1 mg / kg
- Thiopentone
  - 1 - 2 mg / kg
Chapter 6
Neuraxial Anesthesia

Definition:
Rendering a specific area of the body, e.g. foot, arm, lower extremities, insensate to stimulus of surgery or other instrumentation.

Uses:
• Provide anesthesia for a surgical procedure
• Provide analgesia post-operatively or during labor and delivery
• Diagnosis or therapy for patients with chronic pain syndromes

Types:
• Topical
• Local/Field
• Intravenous block (“Bier” block)
• Peripheral (named) nerve, e.g. radial n.
• Plexus - brachial, lumbar
• Central neuraxial - epidural, spinal

Topical anesthesia:
• Application of local anesthetic to mucous membrane - cornea, nasal/oral mucosa
• Uses :
  – awake oral, nasal intubation, superficial surgical procedure
• Advantages :
  – technically easy
  – minimal equipment
• Disadvantages :
  – potential for large doses leading to toxicity

Local field Anesthesia:
• Application of local subcutaneously to anesthetize distal nerve endings
• Uses:
  – Suturing, minor superficial surgery, line placement, more extensive surgery with sedation
• Advantages:
  – minimal equipment, technically easy, rapid onset
• Disadvantages:
  – potential for toxicity if large field

**IV Block - “Bier” block**
Injection of local anesthetic intravenously for anesthesia of an extremity

**Uses**
  Any surgical procedure on an extremity

**Advantages:**
  Technically simple, minimal equipment, rapid onset

**Disadvantages:**
  Duration limited by tolerance of tourniquet pain, toxicity

**Peripheral nerve block**
• Injecting local anesthetic near the course of a named nerve
• Uses:
  – Surgical procedures in the distribution of the blocked nerve
• Advantages:
  – relatively small dose of local anesthetic to cover large area; rapid onset
• Disadvantages:
Technical complexity, neuropathy

- Injection of local anesthetic adjacent to a plexus, e.g. cervical, brachial or lumbar plexus
- Uses:
  - surgical anesthesia or post-operative analgesia in the distribution of the plexus
- Advantages:
  - large area of anesthesia with relatively large dose of agent
- Disadvantages:
  - Technically complex, potential for toxicity and neuropathy.

*The Advantages of Neuroaxial Anaesthesia:*
- 1. Cost.
- 3. Respiratory disease.
- 5. Diabetic patients.
- 8. Splanchnic blood flow.
- 10. Coagulation.
**Contraindications**

There are certain ABSOLUTE contraindications to Regional Anesthesia:

1) **Infection at the site:**

   Could theoretically pre-dispose patients to hematogenous spread of the infectious agents into the epidural or subarachnoid space.

2) **Patient Refusal:**

   Any denial by the patient should end there and then; DO NOT continue to try to convince a patient for regional anesthesia unless you have a valid medical reason to persist; even then a NO is a NO!!!! Just make sure you document that the “patient was offered a regional and risks/benefits were explained, but patient refused”

3) **Coagulopathy or other Bleeding Diathesis:**

   Do I really need to explain why not in these circumstances????

   (Just Kidding) If they can’t clot then you stick the minimum number of needles into a patient (hopefully just an IV and that is it!!)

4) **Severe Hypovolemia:**

   Any sympathectomy will compound the hypotension TREMENDOUSLY

5) **Increased Intracranial Pressure:**

   Any increase can lead to a brain stem herniation if a spinal is performed and even a minute amount of CSF is lost

6) **Severe Aortic Stenosis:**

   Any change in SVR or preload and hypovolemia can result in SEVERE myocardial ischemia and Sudden Cardiac Death; NOT GOOD

7) **Severe Mitral Stenosis:**

   Any change in SVR can lead to sudden Right Heart failure and rapid onset of Pulmonary edema

**Anatomical Points**

Curvature is key in spinal anesthetics (no matter in epidurals). Note that in the lumbar area, the spinous processes are near-perpendicular to the VB, whereas in the thoracic area they point downwards. Also in the thoracic area, the interlaminar space is only a few millimeters. The sacral hiatus (unfused opening between S4 and S5) is missing in 8% of adults. C7 is the bony knob at the bottom of the neck. T7-8 is at the lower limits of the scapulae. Terminal point of 12th ribs is at L2. The line across the iliac crests crosses L4 VB. Posterior iliac spines are at S2 (caudal limit of dural sac in adults). The cord itself terminates at L1 in adults and L3 in infants.
Dura mater thins as nerves exit the intervertebral canal, facilitating penetration of local anesthetic. Spinal subarachnoid space is continuous with intracranial, thus excessive migration can lead to blockade of cranial nerves. The epidural space is not a closed space and communicates with the paravertebral spaces via the foraminae. The depth of the epidural space is maximal at L2 (terminal point of 12th ribs), where it is 6 mm in depth. It is 4-5 mm in the midthoracic area. There is considerable debate about whether or not the plica mediana dorsalis, which is purported to connect the dura mater to the ligamentum flavum, even exists, and if so, how relevant it is. Artery of Adamkiewicz is highly variable but most commonly enters the canal at the left L1 foramen. The internal venous plexus, which drains the cord, is prominent in the lateral epidural space and ultimately empties into the azygous system.

Central neuraxial blockade - “Spinal”
- Injection of local anesthetic into CSF
- Uses:
  - profound anesthesia of lower abdomen and extremities
- Advantages:
  - Technically easy (Lumbar Puncture (LP) technique), high success rate, rapid onset
- Disadvantages:
  - “high spinal”, hypotension due to sympathetic block, post dural puncture headache.

Central neuraxial blockade - “epidural”
- Injection of local anesthetic into the epidural space at any level of the spinal column
- Uses:
  - Anesthesia/analgesia of the thorax, abdomen, lower extremities
- Advantages:
  - Controlled onset of blockade, long duration when catheter is placed, post-operative analgesia.
- Disadvantages: Technically complex, toxicity, “spinal headache”
**Side Effects of Spinal Anesthesia**

Local anesthetics have been shown to produce permanent injury. Hypotension occurs in 1/3 of patients, initially due to decreased SVR but in severe cases due to decreased venous return and cardiac output (greatly enhanced by hypovolemia). Baby Miller recommends a modest head-down position (5-10 degrees) to increase venous return without altering the spread of anesthetic. Hydration is critical, although in excess can be detrimental. Ephedrine is the first line drug (phenylephrine may decrease cardiac output but is still commonly used by anesthesiologists, may have a role in an add-on drug when ephedrine causes increased HR). 10-15% of patients will experience bradycardia, the treatment of which is volume -> ephedrine -> atropine -> epinephrine as needed.

**Post-dural puncture headaches** are postural and can be accompanied by abnormalities on formal audiographic testing. Risk factors include age (peaks slightly after puberty, children and older people are rare), needle type (24-25G pencil point tips are ideal), and possibly gender (although the incidence of PDPHA in women may simply reflect the vulnerability of pregnant women. Treat with bed rest, IVF, analgesia, caffeine, and possibly a blood patch (15-20 mL, injected at or below the site, as the blood will travel cephalad).

High spinals are often accompanied by hypotension, nausea, and agitation. “Total spinal anesthesia” is accompanied by LOC. Treat with ABCs (airway control and ventilation, IVF, sympathomimetics). Nausea which occurs after a spinal alerts the physician to the possibility of a high spinal and hypotension severe enough to cause a stroke, thus nausea is a critical warning sign, although it can also be caused by a predominance of residual parasympathetic activity.
Other potential side effects include urinary retention, backache, and hypoventilation secondary to thoracic or cervical spread.

**Figure: Lateral Position landmarks of neuroaxial anesthesia**

**Epidural hematoma** has traditionally been associated with vascular trauma, but it is recognized that both epidural hematomas and abscesses can occur spontaneously.

Dural puncture significantly increases the risk of headache - epidural anesthesia can be attempted at a different level, or the procedure can be converted to a spinal.

Systemic hypotension is more delayed than that seen following spinal anesthetics, but can occur. It is rare, however, in normovolemic patients.

**Absorption/intravascular injection** are particularly troublesome for bupivacaine, which has known cardiovascular side effects. Epidural doses of any local anesthetic, when injected in the subarachnoid space, can lead to permanent nerve injury. If this occurs, consider irrigating the subarachnoid space with saline. This is easily recognized in an awake patient, however in a patient under general anesthesia, look for a dilated, non-reactive pupil
Neural injury is more likely if paresthesias occur, thus injection of local anesthetics in the presence of paresthesias is contraindicated.

**Post-Dural Puncture Headache**

The risk of a headache after *accidental* dural puncture (i.e. with an epidural needle) is approximately 50%. However, keep in mind that headaches occur in 12% of all parturients who have an epidural (and 15% of parturients who don’t have an epidural).

For patients whose dura is violated intentionally (ex. spinal anesthetic, CSE, DPE), the most important modifiable risk factors have to do with needle selection - small (24 or 25 ga.) pencil point (Whitacre or Sprotte) needles should be selected. A large (22 ga.) Quincke needle can produce PDPH in 30-70% of cases, whereas a small (24-25 ga.) Whitacre or Sprotte needle will produce PDPH in only 3-5%.

**Risk Factors for Post-Dural Puncture Headache**

- Beveled (Quincke) needle (pencil-point needles are preferable)
- Larger needle
- Female gender
- Pregnancy
- Younger age
- History of headache prior to the dural puncture
Chapter 7
Management of anesthetic complication

Objectives:
By the end of this chapter the student should be able to:
1. Identify the most common types of anesthetic complications
2. Discuss the management of complications during anesthesia.
3. Discuss the management of postoperative anesthetic complications.

Introduction
Although anesthesia is safer than in the past, complications do occur. The complication could be as major as brain damage (but extremely rare) or as minor as muscle soreness (but more common). The most frequent complications are nausea, vomiting and sore throat. Anesthetists are trained to recognize and manage complications quickly, and many will undergo part of this emergency training in simulators, much like airline pilots do.

Complications during anesthesia (Intraoperative complication).

Allergy
Allergy to anesthetic drugs is rare. The severity of allergic responses can range from mild (wheeze and rash) to severe (life-threatening anaphylactic reactions). As well as anaphylactic or immune-related reactions, some patients develop anaphylactoid reactions. Although this type of reaction does
not involve antibodies, these reactions may also be severe, through the release of histamine.

If a patient is undergoing general anesthesia and is unconscious, the signs of an anaphylactic reaction may vary. The diagnosis is made by the recognition of such things as low blood pressure, wheezing, hives, rash, swelling (edema) around the eyes or in the mouth and throat, and breathing difficulties.

Anesthetists are trained to recognize and treat allergic reactions in the operating room (OR). However, an important part of treatment of any allergic reaction is prevention. Any complain of swelling of the face or generalized itching, the anesthetist should know. Skin testing can be used to identify allergens (substances that cause allergic reactions). This may be helpful in identifying the particular drugs causing a reaction in those patients who apparently are ‘allergic to anesthesia’.

The prevention of latex allergy includes removing all latex containing materials from the operating room, where possible. Most OR have a special equipment kit for use in caring for latex-allergic patients. If the allergy suspected, the patients should receive oxygen, steroids, antiallergics up to subcutaneous adrenalin as an active management.

**Adverse drug reactions**

Some patients may react abnormally to one or more drugs used during anesthesia. History of previous exposure to anesthesia can detect that warning. Occasionally, however, there is little warning, and the anesthetist must be constantly alert to the potential for abnormal reactions.

Some patients develop complications because of the interaction of specific anesthetic drugs with a pre-existing condition. There are few diseases that are precipitated by the anesthetic drugs, e.g. malignant hyperthermia (MH),
favism,... These are a specific disease for which anesthetic drugs must be carefully selected so as to minimize the risk of problems.

Treatment of episodes of MH include

1. Stopping the triggering drug (Halothane, Suchcinylcholine,)
2. Change the breathing circuits.
3. Stopping the operation if possible.
4. Administering a drug called dantrolene (intravenous). This is the only specific drug treatment for this syndrome; without it, about half of all patients who suffer a malignant hyperthermia reaction will die.
5. Extra oxygen, cooling, and resuscitative drugs and fluids.

If a patient with known MH (patient with neuromuscular diseases or family history of MH) requires an operation, the operating room should be specially prepared. No volatile anesthetic agents should be used in the room for 12 hours and, if possible, the patient should be scheduled as the first case of the day. A ‘safe’ technique consists of avoiding the known triggering agents and is not difficult to achieve. The patient’s condition, including temperature, sweeting, hypercarbia, and trismus of the jaw should be carefully monitored as with any general anesthetic. This monitoring should continue into the postoperative period. Some patients have been reported to have a reaction after a ‘safe’ anesthetic.

**Heart attack or stroke.**

It is possible to suffer a heart attack during the course of anesthesia. However, it is more likely to be on the second or third day after the operation. The risk of having a heart attack or myocardial infarction (MI) is very low, but patients who have suffered an MI in the past should consider not having elective surgery during the following six months after regulation with the cardiologist.
Other patients with severe hardening of the arteries of the neck (carotids) are not only at risk of myocardial infarction, but also of a cerebral stroke (Cerebro-vascular accident or CVA).

**Obstructed breathing.**

**Difficult airway**

Some patients have anatomical features of their neck, mouth and teeth that make management of their airway or intubation difficult. The anesthetist will make good assessment for the upper airway to judge the likelihood of such a problem, during the pre-anesthetic assessment. If he or she suspects that there may be a difficult airway, the anesthetist will ensure that additional specialized equipment and expert assistance is immediately available.

**Laryngospasm.**

Sometimes, especially at the beginning or end of the general anesthesia, the vocal chords in the larynx (voice box) may close, making it very difficult for any air or oxygen to pass to and from the lungs. The condition can be likened to “choking”, and if allowed to continue, can result in a lack of oxygen entering the bloodstream. Anesthetists are trained to deal effectively with this potentially serious complication, sometimes requiring the emergency administration of drugs to relax all muscles followed by endotracheal intubation.

**Bronchospasm.**

Bronchospasm refers to a narrowing of the major airway branches in the lung. The result is similar to severe asthma with wheezing. When it occurs, the flow of air is reduced, especially during expiration. Commonly, bronchospasm is easily treated by deepening the anesthetic, removing the stimulus, or giving
drugs such as salbutamol, aminophylline, or steroids. For particularly severe reactions, subcutaneous adrenaline may be required.

Patients with asthma or chronic obstructive pulmonary (lung) disease (COPD) and smokers may develop wheezing or bronchospasm. Bronchospasm may also occur in previously healthy patients during an allergic reaction due to drugs or blood products or after aspiration of gastric contents. Bronchospasm may also occur after such procedures as insertion of the breathing tube.

**Pneumothorax.**

In this condition, air (or another gas) enters the normally empty space between the lungs and the chest wall (pleura). If not detected and treated, this can be life threatening (especially the tension pneumothorax) as the gas expands and compresses the heart and the major blood vessels in the chest, preventing blood from entering or leaving. Most often a patient has a small but undiagnosed leak in the lining of the lung. This leak increases with the use of artificial ventilation. The problem may occur spontaneously in those with congenital swellings (bullae) of the lungs, patients with chronic lung disease and emphysema, or in asthmatic patients. In addition, the lining of the lung may be accidentally punctured by some injections around the neck or in the chest region. Pneumothorax managed in the emergency room by insertion large bore canula in the second intercostal space in the midclavicular line, followed by insertion of chest tube at the fifth intercostal space in the mid axillary line as an active management.

**Complications after anesthesia (Postoperative Complications)**

**Hypoxemia:**

This is the most important respiratory complication after anesthesia and surgery. It may start at recovery and in some patients persist for 3 days or
more after surgery. The presence of cyanosis is very insensitive and when detectable the arterial oxygen saturation (SpO₂) will be 85%. The advent of pulse oximetry had a major impact on the prevention of hypoxemia and should be used routinely in all patients. If hypoxemia is severe, persistent or when there is any doubt, arterial blood gas analysis should be performed.

Hypoxemia can be caused by a number of factors, either alone or in combination:

- Alveolar hypoventilation.
- Ventilation and perfusion mismatch within the lungs.
- Diffusion hypoxia.
- Pulmonary diffusion defects.
- A reduced inspired oxygen concentration.

Management of hypoxemia

All patients should be given oxygen in the immediate postoperative period to:

- Counter the effects of diffusion hypoxia when nitrous oxide has been used.
- Compensate for any hypoventilation.
- Compensate for V/Q mismatch.
- Meet the increased oxygen demand when shivering.

Patients who continue to hypoventilate, have persistent V/Q mismatch, are obese, anemic or have ischemic heart disease, will require additional oxygen for an extended period of time. This is best determined either by arterial blood gas analysis or by using a pulse oximeter.

**Hypotension**

This can be due to a variety of factors, alone or in combination, that reduce the cardiac output, the systemic vascular resistance or both.
The blood pressure must always be interpreted in conjunction with the other assessments.

**Management**

- Ensure adequate oxygenation and ventilation.
- Intravenous fluid, either crystalloid or colloid, should be given, using a pressure infuser to speed administration.
- Pharmacological treatment by vasoactive drugs and discontinuation of vasodilated drugs.
- Consider cross-matching blood if not already done.
- Stop any external hemorrhage with direct pressure.
- Get surgical assistance if internal hemorrhage suspected.
- Monitoring of the patient’s central venous pressure (CVP).

**Nausea and vomiting**

Postoperative nausea and vomiting (PONV) are one of the most common postoperative complications, affecting up to as many as 40 per cent of patients. The patient most likely to vomit is a young, non-smoking, overweight woman who has undergone gynecological surgery. Also, at risk are patients with a history of PONV and those with a history of motion sickness (in a car or aeroplane or at sea).

All anesthetic agents have been blamed, with opiates or narcotics most often implicated. Indeed, the anesthetic is most often blamed for all PONV, even when nausea and vomiting occur days after the operation and all traces of the anesthetic have disappeared from the body.

Other factors may contribute, including:

- Preoperative conditions, such as vomiting, increased intracranial tension (ICP), intoxication with alcohol or other drugs
- Operations on the eyes, the inner ear, the testicles, or the gastrointestinal tract.
- Postoperative conditions, such as the presence of blood in the stomach (which no anti-emetic can counter) or blockage of the bowel (intestinal obstruction).
- Pain and anxiety.
- The presence of other vomiting patients or the smell of food.
- Rapid movement (as on a stretcher) or even slight elevation of the head from the pillow.
- Pain killers given during the anesthetic or in the postoperative period.

Many of these factors can be avoided or treated, to reduce the chance of postoperative nausea and vomiting occurring.

**Dental damage**

Although anesthetists are very careful to avoid contact with the teeth, damage may occur when metal or hard plastic instruments are used to maintain an open airway, to help with insertion of the breathing (endotracheal) tube, or to suck out secretions from the mouth and back of the throat. Damage occurs at the time of tracheal intubation. Dental damage may also occur when a patient bites down on an oral airway during recovery from anesthesia. The force generated is enough to break both natural and restored teeth and has been noted in between a quarter and a half of all reported cases of dental damage.

Although human teeth are very strong, they become more brittle with age. Cosmetic dental work, with veneers, crowns or bridges, is a particular concern, as these structures are not as strong as natural teeth.

Adults with loose teeth should see a dentist, if possible, before their anesthetic. The same suggestion applies if any of the teeth are badly broken.
or decayed. In addition, professional dental cleaning is recommended for patients who have gum disease, especially for those patients who are scheduled to have a major operation.

**Bruises**

Patients often develop a small bruise at the site of insertion of the intravenous cannula, in the back of the hand, in the forearm near the wrist, or in the bend of the elbow. These bruises can become painful and may take a week or so to resolve. Elderly patients, and those with fragile skin and veins, bruise more easily and the bruise often takes longer to disappear.

**Eye problems**

Various types of eye damage may occur. The cornea or surface of the eye may be scratched when the eyelids are not completely closed, particularly if the face is covered with drapes or towels. The exposed eyes are precipitated to corneal dryness, so closing of the eye is preferred. Some anesthetists choose to secure the eyelids closed with tape - although certain patients may develop skin reactions and others may complain of loss of eyelashes after removal of the tape. Other anesthetists choose to insert a lubricating ointment into the eye - although eye infections have been reported if the ointment is contaminated. Some patients have complained of blurring of vision for a few hours postoperatively, because of the residual ointment. However, corneal damage may occur even if the eye is lubricated and taped shut. The presence of make-up, such as mascara, is potentially hazardous. Anesthetist should be careful to avoid the pressure on the eyeball during intraoperative prone position.

**Nerve damage**

Almost any nerve can be damaged. Nerves of the face may be damaged by pressure from the anesthetic breathing circuit or from the anesthetist’s
fingers holding the facemask on and the chin forward. The most common nerve injury is to the ulnar nerve at the elbow, from compression against a hard surface. In general, the prevention of nerve damage is by careful positioning and padding of the patient during anesthesia. In the past, the cause of postoperative nerve damage was always thought due to improper positioning of the patient; however, some patients who develop nerve damage have been found to have a pre-existing problem. The commonest cause of nerve damage is tourniquet palsy.

**Bleeding from the nose**

Nasal intubation is normally used for operations around the face and mouth e.g. tonsillectomy.

Insertion of the tube through the nostril often results in some bleeding from the nose after the tube is removed. This bleeding normally stops after a few minutes, although seeing the nose bleed may be distressing to family members.

**Blood clots**

Certain patients are at increased risk of having blood clots - those taking oral contraceptives or hormonal replacement. Certain surgical procedures also increase the risk of clots, such as operations that last several hours or are on the lower part of the body. In general, anesthetics do not increase the risk of having a blood clot.

**Brain damage**

Blood supply to the brain may be subtly altered by a decrease in the amount of carbon dioxide in the blood and by slight changes in blood pressure. Many anesthetic drugs have side effects which can alter blood flow, although modern drugs are less likely to produce these effects.
On rare occasions, patients have suffered brain damage due to lack of oxygen delivery to the brain. Even though all aspects of the anesthetic are carefully monitored, sometimes, problems can occur.

Some operations may lead to a decrease in intellectual ability, after major brain or open heart surgery. Other patients are at risk because of pre-existing medical conditions, such as age-related loss of memory. Elderly patients, particularly those with progressive heart disease, high blood pressure or a history of minor strokes may suffer permanent changes after anesthesia. This may be a result of a change in critical blood supply to certain parts of the brain, altering specific chemicals in the brain.
Chapter 8
Intravenous Canulation and Intravenous Fluids

Objectives

1. Intravenous cannulation and fluid administration.
2. Central venous cannulation.
3. Intravenous fluids.
5. Risks of intravenous blood and blood products.
6. Management of complications

1)-Intravenous cannulation

Is a process by which a small plastic tube (a cannula) is inserted into a peripheral vein? The subsequent venous access can be used for the administration of fluids, medication and nutrition. In some cases, blood samples can also be obtained from the cannula. The process of cannulation can be divided into four steps; explanation and consent, preparation, procedure and aftercare.

We shall now look at these stages in more detail:

Figure: Cannula in place

Explanation and Consent
• Confirm the patient's identification, check full name, DOB, and hospital number, then confirm against patients wristband.

• Explain rationale for the procedure, describe the procedure, and state the importance of the procedure.

• Explain the risks of the procedure to the patient, infection (can be minimized by sterile equipment and aseptic non-touch technique), structure missed or another structure hit (nerve, artery, or bone), hematoma or phlebitis may develop.

• Ask about relevant past medical history, blood clotting disorders or medication that affects blood clotting (e.g. warfarin), arterio-venous fistula present, previous breast surgery or lymph node removal (avoid the side of previous mastectomy).

• Ask about needle phobia.

• Ask about preferred location of cannula and check that the patient is happy to go ahead with the procedure. Ask the patient if they would like a chaperone present.

**Figure 2: Cannula catheter 3 way**

What does a cannula consist of?

**Figure: Cannula parts**

**Selected Sites:**

- Veins of the Foot
- Great Saphenous Vein
- Lesser Saphenous Vein
- Dorsal Venous Arch
- Veins of the Hand
- Cephalic
- Dorsal Venous Arch
- Antecubital
Preparation:
When in the treatment room, prepare your equipment on an appropriate equipment trolley. Decontaminate your hands.
- Clean your trolley and plastic tray with appropriate aseptic agent (e.g. Chlor-clean), allowing to dry fully. Decontaminate your hands.
- Check expiry date of saline solution with another member of staff. Clean the top of the saline vial with chlorhexidine wipe and open. Draw up saline into sterile syringe and discard the needle.
- Open the sterile package, flush it, and place in the tray.
- Gather the rest of the equipment into the plastic tray on the trolley and move to the patient’s bedside.
  - Equipment required: cannula pack, 2 chlorhexidine wipes, saline-filled syringe, tourniquet, gauze, sterile dressing, absorbent pad, and cannula assessment record.

Once at the patient’s bedside
- Re-confirm the patients identification
- Decontaminate your hands and position the patient’s arm underneath a pillow with the inco pad
- Apply the tourniquet, select a suitable vein, remove the tourniquet and carry on with the procedure.

Procedure
- Don your gloves and apron
- Clean the puncture site with the chloraprep wipe (in a cross-hatch formation) and allow to air dry.
- Apply the tourniquet and do not repalpate the cleaned skin.
- Placing traction on the skin below the intended puncture site, insert the cannula with the bevel up at an angle of 30° into the puncture site.
• Advance the cannula and observe flashback.
• Hold the needle introducer still whilst advancing the cannula forward, over the needle and fully into the vein.
• Release the tourniquet and place pressure on the vein above the puncture site, disposing the needle into your sharps bin.
• Secure the cannula in place with the sterile dressing.
  o Ensure not to cover the puncture site with the tape when securing down, as this can cover up any possible phlebitis developing.
• Flush the cannula with 5ml of saline
  o No resistance should be felt
  o Check for any signs of extravasation / tissuing around the cannula site. Remove cannula if suspected
• Discard all waste into the correct disposal bins and ensure the patient is comfortable.
• Remove your gloves and decontaminate your hands

Aftercare
• Instruct the patient to inform the nursing staff if:
  • Cannula site becomes painful, red, hot, or swollen.
  • The area around the cannula feels wet or the dressing is coming loose.
  • The cannula is limiting their self-care Thank the patient and leave... the patient’s bedside.
• Ensure the correct cannula insertion documentation is filled out completely and placed in the patients notes.
• Inform the nursing staff and place any cannula care pathway stickers into the nursing notes.
• Ideally, the cannula should be checked and flushed 3 times a day, and should be removed after 72hrs.

Internal jugular vein catheterization (Central venous line)
To perform catheterization of a central vein (here of a right internal jugular vein (IJV) using Seldinger technique you will need a Catheterization set that consist of 18G needle, J-tipped guidewire, dilator and central venous catheter (CVC).
Indications of CVP

- Limited vascular access
- Administration of highly osmotic or caustic fluids or medications
- Frequent administration of blood and blood products
- Frequent blood sampling
- Measurement of CVP
- Hemodialysis
- Hemofiltration
- Apheresis

- Complications of central venous cannulation
  - Arterial puncture with hematoma
  - Arteriovenous fistula
  - Hemothorax
  - Chylothorax
  - Pneumothorax
  - Nerve injury Brachial plexus Stellate ganglion (Horner’s syndrome)
  - Air emboli
  - Catheter or wire shearing

- Complications of catheter presence
  - Thrombosis, thromboembolism
  - Infection, sepsis, endocarditis
  - Arrhythmias
  - Hydrothorax

Contraindication of CVP

- Distorted Anatomy
- Infection at the Site of Access
- Proximal Vascular Injury
- Bleeding Disorders or Anticoagulation
- Combative Patients

Some of this contraindications are solved by ultrasound Seldinger technique.

The figure showed the main landmarks, the sternocleidomastoid muscle (SCM), its sternal and clavicular heads, external jugular vein, the clavicle and jugular notch. Numbers are for several routinely used approaches: 1 - anterior; 2 - central; 3 - posterior; 4 - supraclavicular. Recall the course of the IJV relatively to ICA - in the upper neck behind the ICA, in the middle neck laterally and in the lower third -
in front of ICA joining the ipsilateral subclavian vein.

Posterior or lateral approach: Puncture site is at the crossing of external jugular vein and lateral border of SCM. If external jugular is not prominent you may relate to the upper border of thyroid cartilage. The needle under aspiration is advanced under the SCM pointing to jugular notch. The vein is usually found at the depth of 2-5 cm. If the vein is not encountered one may change the angle of the needle more cranially or caudally.

Here the needle was directed more caudally, however the needle is still advancing under the SCM. When you’ve got blood in your syringe try to push it back assessing the resistance, you may suspect carotid puncture if it's quite high).

Gently detach the syringe. The guidewire should be in advance placed in the known position

While advancing the guidewire you shouldn’t feel much resistance, apart from gentle rubbing of corrugated guidewire against the needle edge. If you feel some noticeable resistance, don't withdraw the guidewire, first try to rotate it and if it was set against the vein's wall it may slip further. If you decide to withdraw it through the needle the best scenario would be the guidewire got shaggy, the worst - it's cut off and you have problems far more serious than the need for repeat puncture when you withdraw the guidewire with the needle. If, during the repeat try you are in the same situation, try to insert the guidewire with its straight end. In case of failure change your approach. After successful insertion of the guidewire (no further than 20 cm to avoid arrhythmias), withdraw the needle, holding the guidewire in place.
We have the classic point for central approach, namely the angle between the SCM heads. The needle is advanced at the angle of 30-40 degrees towards the ipsilateral nipple. The vein has not been found - change your direction a little medially or laterally. Remember, the vein is usually located at 1-3 cm depth, in some slender persons it could be found just under the skin.

Then, follow up the previous steps.

Introducer-dilator are advanced over the guidewire. Try to hold them by your fingers near to the skin to avoid bending and additional tissue injury. Remember, you should simultaneously withdraw the guidewire and the dilator, after that the introducer hemostatic valve comes into work.

- **Intravenous Fluids**

  ![Types of IV fluid](image)

  **A) Adult Resuscitation Fluid**

  Generally 20mls/kg (over less than 10 minutes) aliquots of a glucose free iso-tonic / iso-osmotic crystalloid solution (e.g. 0.9% saline or Hartmann’s solution) should be given according to clinical response except in trauma / head injury patients where 10mls/kg of 0.9% saline should be first choice (followed by blood products if required).
**B)-Perioperative Intravenous Fluids Prescription and Monitoring for Children**

These guidelines are a starting point for the prescription of fluid in previously well surgical children. For diabetic children follow paediatric diabetic guideline with careful assessment of fluid and electrolyte requirements and careful monitoring.

*Resuscitation Fluid:* Generally 20mls/kg of 0.9% Saline (No Glucose) infused in under 10 minutes. Use 10mls / kg in Trauma or suspected head injury. 20mls/kg of 4.5% Albumin can be used in septic / burn shock.

*Maintenance Fluids:* Use an isotonic crystalloid solution that contains Sodium in the region of 131-150 mmol/L

*Ongoing Fluid Losses:* Replace all losses ml for ml with 0.9% saline with 20mmol/L KCl

**Monitoring:**

- Weigh all children prior to starting fluids, daily thereafter until IV fluids discontinue. Document an accurate daily fluid balance.
- Check urin and electrolyte (U&E) before starting intravenous fluids (except well children, elective surgery) Check U&E daily for the first 4 days of intravenous fluids, thereafter as clinically indicated.
- If electrolytes are abnormal, consider rechecking 6 hourly, definitely if sodium <130 mmol/l
- Check blood glucose (BG) if prolonged fasting or unwell child If symptoms of hyponatraemia develop: headache, nausea and vomiting, seizure- call for senior help and take serum electrolytes and treat.
Chapter 9
Anesthesia Monitors

1)-Electrocardiogram (ECG)
This monitors the electrical activity of the heart with electrical potentials of 0.5–2 mV at the skin surface. It is useful in determining the heart rate, ischaemia, the presence of arrhythmias and conduction defects. It should be emphasized that it gives no assessment of cardiac output. The bipolar leads (I, II, III, AVR, AVL and AVF) measure voltage difference between two electrodes. The unipolar leads (V1–6) measure voltage at different electrodes relative to a zero point.

Components
1. Skin electrodes detect the electrical activity of the heart. Silver and silver chloride form a stable electrode combination. Both are held in a cup and separated from the skin by a foam pad soaked in conducting gel.
2. Colour-coded cables to transmit the signal from electrodes to the monitor. Cables are available in 3- and 5-lead versions as snap or grabber design and with a variety of lengths. All the cables of a particular set should have the same length to minimize the effect of electromagnetic interference.
3. The ECG signal is then boosted using an amplifier. The amplifier covers a frequency range of 0.05–150 Hz. It also filters out some of the frequencies considered to be noise. The amplifier has ECG filters that are used to remove the noise/artifacts from ECG and produce a ‘clean’ signal.
4. An oscilloscope that displays the amplified ECG signal. A high-resolution monochrome or colour monitor is used.

Mechanism of action
1. Proper attachment of ECG electrodes involves cleaning the skin, gently abrading the stratum corneum and ensuring adequate contact using conductive gel. Skin impedance varies at different sites and it is thought to be higher in females. The electrodes are best positioned on bony prominences to reduce artifacts from respiration.
2. Modern ECG monitors use multiple filters for signal processing. The filters used should be capable of removing the unwanted frequencies, leaving the signal intact. Two types of filters are used for this purpose:

a) **high-pass filters** attenuate the frequency components of a signal below a certain frequency. They help to remove lower frequency noise from the signal. For example, the respiratory component from ECG can be removed by turning on a 1-Hz high pass filter on the amplifier. The filter will centre the signal around the zero isoleine.

b) **low-pass filters** attenuate the frequency components of a signal above a certain frequency. They are useful for removing noise from lower frequency signals. So an amplifier with a 35-Hz low-pass filter will remove/attenuate signals above 35 Hz and help to ‘clean’ the ECG signal.

3. The ECG monitor can have two modes:

a) the **monitoring mode** has a limited frequency response of 0.5–50 Hz. Filters are used to narrow the bandwidth to reduce environmental artifacts. The high-frequency filters reduce distortions from muscle movement, mains current and electromagnetic interference from other equipment. The low-frequency filters help provide a stable baseline by reducing respiratory and body movement artifacts.

b) the **diagnostic mode** has a wider frequency response of 0.05–150 Hz. The high-frequency limit allows the assessment of the ST segment, QRS morphology and tachyarrhythmias. The low-frequency limit allows representation of P- and T-wave morphology and ST-segment analysis.

4. There are many ECG electrode configurations. Usually during anaesthesia, three skin electrodes are used (right arm, left arm and indifferent leads). The three limb leads used include two that are ‘active’ and one that is ‘inactive’ (earth). Sometimes five electrodes are used. Lead II is ideal for detecting arrhythmias. CM5 configuration is able to detect 89% of ST-segment changes due to left ventricular ischaemia. In CM5, the right arm electrode is positioned on the manubrium (chest lead from manubrium), the left arm electrode is on V5 position (fifth interspace in the left anterior axillary line) and the indifferent lead is on the left shoulder or any convenient position.

5. The CB5 configuration is useful during thoracic anaesthesia. The right arm electrode is positioned over the centre of the right scapula and the left arm electrode is over V5.

6. A display speed of 25 mm/s and a sensitivity of 1 mV/cm are standard in the UK.
Problems in practice and safety features

1. Incorrect placement of the ECG electrodes in relation to the heart is a common error, leading to false information.

2. Electrical interference can be a 50-Hz (in UK) mains line interference because of capacitance or inductive coupling effect. Any electrical device powered by AC can act as one plate of a capacitor and the patient acts as the other plate. Interference can also be because of high-frequency current interference from diathermy. Most modern monitors have the facilities to avoid interference. Shielding of cables and leads, differential amplifiers and electronic filters all help to produce an interference-free monitoring system. Differential amplifiers measure the difference between the potential from two different sources. If there is interference common to the two input terminals (e.g. mains frequency), it can be eliminated as only the differences between the two terminals is amplified. This is called common mode rejection ratio (CMRR). Amplifiers used in ECG monitoring should have a high CMRR of 100,000 : 1 to 1,000,000 : 1, which is a measurement of capability to reject the noise. They should also have a high input impedance (about 10 MΩ) to minimize the current taken from the electrodes.

3. Muscular activity, such as shivering, can produce artifacts. Positioning the electrodes over bony prominences and the use of low-pass filters can reduce these artifacts.

4. High and low ventricular rate alarms and an audible indicator of ventricular rate are standard on most designs. More advanced monitors have the facility to monitor the ST segment. Continuous monitoring and measurement of the height of the ST segment allows early diagnosis of ischaemic changes.

5. Absence of or improperly positioned patient diathermy plate can cause burns at the site of ECG skin electrodes. This is because of the passage of the diathermy current via the electrodes causing a relatively high current density.

### Table 10.1 ECG signal interference

<table>
<thead>
<tr>
<th>Type of interference</th>
<th>Sources of interference</th>
<th>How to reduce interference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electromagnetic induction</td>
<td>Any electrical cable or light</td>
<td>Use long ECG and twisted leads (rejecting the induced signal as common mode)</td>
</tr>
<tr>
<td>Electrostatic induction</td>
<td>Stray capacitances between table, lights, monitors, patients and electrical cables</td>
<td>Use selective filters in amplifiers ECG leads are surrounded by copper screens</td>
</tr>
<tr>
<td>Electrostatic induction + capacitance coupling</td>
<td>Diathermy enters the system by: mains supply</td>
<td>High-frequency filters clean up signal before entering input</td>
</tr>
<tr>
<td>Radiofrequency interference (&gt;150 Hz)</td>
<td>direct application by probe</td>
<td>Filtering power supply of amplifiers</td>
</tr>
<tr>
<td></td>
<td>radio transmission via probe and wire</td>
<td>Double screen electronic components of amplifiers and earth outer screen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Never machines operate at higher frequencies</td>
</tr>
</tbody>
</table>

2-Pulse Oximetry (arterial Oxygen saturation Monitoring):

This is a non-invasive measurement of the arterial blood oxygen saturation at the level of the
arterioles. A continuous display of the oxygenation is achieved by a simple, accurate and rapid method.
Pulse oximetry has proved to be a powerful monitoring tool in the operating theatre, recovery wards, intensive care units, general wards and during the transport of critically ill patients. It is considered to be the greatest technical advance in monitoring of the last decade. It enables the detection of incipient and unsuspected arterial hypoxaemia, allowing treatment before tissue damage.

**Components**
1. A probe is positioned on the finger, toe, ear lobe or nose. Two light-emitting diodes (LEDs) produce beams at red and infrared frequencies (660 nm and 940 nm respectively) on one side and there is a sensitive photodetector on the other side. The LEDs operate in sequence at a rate of about 30 times per second.
2. The case houses the microprocessor. There is a display of the oxygen saturation, pulse rate and a plethysmographic waveform of the pulse. Alarm limits can be set for a low saturation value and for both high and low pulse rates.

**Mechanism of action**
1. The oxygen saturation is estimated by measuring the transmission of light, through a pulsatile vascular tissue bed (e.g. finger). This is based on Beer’s law (the relation between the light absorbed and the concentration of solute in the solution) and Lambert’s law (relation between absorption of light and the thickness of the absorbing layer).
2. The amount of light transmitted depends on many factors. The light absorbed by non-pulsatile tissues (e.g. skin, soft tissues, bone and venous blood) is constant (DC). The non-constant absorption (AC) is the result of arterial blood pulsations. The sensitive photodetector generates a voltage proportional to the transmitted light. The AC component of the wave is about 1–5% of the total signal.
3. The high frequency of the LEDs allows the absorption to be sampled many times during each pulse beat. This is used to enable running averages of saturation to be calculated many times per second. This decreases the ‘noise’ (e.g. movement) effect on the signal.
4. The microprocessor is programmed to mathematically analyse both the DC and AC components at 660 and 940 nm calculating the ratio of absorption at these two frequencies (R/IR ratio). The result is related to the arterial saturation. The absorption of oxyhaemoglobin and deoxyhaemoglobin at these two wavelengths is very different. This allows these two wavelengths to provide good sensitivity. 805 nm is one of the
isobestic points of oxyhaemoglobin and deoxyhaemoglobin. The OFF part allows a baseline measurement for any changes in ambient light.

5. A more recent design uses multiple wavelengths to eradicate false readings from carboxyhaemoglobin and methaemoglobin. Advanced oximeters use more than seven light wavelengths. This has enabled the measurement of haemoglobin value, oxygen content, carboxyhaemoglobin and methaemoglobin concentrations.

6. A variable pitch beep provides an audible signal of changes in saturation.

**Problems in practice and safety features**

1. It is accurate (±2%) in the 70–100% range. Below the saturation of 70%, readings are extrapolated.

2. The absolute measurement of oxygen saturation may vary from one probe to another but with accurate trends. This is due to the variability of the centre wavelength of the LEDs.

3. Carbon monoxide poisoning (including smoking), coloured varnish, intravenous injections of certain dyes (e.g. methylene blue, indocyanine green) and drugs responsible for the production of methaemoglobin are all sources of error.

4. Hypoperfusion and severe peripheral vasoconstriction affect the performance of the pulse oximeter. This is because the AC signal sensed is about 1–5% of the DC signal when the pulse volume is normal. This makes it less accurate during vasoconstriction when the AC component is reduced.

5. The device monitors the oxygen saturation with no direct information regarding oxygen delivery to the tissues.

6. Pulse oximeters average their readings every 10–20 s. They cannot detect acute desaturation. The response time to desaturation is longer with the finger probe (more than 60 s) whereas the ear probe has a response time of 10–15 s.

7. Excessive movement or malposition of the probe is a source of error. Newer designs such as the Masimo oximeter claim more stability despite motion. External fluorescent light can be a source of interference.

8. Inaccurate measurement can be caused by venous pulsation. This can be because of high airway pressures, the Valsalva manoeuvre or other consequences of impaired venous return. Pulse oximeters assume that any pulsatile absorption is caused by arterial blood pulsation only.

9. The site of the application should be checked at regular intervals as the probe can cause pressure sores with continuous use. Some manufacturers recommend changing the site of application every 2 h especially in patients with

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**Table 10.3 Sources of error in pulse oximetry**

<table>
<thead>
<tr>
<th>Source</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HbF</td>
<td>No significant clinical change</td>
</tr>
<tr>
<td></td>
<td>(absorption spectrum is similar to the adult Hb)</td>
</tr>
<tr>
<td></td>
<td>(over the range of wavelengths used)</td>
</tr>
<tr>
<td>Methylene blue</td>
<td>False low reading</td>
</tr>
<tr>
<td>Indocyanine green</td>
<td>False low reading</td>
</tr>
<tr>
<td>Nail varnish</td>
<td>May cause false low reading</td>
</tr>
</tbody>
</table>
impaired microcirculation. Burns in infants have been reported.

10. Pulse oximetry only gives information about a patient’s oxygenation. It does not give any indication of a patient’s ability to eliminate carbon dioxide.

3-Capnography (ETCO2 Monitoring):
Gases with molecules that contain at least two dissimilar atoms absorb radiation in the infrared region of the spectrum. Using this property, both inspired and exhaled carbon dioxide concentration can be measured directly and continuously throughout the respiratory cycle.

The end-tidal CO2 is less than alveolar CO2 because the end-tidal CO2 is always diluted with alveolar dead space gas from unperfused alveoli. These alveoli do not take part in gas exchange and so contain no CO2. Alveolar CO2 is less than arterial CO2 as the blood from unventilated alveoli and lung parenchyma (both have higher CO2 contents) mixes with the blood from ventilated alveoli. In healthy adults with normal lungs, end-tidal CO2 is 0.3–0.6 kPa less than arterial CO2. This difference is reduced if the lungs are ventilated with large tidal volumes. The Greek root kapnos, meaning ‘smoke’, give us the term capnography (CO2 can be thought as the ‘smoke’ of cellular metabolism).

In reality, the devices used cannot determine the different phases of respiration but simply report the minimum and maximum CO2 concentrations during each respiratory cycle.

Components
1. The sampling chamber can either be positioned within the patient’s gas stream (mainstream version, or connected to the distal end of the breathing system via a sampling tube (side-stream version).
2. A photodetector measures light reaching it from a light source at the correct infrared wavelength (using optical filters) after passing through two chambers. One acts as a reference whereas the other one is the sampling chamber.

Mechanism of action
1. Carbon dioxide absorbs the infrared radiation particularly at a wavelength of 4.3 μm.
2. The amount of infrared radiation absorbed is proportional to the number of carbon dioxide molecules (partial pressure of carbon dioxide) present in the chamber.
3. The remaining infrared radiation falls on the thermopile detector, which in turn produces heat. The heat is measured by a temperature sensor and is proportional to
the partial pressure of carbon dioxide gas present in the mixture in the sample chamber. This produces an electrical output. This means that the amount of gas present is inversely proportional to the amount of infrared light present at the detector in the sample chamber.

4. In the same way, a beam of light passes through the reference chamber which contains room air. The absorption detected from the sample chamber is compared to that in the reference chamber. This allows the calculation of carbon dioxide values.

5. The inspired and exhaled carbon dioxide forms a square wave, with a zero baseline unless there is rebreathing.

6. A microprocessor-controlled infrared lamp is used. This produces a stable infrared source with a constant output. The current is measured with a current-sensing resistor, the voltage across which is proportional to the current flowing through it. The supply to the light source is controlled by the feedback from the sensing resistor maintaining a constant current of 150 mA.

7. Using the rise and fall of the carbon dioxide during the respiratory cycle, monitors are designed to measure the respiratory rate.

8. Alarm limits can be set for both high and low values.

9. To avoid drift, the monitor should be calibrated regularly with known concentrations of CO2 to ensure accurate measurement. Photo-acoustic spectroscopy: in these infrared absorption devices, the sample gas is irradiated with pulsatile infrared radiation of a suitable wavelength. The periodic expansion and contraction produces a pressure fluctuation of audible frequency that can be detected by a microphone. The advantages of photo-acoustic spectrometry over conventional infrared absorption spectrometry are:

1. The photo-acoustic technique is extremely stable and its calibration remains constant over much longer periods of time.

2. The very fast rise and fall times give a much more accurate representation of any change in CO2 concentration. Carbon dioxide analysers can be either side-stream or main-stream analysers.

**SIDE-STREAM ANALYSERS**

1. This consists of a 1.2-mm internal diameter tube that samples the gases (both inspired and exhaled) at a constant rate (e.g. 150–200 mL/min). The tube is connected to a lightweight adapter near the patient’s end of the breathing system (with a pneumotachograph for spirometry) with a small increase in the dead space. It delivers the gases to the sample chamber. It is made of Teflon so it is impermeable to carbon dioxide and does not react with anaesthetic agents.
2. As the gases are humid, there is a moisture trap with an exhaust port, allowing gas to be vented to the atmosphere or returned to the breathing system.
3. In order to accurately measure end-tidal carbon dioxide, the sampling tube should be positioned as close as possible to the patient’s trachea.
4. A variable time delay before the sample is presented to the sample chamber is expected. The *transit time* delay depends on the length (which should be as short as possible, e.g. 2 m) and diameter of the sampling tube and the sampling rate. A delay of less than 3.8 s is acceptable. The *rise time* delay is the time for the analyser to respond to the signal and depends upon the size of the sample chamber and the gas flow.
5. Other gases and vapours can be analysed from the same sample.
6. Portable hand-held side-stream analysers are available. They can be used during patient transport and out-of-hospital situations.

### MAIN-STREAM ANALYSER

1. The sample chamber is positioned within the patient’s gas stream, increasing the dead space. In order to prevent water vapour condensation on its windows, it is heated to about 41°C.
2. Since there is no need for a sampling tube, there is no transport time delay in gas delivery to the sample chamber.
3. Other gases and vapours are not measured simultaneously. See the Table for a comparison of side-stream and main-stream analysers.

### Table 10.4 Comparison of various qualities between side-stream and main-stream analysers

<table>
<thead>
<tr>
<th></th>
<th>Side stream</th>
<th>Main stream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disconnection possible</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sampling catheter leak common</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Calibration gas required</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Sensor damage common</td>
<td>No</td>
<td>Some</td>
</tr>
<tr>
<td>Multiple gas analysis possible</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Use on non-intubated patients</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

### Table 10.5 Summary of the uses of end-tidal CO₂

<table>
<thead>
<tr>
<th>Increased end-tidal carbon dioxide</th>
<th>Decreased end-tidal carbon dioxide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypoventilation</td>
<td>Hyperventilation</td>
</tr>
<tr>
<td>Rebreathing</td>
<td>Pulmonary embolism</td>
</tr>
<tr>
<td>Sepsis</td>
<td>Hypoperfusion</td>
</tr>
<tr>
<td>Malignant hyperpyrexia</td>
<td>Hypometabolism</td>
</tr>
<tr>
<td>Hyperthermia</td>
<td>Hypothermia</td>
</tr>
<tr>
<td>Skeletal muscle activity</td>
<td>Hypovolaemia</td>
</tr>
<tr>
<td>Hypermetabolism</td>
<td>Hypotension</td>
</tr>
</tbody>
</table>

### Uses

In addition to its use as an indicator for the level of ventilation (hypo-, normo- or hyperventilation), end-tidal carbon dioxide measurement is useful:
1. To diagnose oesophageal intubation (no or very little carbon dioxide is detected). Following manual ventilation or the ingestion of carbonated drinks, some carbon dioxide might be
3-Monitoring Arterial Blood Pressure:

Oscillometry is the commonest method used to measure blood pressure non-invasively during anaesthesia. The systolic, diastolic and mean arterial pressures and pulse rate present in the stomach. Characteristically, this may result in up to 5–6 waveforms with an abnormal shape and decreasing in amplitude.

2. As a disconnection alarm for a ventilator or breathing system. There is sudden absence of the end-tidal carbon dioxide.

3. To diagnose lung embolism as a sudden decrease in end-tidal carbon dioxide assuming that the arterial blood pressure remains stable.

4. To diagnose malignant hyperpyrexia as a gradual increase in end-tidal carbon dioxide.

Problems in practice and safety features

1. In patients with chronic obstructive airways disease, the waveform shows a sloping trace and does not accurately reflect the end-tidal carbon dioxide. An ascending plateau usually indicates impairment of ventilation: perfusion ratio because of uneven emptying of the alveoli.

2. During paediatric anaesthesia, it can be difficult to produce and interpret end-tidal carbon dioxide because of the high respiratory rates and small tidal volumes. The patient’s tidal breath can be diluted with fresh gas.

3. During a prolonged expiration or end-expiratory pause, the gas flow exiting the trachea approaches zero. The sampling line may aspirate gas from the trachea and the inspiratory limb, causing ripples on the expired CO2 trace (cardiogenic oscillations). They appear during the alveolar plateau in synchrony with the heart beat. It is thought to be due to mechanical agitation of deep lung regions that expel CO2-rich gas. Such fluctuations can be smoothed over by increasing lung volume using positive end expiratory pressure (PEEP).

4. Dilution of the end-tidal carbon dioxide can occur whenever there are loose connections and system leaks.

5. Nitrous oxide (may be present in the sample for analysis) absorbs infrared light with an absorption spectrum partly overlapping that of carbon dioxide. This causes inaccuracy of the detector, nitrous oxide being interpreted as carbon dioxide. By careful choice of the wavelength using special filters, this can be avoided. This is not a problem in most modern analysers.

6. Collision broadening or pressure broadening is a cause of error. The absorption of carbon dioxide is increased because of the presence of nitrous oxide or nitrogen. Calibration with a gas mixture that contains the same background gases as the sample solves this problem.
are measured, calculated and displayed. These devices give reliable trend information about the
blood pressure. They are less reliable in circumstances where a sudden change in blood pressure is anticipated, or where a minimal change in blood pressure is clinically relevant. The term ‘device for indirect non-invasive automatic mean arterial pressure’ (DINAMAP) is used for such devices.

**Components**
1. A cuff with a tube used for inflation and deflation. Some designs have an extra tube for transmitting pressure fluctuations to the pressure transducer.
2. The case where the microprocessor, pressure transducer and a solenoid valve which controls the deflation of the arm cuff are housed. It contains the display and a timing mechanism which adjusts the frequency of measurements. Alarm limits can be set for both high and low values.

**Mechanism of action**
1. The microprocessor is set to control the sequence of inflation and deflation.
2. The cuff is inflated to a pressure above the previous systolic pressure, then it is deflated incrementally. The return of blood flow causes oscillation in cuff pressure.
3. The transducer senses the pressure changes which are interpreted by the microprocessor. This transducer has an accuracy of ±2%.
4. The output signal from the transducer passes through a filter to an amplifier that amplifies the oscillations. The output from the amplifier passes to the microprocessor through the analogue digital converter (ADC). The microprocessor controls the pneumatic pump for inflation of the cuff and the solenoid valve for deflation of the cuff.
5. The mean arterial blood pressure corresponds to the maximum oscillation at the lowest cuff pressure. The systolic pressure corresponds to the onset of rapidly increasing oscillations.
6. The diastolic pressure corresponds to the onset of rapidly decreasing oscillations. In addition, it is mathematically computed from the systolic and mean pressure values (mean blood pressure = diastolic blood pressure + 1/3 pulse pressure).
7. The cuff must be of the correct size. It should cover at least two-thirds of the upper arm. The width of the cuff’s bladder should be 40% of the mid-circumference of the limb. The middle of the cuff’s bladder should be positioned over the brachial artery.
8. Some designs have the ability to apply venous stasis to facilitate intravenous cannulation.

**Problems in practice and safety features**
1. For the device to measure the arterial blood pressure accurately, it should have a fast cuff inflation and a slow cuff deflation (at a rate of 3 mmHg/s or 2 mmHg/beat). The former is to avoid venous congestion and the latter provides enough time to detect the arterial pulsation.

2. If the cuff is too small, the blood pressure is over-read, while it is under-read if the cuff is too large. The error is greater with too small than too large a cuff.

3. The systolic pressure is over-read at low pressures (systolic pressure less than 60 mmHg) and under-read at high systolic pressures.

4. Atrial fibrillation and other arrhythmias affect performance.

5. External pressure on the cuff or its tubing can cause inaccuracies.

6. Frequently repeated cuff inflations can cause ulnar nerve palsy and petechial haemorrhage of the skin under the cuff. The Finapres (finger arterial pressure) device uses a combination of oscillometry and a servo control unit. The volume of blood in the finger varies with the cardiac cycle. A small cuff placed around the finger is used to keep the blood volume of the finger constant. An infrared photoplethysmograph detects changes in the volume of blood within the finger with each cardiac cycle. A controller system alters the pressure in the cuff accordingly, to keep the volume of blood in the finger constant. The applied pressure waveform correlates with the arterial blood volume and, therefore, with the arterial blood pressure. This applied pressure is then displayed continuously, in real time, as the arterial blood pressure waveform.

**THE VON RECKLINGHAUSEN OSCILLOTONOMETER**

During the premicroprocessor era, the Von Recklinghausen Oscillotonometer was widely used.

**Components**

1. Two cuffs: the upper, occluding cuff (5 cm wide) overlaps a lower, sensing cuff (10 cm wide). An inflation bulb is attached.

2. The case which contains:
   a) two bellows, one connected to the atmosphere, the other connected to the lower sensing cuff
   b) a mechanical amplification system
   c) the oscillating needle and dial
   d) the control lever
   e) the release valve.

**Mechanism of action**

1. With the control lever at rest, air is pumped into both cuffs and the air-tight case of the instrument using the inflation bulb to a pressure exceeding systolic arterial pressure. By operating the control lever, the lower sensing cuff is isolated and the
pressure in the upper cuff and instrument case is allowed to decrease slowly through an adjustable leak controlled by the release valve. As systolic pressure is reached, pulsation of the artery under the lower cuff results in pressure oscillations within the cuff and its bellows. The pressure oscillations are transmitted via a mechanical amplification system to the needle. As the pressure in the upper cuff decreases below diastolic pressure, the pulsation ceases.

2. The mean pressure is at the point of maximum oscillation.
3. This method is reliable at low pressures. It is useful to measure trends in blood pressure.

Problems in practice and safety features
1. In order for the device to operate accurately, the cuffs must be correctly positioned and attached to their respective tubes.
2. The diastolic pressure is not measured accurately with this device.

**4-CVP Monitoring:**

**OVERVIEW**

- Central venous pressure (CVP) is the pressure recorded from the right atrium or superior vena cava and is representative of the filling pressure of the right side of the heart.
- CVP monitoring in the critically ill is established practice but the traditional belief that CVP reflects ventricular preload and predicts fluid responsiveness has been challenged by a large body of evidence.
- CVP represents the driving force for filling the right atrium and ventricle.
- Normal is 0-6mmHg in a spontaneously breathing non-ventilated patient.

**MEASUREMENT**

- **Dra**
  - **a** = peak atrial contraction (follows the P wave on ECG)
  - **c** = Tricuspid valve closes, causing dicrotic notch
  - **x descent** = RV contraction, bulging the TC valve into the atra
  - **y descent** = passive blood flow from RA to RV
  - **Tricuspid valve opens**
  - **Tricuspid valve closes**
  - **Tricuspid valve opens**
  - **Tricuspid valve closes**

- **Subclavian vein**
- **Internal jugular vein**
- **External jugular vein**

- **ECG**
- **CVP**
- **Systole**
- **Diastole**

- **Tricuspid**
- **Valve closes**
- **Valve opens**

- **P**
- **T**
- **A**
- **V**
-**CVP wave relationship**

- Recorded at the end of expiration
- Measured by transducing the waveform of a central venous line
- Electronic transducer placed and zeroed at the level of the RA (the “phlebostatic axis” - usually the 4th intercostal space in the mid-axillary line is used)

**CVP WAVEFORM**

- **a** = atrial contraction
- **c** = closing and bulging of the tricuspid valve
- **x** = atrial relaxation
- **v** = passive filling of atrium
- **y** = opening of the tricuspid valve

**Determinants include:**

- right atrial pressure
- intravascular fluid volume
- venous capacitance/ tone
- mean systemic filling pressure
- right and left ventricular function and compliance
- pulmonary vascular resistance
- intrathoracic/pleural pressure
- intrabdominal pressure

**USE**

Value and waveform assists with diagnosis of:

- right ventricular infarction
- right heart failure and cor pulmonale
- tamponade
- Tricuspid regurgitation or stenosis
- Complete heart block
- Constrictive pericarditis
Determining:
- mechanical atrial capture with AV pacing
- presence of P waves in cases of SVT
- differential diagnosis of shock state
- correct central line placement

Do not use CVP in isolation to assess fluid responsiveness
- very poor relationship between CVP and blood volume and CVP/Delta CVP is a poor predictor of the hemodynamic response to a fluid challenge
- interpretation of CVP should be in association with information relating to other hemodynamic variables

**CAUSES OF RAISED CVP**
- Right ventricular failure
- Tricuspid stenosis or regurgitation
- Pericardial effusion or constrictive pericarditis
- Superior vena caval obstruction
- Fluid overload
- Hyperdynamic circulation
- High PEEP settings

**CVP WAVEFORM ANALYSIS**
- Dominant a wave - pulmonary hypertension, TS, PS
- Cannon a wave - complete heart block, VT with AV dissociation
- Dominant v wave - TR
- Absent x descent - AF
- Exaggerated x descent - pericardial tamponade, constrictive pericarditis
- Sharp y descent - severe TR, constrictive pericarditis
- Slow y descent - TR, atrial myxoma
- Prominent x and y descent - RV infarction

**FACTORS DETERMINING ACCURACY**
CVP measurement should be performed at end-expiration, ideally without
fluids running

- Placement of device tip (RA, RV, SVC, SCV, femoral vein)
- Levelling - the position on the patient that you want to be zero (usually level of RA)
- Zeroing - zero means atmospheric pressure
- Calibration - comparing zero and a level above to a gold standard (mercury sphygmomanometer)
- Damping - assess by a fast flush test, preferred co-efficient around 0.7
- Frequency response of the system (intrinsic + additional tubing) -> may significantly alter damping (preferred shorter stiffer tubing)
- Running averages rather than single spontaneous readings
- PEEP – PEEP of 10 cmH20 usually results in increase of CVP by ~3 cmH20 (depends on lung compliance)

OTHER INFORMATION

- minimal difference between SVC and femoral CVP measurements in the supine patient (in the absence of intra-abdominal hypertension)
- CVP cannot be measured if fluid is running through the same lumen, but if flow rates are slow CVP is minimally affected by infusions through other lumens of the same CVC

7-Temperature management under general anesthesia:

Introduction:

Body temperature is a vital sign and is tightly regulated for normal physiological functioning. Mean core temperature in healthy humans is 36.5°C-37.3°C. Intraoperative inadvertent changes in the body temperature occur quite commonly. Incidence of inadvertent hypothermia (up to 90%) is much higher than hyperthermia. Temperature fluctuations have harmful physiological effects and can adversely affect patient outcome.

Physiology of Thermoregulation

Temperature of core compartment of the body (head and thorax) is normally around 37°C. Periphery is typically 2°C-4°C cooler than the core. This gradient is maintained by tonic thermoregulatory vasoconstriction. Thermoregulation is the mechanism by which hypothalamus regulates body temperature at a stable
level. Infants regulate their temperature remarkably well, but it is less robust in neonates and elderly.

**Thermoregulation:**
The processing of thermal information occurs in three phases: afferent input, central regulation, and efferent responses. Hypothalamus is the primary central structure regulating temperature. Efferent responses include behavioral and autonomic regulation. Behavioral regulation is the most powerful mechanism and requires conscious perception of body temperature; it is 50% mediated by skin temperature. Autonomic responses include various mechanisms. Sweating is the only mechanism by which body dissipates heat in hot surroundings; each gram of sweat evaporated dissipates 0.58 kcal of heat.

**Thermoregulation under Anesthesia:** Under general anesthesia, patient relies on autonomic defenses and external thermal management for thermoregulation. Autonomic responses also are markedly impaired under anesthesia; most anesthetics increase warm response and reduce cold response thresholds. The interthreshold range increases up to 10-fold, from 0.3°C to about 2°C–4°C. Temperatures within this range do not trigger thermoregulatory defense and patients are poikilothermic. Hence, sweating is the best preserved thermoregulatory defense during general anesthesia. In contrast, vasoconstriction and shivering thresholds are markedly reduced, and efficacy of these responses is diminished even after being activated.

**Measurement of Intraoperative Body Temperature:**
Combination of core and mean skin temperature measurement is required to accurately estimate body heat content. Mercury-in-glass thermometers are slow, cumbersome, and no longer recommended. Electronic thermometers use thermistors and thermocouples. They are sufficiently accurate (±0.5°C), inexpensive, and most dependable modality. Infrared monitors detect heat given off by radiation and can measure temperature from tympanic membrane and forehead skin but are less reliable. Thermotropic liquid crystals incorporated in disposable sheets are also available.

Temperature can be monitored at various sites as described in. The site and device selection depend on the physician, type of surgery, and accessibility of monitoring sites. The least invasive modality that gives a reliable assessment of core temperature should be preferred. National Institute for Clinical Excellence (NICE) guidelines recommend temperature measurement at 1 h before induction, every 30 min intraoperatively, every 15 min in the
postanesthesia care unit, and every 4 h in the ward or every 30 min, if active warming is required in the ward.

**Hypothermia during General Anesthesia:** Hypothermia during general anesthesia occurs from a combination of anesthetic-induced impaired thermoregulation (cause vasodilation, inhibit vasoconstriction, and reduce metabolic rate by 20%-30%) and from exposure to cold environment. Heat transfer from the human body occurs in four ways: conduction, convection, radiation, and evaporation.

Hypothermia under general anesthesia has three phases: initial rapid decrease, slow linear reduction, and plateau phase as shown in. Like general anesthesia, neuraxial anesthesia also impairs behavioral and autonomic thermoregulation. It blocks all thermal input from anesthetized regions and reduces vasoconstriction and shivering thresholds by 0.6°C above the level of block.

**Inadvertent Intraoperative Hypothermia:** Inadvertent intraoperative hypothermia (core temperature <36°C) is the most common perioperative thermal disturbance. Risk is higher with prolonged surgery, extremes of age, extensive burns, lower preoperative temperature, severe trauma and major intraoperative, fluid shifts.

Effects of hypothermia: Prolonging anesthetic drugs actions, impairs coagulation and platelet function, increases blood loss and transfusion requirements, increases wound infections, prolongs hospital stay, causes postoperative discomfort, and increases heart rate, blood pressure, and plasma catecholamine levels.

Postanesthetic shivering: Incidence is higher in younger patients. Apparently benign, but several adverse effects such as increased oxygen consumption of up to 100%, raised intraocular and intracranial pressures, surgical incision stretch causing wound pain, and morbid myocardial outcomes are associated with it.

Risk of postanesthetic shivering is reduced by maintaining strict normothermia. Treatment options include skin surface warming, pharmacological treatment with meperidine (25 mg/intravenous [IV]). Meperidine reduces shivering threshold twice as much as vasoconstriction threshold. Dexmedetomidine is a newer agent which reduces vasoconstriction and shivering thresholds and is very effective in reducing shivering.

**Thermal Management Guidelines**
ASA standards require every patient receiving anesthesia to have temperature monitoring when clinically significant changes in body temperature are intended, anticipated, or suspected.

**Perioperative Thermal Manipulations:** Perioperative temperature fluctuations can be minimized by a variety of methods. Intraoperative warming, when patients are vasodilated due to anesthetic agents, is more effective, appropriate, and easier than treating hypothermia postoperatively.

**Preventing Redistribution Hypothermia**

1. **Preoperative warming:** Skin surface warming for only 30 min before induction of anesthesia has been shown to prevent redistribution hypothermia. The efficacy of prewarming children by increasing ambient temperature in the induction room and OT to 26°C for 30-40 min has been found to be safe and effective.

2. **Airway heating and humidification:**
   With use of low flow rates and semi-closed circuits, heat loss by evaporation from respiratory system is minimal.

3. **Warming intravenous fluids:** Administration of large quantity of cold fluids causes significant heat loss. Fluid warming is the only method that produces direct core warming and is recommended for all intraoperative infusions ≥500 ml in adults.

Rapid blood transfusion (>100 ml/min) may cause sudden decrease in temperature with serious consequences.

4. **Cutaneous warming:**
   The amount of heat lost through skin is roughly proportional to the exposed body surface area. Cotton blankets, surgical drapes, plastic sheets, reflective composites ("space blankets"), and sleeping bags are used. Insulation is provided by the layer of still air trapped beneath the device. A single layer reduces heat loss by approximately 30%; addition of extra layers further reduces heat loss only minimally.

**Active warming devices:**
Include circulating-water mattresses/garments, FAWs, resistive heating devices, negative pressure water warming systems, and radiant heaters.

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**8-Perioperative Neuromuscular Monitoring**

**Introduction**
Neuromuscular monitoring devices were introduced into clinical practice in the 1970s. Peripheral nerve stimulators, provide an electrical stimulus to a motor nerve and the response of corresponding muscle subjectively evaluated. A standard peripheral nerve stimulator provides several patterns of nerve stimulation, including train-of-four (TOF), double-burst, tetanic, and post-tetanic count. Qualitative (and quantitative) monitors are needed to determine onset of neuromuscular blockade, maintain the required depth of muscle relaxation during the surgical procedure, and assess an appropriate dose of reversal agent.

Several different technologies have been developed, including mechanomyography, electromyography, acceleromyography, kineograph, and phononomyography.

**BASIC PRINCIPLES OF NEUROMUSCULAR MONITORING**

Two types of neuromuscular monitors have been developed for use in the perioperative period.

1. Qualitative monitors (or peripheral nerve stimulators) are devices that deliver a stimulus to a peripheral nerve, and the subsequent muscular response is visually or tactiley observed.

2. In contrast, quantitative monitors objectively measure the strength of muscle contraction and display the results on a screen (0-1.0 or 0%-100%).

Following electrical stimulation of a muscle, the strength of contraction is determined by the number of muscle fibers activated. Maximal contraction occurs when the electrical stimulation is sufficient to cause all muscle fibers to contract. In most patients, this threshold is approximately 40 to 50 mA for the ulnar nerve.

The 2 most common sites for neuromuscular monitoring are the ulnar nerve/adductor pollicis muscle and the facial nerve/orbicularis oculi.

In contrast, the adductor pollicis is more sensitive to the effects of NMBAs, and monitoring at this site may more accurately reflect recovery of pharyngeal muscles (the last muscles to recover from the effects of muscle relaxants).

A TOF count can be performed to assess the depth of neuromuscular blockade. Tracheal intubation can be performed when all 4 responses have disappeared. The ulnar nerve/adductor pollicis should be assessed at the end of the procedure before the administration of reversal to properly determine the degree of neuromuscular blockade. Neostigmine should not be administered until the TOF count recovers to at least 2 or 3, while sugammadex is effective in reversing any level of neuromuscular blockade.
QUALITATIVE NEUROMUSCULAR MONITORING:

A - **Standard peripheral nerve stimulator** provides several patterns of nerve stimulation. Four stimuli are provided at a 2-Hz frequency (every 0.5 seconds).

B - **TOF monitoring** should be used to assess recovery of neuromuscular function at the end of the surgical procedure.

- **Double-burst stimulation (DBS)**: Two short (or 3) 50-Hz bursts are provided, separated by a 750-millisecond interval.

D - **Tetanic stimulation**

involves the application of high-frequency impulses for 5 seconds.
Quantitative neuromuscular monitors are devices which measure and quantify the degree of neuromuscular blockade and display the results numerically (0-1.0 or 0%-100%). To determine whether full recovery of neuromuscular function has occurred at the time of tracheal extubation in all patients, quantitative monitors are required.
Chapter 10
Analysis of Oxygen, Anesthesia Agent and Flows in Anesthesia Machine

INTRODUCTION
The technical advancement in anesthesia workstations has made the intra-operative anesthesia better and safer. Monitoring devices, such as an oxygen analyzer with an audible alarm, carbon dioxide analyzer, a vapour analyzer, whenever a volatile anesthetic is delivered have also been recommended by various anesthesia societies.

Figure: Monitor showing gas analysis and electronic flowmeters on anesthesia workstation

HISTORICAL PERSPECTIVE:
The use of the mass spectrometer was introduced in 1981 for monitoring anesthetic gases on breath-by-breath basis. Later, stand-alone mass spectrometers, like the Ohmeda 6000, were introduced which provided continuous readings as compared to intermittent
analysis in centralized devices. Subsequently, various stand-alone sidestream gas analyzer were introduced which were based on infrared spectrometry, Raman spectrometry, infrared photoacoustic spectrometry and piezoelectric crystal agent analysis technology. These devices could identify the specific agents and thus were of help in case any agent was misfed in the vaporizer mistakenly.

A-OXYGEN ANALYSIS

Oxygen analyzer are recommended for all anesthesia cases as measuring oxygen is of utmost importance to prevent any untoward event related to hypoxia. The oxygen is also monitored at the patient end using paramagnetic analyzer.

1-Paramagnetic oxygen analyzer:

An oxygen molecule has unpaired electrons in its outer electron ring which makes it paramagnetic and thus is attracted in the magnetic field. This forms the working principle of paramagnetic oxygen analyzer.

The analyzer comprise of two chambers (sampling and reference chamber) with a sensitive pressure transducer in between. The sampling chamber receives sample gas via sampling tube while a reference chamber receives room air.

The pressure difference across the transducer is proportional to the oxygen partial pressure difference between the sample gas and the reference gas (room air, containing 21% oxygen).

They are accurate and highly sensitive as well with a rapid response allowing measurement of oxygen on a breath-to-breath basis. These devices are incorporated with water trap from the sampled gas as water vapours could affect oxygen analysis.

2-Galvanic oxygen analyzer

These analyzer work on the basis of chemical phenomenon generated by oxygen molecules. Oxygen diffuses across the membrane and an electrolyte solution to a cathode (gold or silver). This is connected to a lead anode via the electrolyte solution. This generates an electrical current which is proportional to partial pressure of oxygen in the sampled gas. The chemical reaction involves: 

\[ \text{Pb} + 2\text{OH}^- \rightarrow \text{PbO} + \text{H}_2\text{O} + 2\text{e}^- \]

They are usually connected to inspiratory limb. These require calibration with 100% oxygen and room air (21% oxygen) and have a response time of around 20 seconds with an accuracy of 3%. These do not require a water trap as water vapour does not affect their performance. These analyzer have a
limited life span because of the depletion of the battery due to continuous exposure to oxygen.

3- Polarographic oxygen analyzer (Clark electrode)

These analyzers have a similar principle like that of a galvanic oxygen analyzer. Here, the oxygen molecules move across a Teflon membrane and current flows between a silver cathode and a platinum anode.

B-Other gaseous (carbon dioxide, nitrous oxide and volatile agents) analysis:

In anesthesia practice, the measurements of other anesthetic gases like nitrous oxide, volatile anesthetic agents and carbon dioxide are also required. These could be analyzed by using various techniques like infrared absorption spectroscopy, photoacoustic spectroscopy, silicone rubber and piezoelectric absorption, refractometry, Raman scattering and mass spectrometry. The infrared analyzers are commonly used for measuring anesthetic agent's concentration by side-sampling method on the anesthesia machines.

1- Infrared absorption spectroscopy

Most commonly, either a dispersive infrared (DIR) method or a non-dispersive infrared (NDIR) method is used to isolate the absorbance characteristics of the gas sample.

The dispersive method uses a single optical filter and either a prism or a diffraction grating to separate the component wavelengths for each agent. The non-dispersive technique incorporates multiple narrow-band optical filters through which the infrared emission is passed to determine the gas present in the mixture.

The absorption of infrared by a specific molecule occurs at a specific wavelength and according to “Beer-Lambert law” (logarithmic dependence between the transmission of light through a substance and the concentration of that substance).

This forms the principle of identifying and analysing the concentration of the gas molecule like the anesthetic agent. They have means of detecting the transmitted infrared (photocells or thermopiles), amplifying and processing the signal.

The recent analyzer avoid such problems by analysing series of absorption peaks and thus correct identification of the volatile agent.
The infrared absorption spectroscopy may be used with both mainstream and sidestream sampling method. The mainstream analyzer are attached to patient end but add bulk to the circuit. They are encased in plastic housing having a source of infrared and a detector as well. Presently, these are available for analysing carbon dioxide. They do not require sampling of gas from the breathing circuit.

Sidestream analyzer are more commonly used in modern anesthesia workstation and require sampling of gas. In modern gas analyzer, the gas sampling rate from the breathing circuit is in the range of 50 to 250 mL/min. The response time is based on sampling speed and also on length of sampling tube which may be 2.5 s for 3 m tubing approximately. These require water trap as water vapour hinders analysis.

2-Refractometry
The monochromatic light source emits beams through a gaseous medium and are focused on a screen. This creates a typical pattern of bands which depends on the light waves arriving in or out of phase of each other, which in turn will depend on the gaseous medium’s refractive index and concentration. Thus, the concentration of agent is analysed and displayed. Rayleigh refractometers have series of prisms which split the light source through sampling and control tubes.

These devices are calibrated for a particular gas. These analyzer do not give breath-to-breath analysis. They are a useful tool to calibrate vaporiser output and detect environmental anesthetic gas exposure.

3-Piezoelectric absorption
The analyzer use a piezoelectric compound such as quartz and resonance property is used for analysis of an anesthetic agent. In such devices, two quartz crystals (one coated with silicone based oil and other remains uncoated) are mounted between electrodes. The oil-coated quartz crystal absorbs the halogenated vapours and changes the resonant frequency in proportion to the concentration of vapour present. These devices have a fast response time. They are limited by inability to differentiate individual vapours of anesthetic gases.

4-Raman scattering
This technique uses intense, coherent and monochromatic light (i.e., from a laser). When this light interacts with an object i.e. anesthetic gas molecule, the light will be scattered, usually elastically, with no change in energy state (Rayleigh scattering). Also, some of the light’s energy will be absorbed leading to transformational shift, either by absorption of the energy or by
release of the energy as a photon, with a different wavelength (Raman scattering). This principle is used for anesthetic gas analysis.

The filters are specific for the gas to be analyzed. The concentration of anesthetic gas is proportional to the emitted photons through the specific filter. These analyzer have fast response times. They can analyze multiple anesthetic agents.

5-Mass spectrometry

For such analyzer, a sample gas is drawn or injected into a low-pressure sample chamber which is connected to another chamber, at a pressure nearing that of a vacuum created by vacuum pumps. The sample gas molecules are ionized in the second chamber and accelerated by a cathode plate. The ions are separated based on the ion's mass and charge by fixed magnets or electromagnets. The ions are narrowband-filtered and detected by photo-voltaic receptors, and the signal amplified and processed. Thus, the identity and concentration of the molecule is displayed. These have a longer response time but are very accurate.

PRACTICAL CONCERNS WITH ANESTHESIA GAS ANALYZER

The conventional anesthesia sidestream gas analyzer uses high sample flow rate (which can exceed 200 mL/min). This may be of concern in paediatric anesthesia.

The sidestream analyzer are also affected with water vapour, liquid water and patient secretions. So the design of the sensor should be such that these are controlled and prevented from reaching and damaging the analyzer or influencing the accuracy of the measurements.

The water trap and Nafion tubing is a simple solution being used to alleviate this concern.

SITE OF SAMPLING FOR GAS ANALYSIS

The two ways for sampling gas for analysis may be by either a side stream or a mainstream analyzer.

1-Side stream sampling:

The tube is connected to a lightweight adapter near the patient’s end of the breathing system, also, the point of sampling should always be as near as possible to the patient's airway. It delivers the gas to the sample chamber. The sampled gas may be returned to breathing circuit and is of concern when low flows are used.

2-Mainstream type of analyzer, the sample chamber is positioned within the gas stream near the patient's end of the breathing system. It does not
remove any gas and no issue of water condensation from humidity from expired air happens.

MEASUREMENT OF VOLUME AND FLOW OF GASES

The measurement of flows and volumes are essential for anesthetists. Types of flow

Many physical variables influence whether the flow is laminar or turbulent. Laminar flow is efficient, with layers passing smoothly over each other producing a parabolic flow profile, with the greatest velocity centrally. It is determined by the Hagen-Poiseuille formula, \( Q = \frac{P\pi r^4}{8\eta l} \) (where \( P \) is pressure drop, \( r \) is the radius of the tube and \( l \) is the length of the tube). This implies that flow is directly proportional to the pressure drop, proportional to the fourth power of the radius and related to the viscosity but not the density of the gas.

Turbulent flow is less efficient, with multiple eddy currents occurring in the overall direction of flow. Because of the variable nature of turbulence, there is no precise and comprehensive equation to calculate flow, but turbulent flow is related to the square root of the pressure drop and density of the gas rather than its viscosity.

Measurement principles

DEVICES FOR FLOW AND VOLUME MEASUREMENT

The various devices available for measurement of flow and volume may also give flow characteristics.

Pneumotachograph:
The technique of pneumotachograph measures flow by pressure drop across a resistance in the gas flow pathway. The water vapour and its condensation may affect the accuracy of flow measurements. These sensors are accompanied with heating element to prevent water condensation. It can be used for both the inspired and expired flow.

Rotameters
Flowmeters measure the flow rate of a gas passing through them. They are individually calibrated for each gas. Calibration occurs at room temperature and atmospheric pressure (sea level). They have an accuracy of about ±2.5%. For flows above 1 L/min, the units are L/min, and for flows below that, the units are 100 mL/min.

Components
1. A flow control (needle) valve.
2. A tapered (wider at the top), transparent plastic or glass tube.
3. A lightweight rotating bobbin or ball. Bobbin-stops at either end of the tube ensure that it is always visible to the operator at extremes of flow.

**Mechanism of action**

1. When the needle valve is opened, gas is free to enter the tapered tube.
2. The bobbin is held floating within the tube by the gas flow passing around it. The higher the flow rate, the higher the bobbin rises within the tube.
3. The effect of gravity on the bobbin is counteracted by the gas flow. A constant pressure difference across the bobbin exists as it floats.
4. The clearance between the bobbin and the tube wall widens as the gas flow increases.
5. At low flow rates, the clearance is longer and narrower, thus acting as a tube. Under these circumstances, the flow is laminar and a function of gas viscosity (Poiseuille’s law).
6. At high flow rates, the clearance is shorter and wider, thus acting as an orifice. Here, the flow is turbulent and a function of gas density.
7. The top of the bobbin has slits (flutes) cut into its side. As gas flows past it, the slits cause the bobbin to rotate. A dot on the bobbin indicates to the operator that the bobbin is rotating and not stuck.
8. The reading of the flowmeter is taken from the top of the bobbin. When a ball is used, the reading is generally taken from the midpoint of the ball.
9. When very low flows are required, e.g. in the circle breathing system, an arrangement of two flowmeters in series is used. One flowmeter reads a maximum of 1 L/min allowing fine adjustment of the flow. One flow control per gas is needed for both flowmeters.
10. There is a stop on the oxygen flow control valve to ensure a minimum oxygen flow of 200–300 mL/min past the needle valve. This ensures that the oxygen flow cannot be discontinued completely.

**Problems in practice and safety features**

1. The flow control knobs are colour-coded for their respective gases. The oxygen control knob is situated to the left (in the UK) and, in some designs, is larger with larger ridges and has a longer stem than the other control knobs, making it easily recognizable. In the USA and Canada, the oxygen control knob is situated to the right.
2. The European Standard for anaesthetic machines (EN 740) requires them to have the means to prevent the delivery of a gas mixture with an oxygen concentration below 25%. Current designs make it impossible for nitrous oxide to be delivered without the addition of a fixed percentage of oxygen. This is achieved by using interactive oxygen and nitrous oxide controls. This helps to prevent the possibility of delivering a hypoxic mixture to the patient. In the mechanical system, two gears are connected together by a precision stainless steel link chain. One gear with 14 teeth is fixed on the nitrous oxide flow control valve spindle. The other gear has 29 teeth and can rotate the oxygen flow control valve spindle, rather like a nut rotating on a bolt. For every 2.07 revolutions of the nitrous oxide flow control knob, the oxygen knob and spindle set to the lowest oxygen flow will rotate once. Because the gear on the oxygen flow control is mounted like a nut on a bolt, oxygen flow can be adjusted independently of nitrous oxide flow.

3. A crack in a flowmeter may result in a hypoxic mixture. To avoid this, oxygen is the last gas to be added to the mixture delivered to the back bar.

4. Flow measurements can become inaccurate if the bobbin sticks to the inside wall of the flowmeter. The commonest causes are:
   a) dirt: this is a problem at low flow rates when the clearance is narrow. The source of the dirt is usually a contaminated gas supply. Filters, acting before gas enters the flowmeters, will remove the dirt
   b) static electricity: the charge usually builds up over a period of time, leading to inaccuracies of up to 35%. Using antistatic materials in flowmeter construction helps to eliminate any build-up of charge. Application of antistatic spray removes any charge present.

5. Flowmeters are designed to be read in a vertical position, so any change in the position of the machine can affect the accuracy.

6. Pressure rises at the common gas outlet are transmitted back to the gas above the bobbin. This results in a drop in the level of the bobbin with an inaccurate reading. This can happen with minute volume divider ventilators as back pressure is exerted as they cycle with inaccuracies of up to 10%. A flow restrictor is fitted downstream of the flowmeters to prevent this occurring.

7. Accidents have resulted from failure to see the bobbin clearly at the extreme ends of the tube. This can be prevented by illuminating the flowmeter bank and installing a wire stop at the top to prevent the bobbin reaching the top of the tube.

8. If facilities for the use of carbon dioxide are fitted to the machine, the flowmeter is designed to allow a maximum of 500 mL/min to be added to the FGF. This ensures that dangerous levels of hypercarbia are avoided.

9. Highly accurate computer controlled gas mixers are available.
**Ultrasonic flowmeters:**
These are based on change in velocity of an ultrasound signal with the change in gas flow.

**Electronic flowmeters:**
These are most commonly used in modern day anesthesia workstation. The gas flow is indicated on the screen in the form of bar. Such flowmeters comprise of a needle valve by which gas is conducted to a chamber of known volume having solenoid. The gas is held here till the transduced pressure within the chamber reaches a preset limit. This measures the gas flow.
# Chapter 11

## Medical Abbreviations List

<table>
<thead>
<tr>
<th>Number</th>
<th>Abbreviation</th>
<th>Original meaning</th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>EMS</td>
<td>Emergency Medical Service</td>
</tr>
<tr>
<td>2.</td>
<td>ABCDE</td>
<td>Airway, Breath, Circulation, Disability, exposure</td>
</tr>
<tr>
<td>3.</td>
<td>CPR</td>
<td>Cardiac Pulmonary Resuscitation</td>
</tr>
<tr>
<td>4.</td>
<td>CBC</td>
<td>complete blood picture</td>
</tr>
<tr>
<td>5.</td>
<td>ABG</td>
<td>arterial blood gases</td>
</tr>
<tr>
<td>6.</td>
<td>ECG</td>
<td>Electro Cardio Gram</td>
</tr>
<tr>
<td>7.</td>
<td>STEMI</td>
<td>St Segment elevation myocardial infarction</td>
</tr>
<tr>
<td>8.</td>
<td>IV</td>
<td>Intravenous</td>
</tr>
<tr>
<td>9.</td>
<td>O2</td>
<td>Oxygen</td>
</tr>
<tr>
<td>10.</td>
<td>B/m</td>
<td>Breath per Minute</td>
</tr>
<tr>
<td>11.</td>
<td>HR</td>
<td>Heart Rate</td>
</tr>
<tr>
<td>12.</td>
<td>5 L/Minute</td>
<td>5 Liters per Minute</td>
</tr>
<tr>
<td>13.</td>
<td>38 C</td>
<td>38 Degrees Celsius</td>
</tr>
<tr>
<td>14.</td>
<td>rTPA</td>
<td>Tissue Activator(streptokinase) Plasminogen</td>
</tr>
<tr>
<td>15.</td>
<td>Hb</td>
<td>Hemoglobin</td>
</tr>
<tr>
<td>16.</td>
<td>HCT</td>
<td>Hematocrit</td>
</tr>
<tr>
<td>17.</td>
<td>degrees F</td>
<td>degrees Fahrenheit</td>
</tr>
<tr>
<td>18.</td>
<td>mm Hg</td>
<td>Millimeters of mercury</td>
</tr>
<tr>
<td>19.</td>
<td>BLS</td>
<td>Basic life support</td>
</tr>
<tr>
<td>20.</td>
<td>PaO₂</td>
<td>Arterial Oxygen Tension</td>
</tr>
<tr>
<td>21.</td>
<td>JVP</td>
<td>Jugular venous pulse</td>
</tr>
<tr>
<td>22.</td>
<td>PaCO₂</td>
<td>Arterial Carbon dioxide tension</td>
</tr>
<tr>
<td>23.</td>
<td>NIV</td>
<td>non-invasive ventilation</td>
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<tr>
<td>No.</td>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>24.</td>
<td>COPD</td>
<td>Chronic Obstructive Pulmonary Disease</td>
</tr>
<tr>
<td>25.</td>
<td>CRT</td>
<td>capillary refill time</td>
</tr>
<tr>
<td>26.</td>
<td>mmHg</td>
<td>ML Meter mercury</td>
</tr>
<tr>
<td>27.</td>
<td>16 G IV cannula</td>
<td>16 gauge Intravenous Cannula</td>
</tr>
<tr>
<td>28.</td>
<td>ACS</td>
<td>Acute Coronary Syndrome</td>
</tr>
<tr>
<td>29.</td>
<td>HDU</td>
<td>High Definition Unite</td>
</tr>
<tr>
<td>30.</td>
<td>ICU</td>
<td>Intensive Care Unite</td>
</tr>
<tr>
<td>31.</td>
<td>AED</td>
<td>Automated External Defibrillator</td>
</tr>
<tr>
<td>32.</td>
<td>VF</td>
<td>ventricular fibrillation</td>
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<tr>
<td>33.</td>
<td>EC</td>
<td>Electrical Cardioversion</td>
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<tr>
<td>34.</td>
<td>MS</td>
<td>ML second</td>
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<tr>
<td>35.</td>
<td>µg/kg</td>
<td>Microgram per Kilogram</td>
</tr>
<tr>
<td>36.</td>
<td>M Eq/kg</td>
<td>ML Equivalent per Kilogram</td>
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<tr>
<td>37.</td>
<td>IO</td>
<td>Interosseous</td>
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<tr>
<td>38.</td>
<td>RSI</td>
<td>Rapid sequence intubation</td>
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<tr>
<td>39.</td>
<td>ETT</td>
<td>Endotracheal tube</td>
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<tr>
<td>40.</td>
<td>ABLS</td>
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</tr>
<tr>
<td>41.</td>
<td>WHO</td>
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<td>42.</td>
<td>SC</td>
<td>subcutaneous</td>
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<tr>
<td>43.</td>
<td>CPAP</td>
<td>continuous positive airway pressure</td>
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<td>44.</td>
<td>BiPAP</td>
<td>bi-level positive airway pressure</td>
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<tr>
<td>45.</td>
<td>PAV</td>
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<tr>
<td>46.</td>
<td>NAVA</td>
<td>neutrally adjusted ventilator assist NAVA</td>
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<td>47.</td>
<td>FiO2</td>
<td>Oxygen fraction</td>
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<td>48.</td>
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<td>positive end-expiratory pressure</td>
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<td>49.</td>
<td>BVM</td>
<td>bag-valve mask</td>
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<td>50.</td>
<td>ABC=A,B,C</td>
<td>Airway Breath and Circulation</td>
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<td>51.</td>
<td>GCS</td>
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<td>52.</td>
<td>AV</td>
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</tr>
<tr>
<td>53.</td>
<td>LBBB</td>
<td>Left Bundle Branch Block</td>
</tr>
<tr>
<td>54.</td>
<td>RBBB</td>
<td>Right Bundle Branch Block</td>
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<tr>
<td>55.</td>
<td>apTT</td>
<td>Activated partial thromboplastin time</td>
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<td>56.</td>
<td>pplat</td>
<td>Plateau Pressure</td>
</tr>
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<td>No.</td>
<td>Abbreviation</td>
<td>Full Form</td>
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<td>57.</td>
<td>Vt</td>
<td>Tidal volume</td>
</tr>
<tr>
<td>58.</td>
<td>STEMI</td>
<td>Non ST segment elevation myocardial infarction</td>
</tr>
<tr>
<td>59.</td>
<td>NSTEMI</td>
<td>Non ST segment elevation myocardial infarction</td>
</tr>
<tr>
<td>60.</td>
<td>AP X ray</td>
<td>Anterior posterior X Ray</td>
</tr>
<tr>
<td>61.</td>
<td>AF</td>
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<tr>
<td>62.</td>
<td>VF</td>
<td>Ventricular Fibrillation</td>
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</tbody>
</table>

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- General Directorate of Technical Education for Health