CHAPTER-1: BASIC CONCEPT

RESPIRATORY ANATOMY:

Larynx

- It is the **organ of voice**
- It extends from root of tongue to trachea and **lies opposite C3 to C 6 .**
- Distance between the teeth (upper incisor) and **vocal cords is 12 -15 cm and between vocal cords and carina is 10 to 15 cm .**
- **The glottis (The space between two vocal cords) is the narrowest part in adults.**
- In contrast, **Subglottis (cricoid ring) is the narrowest part in children upto the age of 5 year.T**his narrowest portion of pediatric airway provides an adequate seal for mechanical ventilation (cuff is not required for seal) — **In children uncuffed endotracheal tubes are used .**
- **Arterial supply:** By laryngeal branches of superior and inferior thyroid arteries.
- **Nerve supply: All Muscles** of the larynx are supplied **by recurrent laryngeal** nerve except cricothyroid which is supplied by external branch of superior laryngeal nerve.
- **Sensory Supply**: up to vocal cord by internal branch of **superior laryngeal nerve and below vocal cord by recurrent laryngeal nerve.**

Trachea

- Trachea starts from cricoid ring (at C6 level and ends at carina T4-5). Carina is the portion where the trachea divides into right and left main bronchus
- **Carina corresponds to manubriosternal junction (angle of louis) anteriorly and t4 vertebrae posteriorly ,** The length of trachea is 10 to 12 cms. and **the diameter is 1.2 - 1.4 cm**

Bronchial tree

- At carina trachea divides into right and left main bronchus. **Distance of Carina from upper incisors is 28 to 30cms**
- **The right main bronchus is shorter (2.5 cm), wider and at a verticle angle (25°)** therefore **foreign body lodgment is more common on right side.** For the same reason, **chances of endotracheal tube to be positioned on right side (endobronchial intubation) are more** (Normally endotracheal tube should be in trachea).
- Left bronchus **is longer (5 cm), narrower and at 45° angle**.
- **In children the angle of both right and left bronchus is same i.e.,** 55° (up to the age of 3 years).
- Further branching of bronchi forms bronchioles which proceed to terminal bronchioles then respiratory bronchioles and finally alveolar duct and alveolar sac.

REGULATION OF RESPIRATION

- Normal respiration is maintained by expiratory (ventral group) and inspiratory (Dorsal group) neurons of **Medulla.** ***Pneumotaxic center*** in upper pons and ***Apneustic center*** in lower pons has regulatory effect on respiration.
- **These central respiratory centers are most sensitive to change in CSF pH which in turn is influence by partial pressure of CO2in blood (pC02).** Increase in pC02 stimulates the respiration while decrease in pC02 inhibits respiration.
- Besides these central receptors, **peripheral chemoreceptors (carotid & aortic bodies)** send stimuli to respiratory center to regulate the respiration. **These chemoreceptors are**

stimulated by rise in pCO2, or decrease in Ph (rise in H+) or decrease in p O2 of blood

Muscles of respiration:

INSPIRATION

- Diaphragm is most important muscled of inspiration (moves 1.5 cm in quiet respiration and 6 to 10 cms in deep breathing).
- External intercostals, pectoralis minor and scalene also assist in normal inspiration.
- Pectoralis major, latissimus dorsi and sternomastoid are needed during deep inspiration.
- Respiration in males is abdominothoracic while in children and females it is thoracoabdominal.

Expiration: Expiration is normally passive. Forced expiration is mediated by internal intercostals and abdominal muscles.

During anaesthesia with inhalational agents expiration is active (mediated by abdominal muscles)

VENTILATION/PERFUSION(V/Q)

- Both ventilation and perfusion is more at bases as compared to apex but perfusion at base is comparatively higher decreasing V/Q ratio towards base (from 2.1 at apex to 0.3 at base, average 0.8).
- This ventilation perfusion mismatch is responsible for producing alveolar dead space (i.e., alveoli are only ventilated but not perfused, wasting the oxygen in alveoli).
- This V/Q mismatch creates alveolar to arterial oxygen difference [(A-a)pO2 difference]which is normally 3 to 5 mmHg.
- This A-a difference is increased in lung **pathologies affecting alveoli like pulmonary edema, ARDS and interstitial lung disease.**

AIRWAY RESISTANCE.

- Airway resistance is the ***opposition to air flow by the forces of friction in the airways. The most important determinant of airway resistance is the radius of airways .***
- Airway resistance is inversely related to fourth power of radius — Decrease in radius of airway increases the airway resistance and vice-versa. So, Single large airway provides small resistance and single small airway provides more resistance.
- Now you must be thinking, smallest airway should provide the maximum resistance. But, this is not the case.Carefully read I have written, Single small airway provides maximum resistance. However, Resistance to airflow depends to numbers of parallel pathway present. Small airways have many small pathways, which decrease resistance.
- Therefore, small airways have less resistance than intermediate airways (as the number of parallel intermediate airways are very much less than small airways).
- Large airways — Trachea- Less resistance due to large radius
- **Intermediate airway (max. resistance) Main Bronchus (Bronchi)**
- Small airways — Bronchiole, terminal bronchiole, respiratory bronchiole- Less resistance due to numerous parallel small airways

ALSO KNOW:

For air to flow in lungs a pressure gradient must develop to overcome the airway resistance. This pressure gradient depends on airway calibre and pattern of airflow.

At laminar flows (which occurs below the main bronchi where velocity is less) resistance is proportional to flow rates but at turbulent flow (seen in trachea and main bronchi) resistance is square of flow rates. In other words it can be said that maximum airway resistance to airflow occurs in trachea and then main bronchus.

- Velocity (V) is proportional to flow (Q) divided by the area of the conduit (A):
- Velocity (V)=Flow(Q)/Total cross sectional area(A)
- Therefore, Q = A x V, and if flow stays constant, velocity increases in direct proportion to any decrease in A
- **Total airwaycross sectional area:**Note the extremely rapid increase in total **Total airwaycross sectional area** in the respiratory zone. As a result, forward velocity of gas during inspiration falls to a very low level in this zone.
- **Remember:**The average velocity of the blood is high in the aorta, **Total cross sectional area** declines steadily in the smaller vessels, and is lowest in the capillaries, which have 1000 times the *total* of the aorta

LAMINAR FLOW	**TURBULENT FLOW**
• Produced when gasses pass through straight tube • Flow is smooth • ***Reynolds number <2000***^{Q} • Dependent on viscosity of gas • **Hagen Poiseulle law** is applicable: [$Q \alpha \pi(P_1-P_2)r^4 /8\eta l$] where, Q= flow rate P_1-P_2 = pressure gradient between ends of the tube η= viscosity l = length of tube 1. Flow is directly proportional to pressure gradient ***2. Flow is directly proportional to***	• Produced when gasses pass through bent tube or flow rate is very high • Flow is rough • ***Reynolds number > 2000***^{Q} [$Re= \rho DV/\eta$] where, Re= Reynolds number ρ= density D= diameter of tube V= velocity η= viscosity • Dependent on density of gas

fourth power of radius of the tube ^{Q} 3. Inversely proportional to viscosity 4. Inversely proportional to length of tube	

DEAD SPACE

Total dead space also called as physiological dead space + anatomical dead space +Alveolar dead space.

Anatomical Dead Space

It is constituted by air which is not participating in diffusion. Therefore it is constituted by air present in nose, trachea and bronchial tree (up to terminal bronchioles). Normally it is 30% of tidal volume or 2 ml/kg or 150ml.

Anatomical dead space is increased in:	**Anatomical dead space is decreased by:**
i. Old age ii. Neck extension iii. Increasing lung volume (like it is more in inspiration) iv. A tropine (causes bronchodilatation) v. Anaesthesia mask, circuits vi. Intermittent positive pressure ventilation (IPPV) and positive end expiratory pressure (PEEP). vii. Jaw protrusion viii. Bronchodilators	i. Intubation (nasal cavity is bypassed and diameter of tube is less than airway diameter) ii. Neck flexion iii. Bronchoconstrictors iv. Tracheostomy (upper airways and nasal cavity bypassed) v. Hyperventilation (decreasing lung volume)

Alveolar Dead Space
Constituted by alveoli which are only ventilated but not perfused. It is 60 to 80 ml in standing position and zero in lying position (in lying position perfusion is equal in all parts of lung). **It is increased by:** i. Lung pathologies affecting diffusion at alveolar capillary membrane like interstitial lung disease, pulmonary embolism, pulmonary edema and ARDS. ii. General anaesthesia iii. IPPV (Intermittent positive pressure ventilation). iv. PEEP (Positive end expiratory pressure). v. Hypotension.

Anaesthesia and Dead Space

- All anaesthesia circuits, masks, humidifiers increases the anatomical dead space.
- Endotracheal tubes, tracheostomy decreases the anatomical dead space bypassing the upper airways
- All inhalational agents increase both anatomical and alveolar dead space. Anatomical dead space is increased because all these agents are bronchodilators. Alveolar dead space is increased because of hypotension produced by these agents (V/Q mismatch).

- Positions during anaesthesia especially lateral position causes more ventilation in upper lung(non dependent) and more blood flow in lower lung (dependent lung) so increasing the V/Q mismatch and hence alveolar dead space. Other positions like Trendelenburg, lithotomy also causes the V/Q mismatch.
- Anaesthesia ventilation techniques like IPPV (Intermittent positive pressure ventilation), PEEP (Positive end expiratory pressure) increase both anatomical and alveolar dead space.

Anatomical dead pace is increased by increasing lung volume and alveolar dead space is increased because of hypotension produced by IPPV and PEEP (compression of venules in alveolar septae and interstitial tissue because of dilated alveoli by PEEP and IPPV leads to increased venous return and compression of small arteries lead to decrease in pulmonary blod flow. Both these factors finally decrease the cardiac output and thus, causing hypotension).
Secondly, alveolar dead space is also increased by PEEP because normal alveoli are over distended during PEEP increasing V/Q mismatch.

Oxygen

- Normal oxygen uptake is 50ml/min.
- Oxygen is mainly carried in blood attached to haemoglobin (1 gm of Hb carries 1.34 ml of oxygen), very less amount, 0.003 ml/dl/mmHg is carried as dissolved fraction. Oxygen content of arterial blood is 20 ml/dl and that of venous blood is 15 ml/dl.

Oxygen dissociation curve:

- Normally Hb is 97% saturated at normal partial pressure (pO_2) of oxygen which is 95 to 98 mm Hg.
- At 60 mmHg, Saturation is still 90%.after this point there is sudden drop in oxygen saturation leading to significant desaturation of Hb(cyanosis appears when pO_2 fall below 50 to 60 mmHg).
- P_{50} is the partial pressure at which oxygen saturation is 50% the partial pressure of oxygen for 50% saturation is 26 mmHg. P_{50} is not affected by anaesthetics.
- Bohr effect: Alkalosis shifts O_2 dissociation curve to left and acidosis to right.
- Oxygen flux: it is the amount of oxygen leaving left ventricle / minute.
- It is 1,000 ml/min.

Shifted to right	**Shifted to left**
Decreased oxygen affinity to hemoglobin	o **Increased oxygen affinity to hemoglobin**
Increased P50	o Decreased P50
Increased oxygen delivery to tissues(Mn:All increase)	**Decrease oxygen delivery to tissues**
o Causes • **Increase H+ion i.e Decreased pH (Acidosis)** • **Increased temperature**	o Causes : - • **Increased pH (alkalosis**

• **Increased PCO2** • **Increased 2,3 DPG in-** i)Growth hormone, Androgen, thyroid hormone ii) **Exercise** iii) **Tissue hypoxia** iv) **High altitude** v) **Anemia** vi) Alkalosis vii) Cyanotic CHD viii) Pregnancy ix) Chemicals : - **Inosine**/ Pyruvate, PEP, phosphate	• **Decreased temperature** • **Decreased PCO2** • Decreased 2,3 DPG in **Stored blood**

LUNG VOLUMES & CAPACITIES:

LUNG

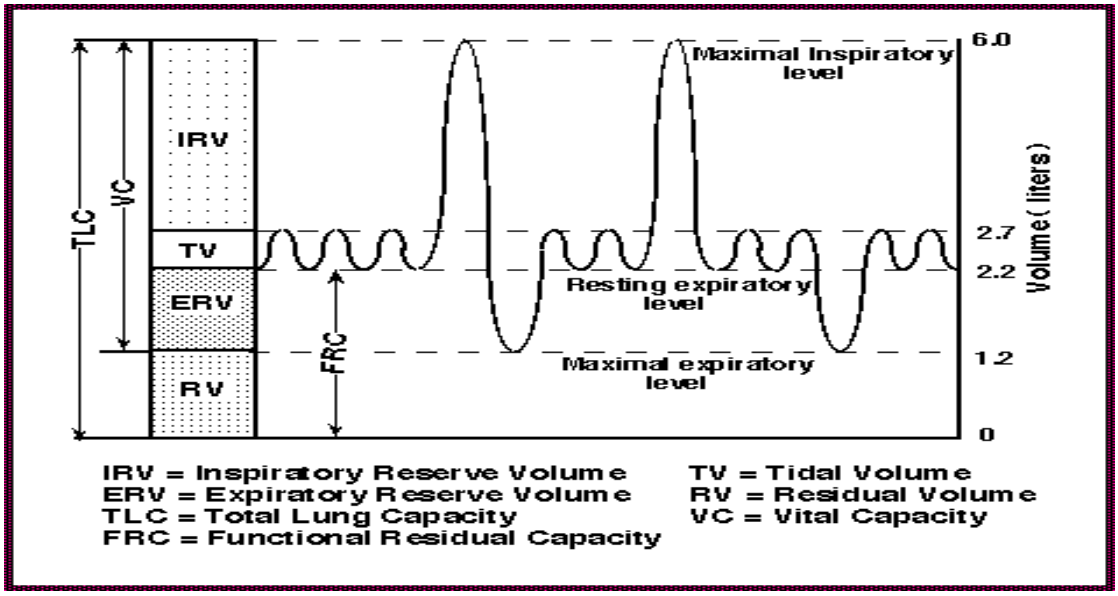
VOLUME			CAPACITIES		
Tidal volume (T.V)	500ml[Q]	Is the air that moves into the lung with each normal inspiration or the volume of air that moves out of lung with each expiration	Inspiratory capacity I C = TV+IRV	380ml	Total amount of air that can be breathed in.
Inspiratory reserve volume (IRV)	3300ml[Q]	The air inspired with a maximal inspiratory effort in excess of tidal volume	Vital capacity VC= TV+ IRV +ERV	480ml	Maximal amt. of air that can be expelled out force fully after a maximal (deep) inspiration.
Expiratory reserve	1000ml[Q]	The air expelled with a maximal	Functional residual	2200ml	It is the volume of air remaining in

volume (ERV)		expiratory effort in excess of tidal volume	capacity FRC=ERV+RV		the lung after normal expiration (after normal tidal expiration)
Residual Volume (RV)	1200ml[Q]	The amt. of air remaining in the lungs even after forced expiration	Total lung capacity TLC= TV+IRV+ER +V+RV	6000ml. (4.2-6 lit[Q])	The amount of air present in the lung after a maximal inspiration. This is the maximum volume to which the lungs can be expanded[Q]

ALSO KNOW:

Pulmonary Ventilation/Respiratory Minute Volume (RMV) **(RMV=TV x RR)**	600ml[Q] (6L) = 500x 12	The amount of air breathed in and out of lungs every minute. It is product of tidal volume (TV) and respiratory rate (RR). RMV = TVX RR
Maximal voluntary ventilation (MVV) Maximal breathing capacity	125-170L/min	The maximum amount of air which can be breathed in and out of lungs by forceful respiration in one minute.
Alveolar ventilation= (TV – Dead space volume) x RR.	4.2 liters	The amount of air utilized for gaseous exchange every minute.
Total dead space/physiological dead space = Anatomical dead space+Alveolar dead space *In normal adult Physiological dead space = Anatomical dead space[Q]	Anatomical dead space- The conducting part where gaseous exchange does not take place. It is volume of respiratory tract from nose up to terminal bronchiole. It is 150ml. Alveolar dead space – Those alveoli which are non functioning and those which do not receive adequate blood flow.	
Closing volume	The lung volume, at which, no further air can be expelled by expiratory effort.	

Alveolar ventilation: (TV-DS) x RR: The amount of air that actually participates in respiratory gas exchange



Simple bed side pulmonary function tests

- **Breath holding time :** - ***Normal*** breath holding time is **> *25 seconds.*** Patients with breath holding time of ***15 to 25 seconds*** are considered ***borderline cases*** and **breath holding time < 15 seconds indicates severe pulmonary dysfunction**
- **Match te st**: - Person is asked to blow of match stick **from a distance of 15 cm .** A normal person still blow off the match stick from this distance.
- **Tracheal auscultation:** - If breath sounds are audible for ***more than 6 sec.,*** It denotes significant ***air obstruction.***

Critical temperature and critical pressure

- ***Critical temperature (Tc)*** of a substance is the temperature at and above which vapour of that substance can not be liquified, no matter how much pressure is applied (Note : Below critical temprature a substance can exist as a liquid or gas depending on pressure).
- The pressure that is needed to cause the gas to condense at the critical temperature is the ***critical pressure (Pc), i.e., Vapour pressure at critical temperature*** is called critical pressur
- ***As the Tc of 0 2 is -119°C; 0 2 can be liquified below - 119°C — So, liquid 02 must be stored below -119°.***
- ***On the other hand, because the critical temprature of N2O is 36.50 C, i.e., above room temprature, it can be liquefied without an elaborate refrigeration system.***

CHAPTER-2: INTRODUCTION TO ANAESTHESIA

HISTORY OF ANAESTHESIA

IMPORTANT HISTORICAL MILESTONES IN ANAESTHESIA

WORK	NAME OF THE SCIENTIST
The word anesthesia means **'No senses'** was suggested	**'Oliver Wendell Holmes'**[Q]
Pioneer of use of thiopentone for IV anesthesia . Balanced anesthesia	John S. Lundy[Q]
Nitrous oxide was first synthesized(also synthesized oxygen).	**Pristely (1774**).
First clinical use of nitrous oxide	**Horace wells' who did a tooth extraction**
First public demonstration of ether anesthesia was given by	**William Thomas Green (WTG) Morton**[Q] **in 1846 on Oct. 16th**
Popularized chloroform & used it at Queen Victoria for childbirth of her 8th child. He was first person to write book on anesthesia for which he is considered to be **the 'father of anesthesia'**.	**John snow**[Q]
First person to make use of analgesic properties of **Cocaine**. He anaesthetized cornea with cocaine.	**'Carl Koller'**[Q]
First spinal in human beings was given by	**August Bier (1898). Cocaine was the first drug used for spinal.**
'Curare' products for muscle relaxation	Harold Griffith
Succinylcholine was synthesized by	Bovet
First anaesthesia machine	Edmund Gaskin Boyle
First intubation by	Ivan Magill[Q]

- **World anaesthesia day is on 16th October. On 16th October 1846 ether was used first time.**

ANAESTHETIC MACHINES &EQUIPMENTS

Gas delivery system has following components : -

1. **Anaesthesia machine:** - Receives ***gases (oxygen, N2O and sometimes air)*** from a gas supply (gas cylinder or pipeline gas supply). It controls the flow and pressure of this gas mixtures. Before delivering this gas mixture to breathing circuit, anaesthesia machine also vaporizes (evaporates) volatile anaesthetics (e.g., Halothane) to mix with this gas mixture. Finally this gas mixture (containing oxygen, N20, air and anaesthetic agent) is delivered to breathing circuit. ***So, mixture of O2 and N2O (and sometimes air) acts as a carrier for a volatile anaesthetic agent.***
2. **Breathing circuit:** - Receives final gas mixture and deliveres it to the patient through an airway. So, ***breathing circuit connects the anaesthesia machine to the patient's airwary.***
3. **Airway:** - Airway delivers the gases directly to the patient after, receiving from breathing circuit

ANAESTHESIA MACHINE

- The anaesthesia machine is used by anaesthesiologists to support the administration of anaesthesia. First anaesthesia machine was made by ***edmund Gaskin Boyle in 1917***, **The Boyle's machine,**
- **Anaesthesia machine** receives gases from a gas supply (gas cylinder or pipeline gas supply). It then controls the flow of desired gases & reduces their pressure to a safe level, and finally vaporizes volatile anaesthetic agent into final gas mixture which is then delivered to breathing circuit that is connected to patients by an airway. It consists of following parts (from starting point to machine outlet):

1. Gas cylinders

□ Gas cylinder acts as a source of gas supply to anaesthetic machine (other gas supply is through pipeline). **Gas cylinder are made from a steel alloy of molybdenum *o n os. Am, serai»»»*** (Aluminium cylinders are also available in western countries). Gas Cylinders contain gases ***at high pressure.*** Cylinders are supplied in different sizes from A to J; **Size A being smallest and size J being the largest. Size E cylinder is commonly used in anaesthetic machines .** Gas cylinder of different gases have different:

- ***Colour coding***
- ***Capacity***
- ***Pressure***
- ***Pin index***
- **Storage forms** (liquid or gas)

Colour, Pressure & pin index of anesthetic gases:

Gas	Physical form	Press (psi)	Pin Index	Coloured cylinder
Air	Gas	1900	1-5	Grey body/whie shoulder
O2	Gas	1900	2-5	Black body/whie shoulder
N2O	Liquid	745	3-5	Blue(**NEELA)**
CO2	Liquid	838	1-6 (>7.5%), 2-6 (<7.5%)	Grey
Entonox N2O + O2)	Gas	1900	7	Blue body/whie shoulder
Cyclo**p**ropane	Gas		3, 6	**O**range**(PEELA)**
Heliox, Helium	Gas		4,6 (>80.5%), 2,4 (<80.5%)	Brown

- Halothane --- colour of bottle is amber.
- Halothane causes corrosion of metals & breathing circuits.
  - **Pin index safety system (PISS): is developed to discouage incorrect cylinder attachment. Used for small cylinders (<40 cubic feet).**
  - **Diameter index safety system (DISS):** is used to standardize connections b/w cylinders and flowmeters. (Pressure regulators).

  Each gas has specific attachments to prevent hook up of wrong gas.

-DISS number for:

N_2O 1040

O_2 1240

Cyclopropane : Most inflammable & explosive agent. Liquid gas-Orange cylinder. Can cause cyclopropane shock.

Note: These days the main source of gas supply (0 2, N20 & air) is ***pipeline gas supply*** which supply gas at **low pressure (50 to 55 psi)** in contrast to cylinders which supply at high pressure (2200 psi for 0 2 & 760psi for N20). Therefore, pressure reduction is not necessory. Cylinder supply source serves as a backup if the pipeline supply fails or as the primary supply if pipeline supply is not available.

2. **Yoke assembly**

□ Yoke assembly is the portion of machine at which cylinder get fitted, i ***,e.,yoke is the part where the cylinder fits onto the anaesthesia machine.*** **Yoke assembly consists of following important parts : -**

i) Pin index system : - This is the safety mechanism so that one cylinder can not be fitted at the other's position consists of 2 pins (4 mm and 6mm long) on yoke of anaesthesia machine .

- These pins are so positioned that the cylinder with corresponding hole can only be fitted, for example, the pins for oxygen are a 2 and 5 position on the yoke and oxygen cylinder has holes at the same position.
- Therefore, the pins can enter only the holes of oxygen cylinder —can be fitted at this position. For pin index of different gases, **see above table.**

o **The pin safety system is ineffective if yokes pin are damaged or cylinder is filled with wrong gas** or using extra sealing washer.
ii) **Bodok seal**: - It is to prevent leak of gas between cylinder and yoke.
iii) **A filter** Traps debris

3. Pressure regulator (Pressure reducing valve)
□ The gases from cylinders flow through narrow steel tubing ***which consists pressure reducing valves (Pressure regulator).*** These pressure regulators reduce the gas pressure to safe level i.e., ***2200psi to 45psi in oxygen cylinder source and 750 psi to 45 psi in N2O cylinder source.*** The newer machines ***(Datex-Ohmeda)*** have a ***second oxygen*** pressure regulator which is adjusted to a precise ***pressure level i.e., 14 psi.***

4. Flow control valves and Flow meter
□ After reduction of pressure of gases by pressure reducing valves (pressure regulaters) gases passes through **flow control valves** which regulate the flow of gases and **flowmeter** measure the flow. Flow meter may be of following two types: -
A) **Rotameter**: - Rotameter is a particular kind of flowmeter based on **variable area (variable orifice) and constant pressure principle.** This rotameter consists of three elements: - i) A uniformly tapered flow tube ***(Thorpe's tube),*** **ii) A bobbin or float (marker),** and iii) a measurement scale. The tube is positioned **vertically** with smallest diameter end of the tapered flow tube at the bottom. As the gas flows through this tube, the marker (bobbin) rises. If the gas flow is increased bobbin rises to higher level. **The upper end of bobbin determines the flow rate**
B) **Connel flowmeter**: - Reading is taken from the centre of bobbin, in contrast to rotameter, where reading is taken from the upper end of bobbin.
Heidbring flowmeter *:-* Reading is taken from the upper end of bobbin (as in rotameter).

- After the gases have passed through their respective flowmeter (rotameter), the different gas tubes are joined together —.**So, at the top of flow meter (rotameter) these gases (02, N20 and sometimes air) mix with each other** (Note:- Upto rotameter, these gases have their separate paths. While joining the different gas tubes, **oxygen tube is added last (at down stream). So that the chances of an hypoxic mixture resulting froma leak are gas is minimized.** Following diagram will help you to understand the mechanics.
- Flow meter sequence in a three gas machine: **The safest configuration is when oxygen is located in down stream position (after both gases)**

5. **Vaporizer**
Vaporizers are the devices used to ***deliver inhalational anaesthetic agents into gaseous mixture.*** **Inhalational anaesthetic agent is present in liquid form in vaporizer .** When fresh gases (mixture of 0 2 & N20) passes over this anaesthetic agent (in liquid form), it vaporizes and its vapours get incorporated in fresh gases and are delivered to patients via breathing circuit and airway.

6. Oxygen flush
□ It is by pass system which bypasses the intermediate and low pressure system —≫***Oxygen from high pressure system directly reaches at machine outlet. It delivers 35-75 litres of oxygen per minute*** at a pressure of 60 psi.

BREATHING CIRCUIT

A. Open System:

- Schimmel Busch Mask was used for ether and chloroform.
- Method: Open drop method. Disadvantages of this method were: open air pollution can't regulate concentration, initial deep breathe or more drug can lead to unconsciousness.

B. Semi-Open/Semi-Closed Systems:

□ In this system, exhaled gases from the patient are partly exhaled in the atmosphere and partly go back in tubing —**Exhaled gases are partially used by the patient** Semiclosed circuits are also called

Mapleson circuits are divided into five types

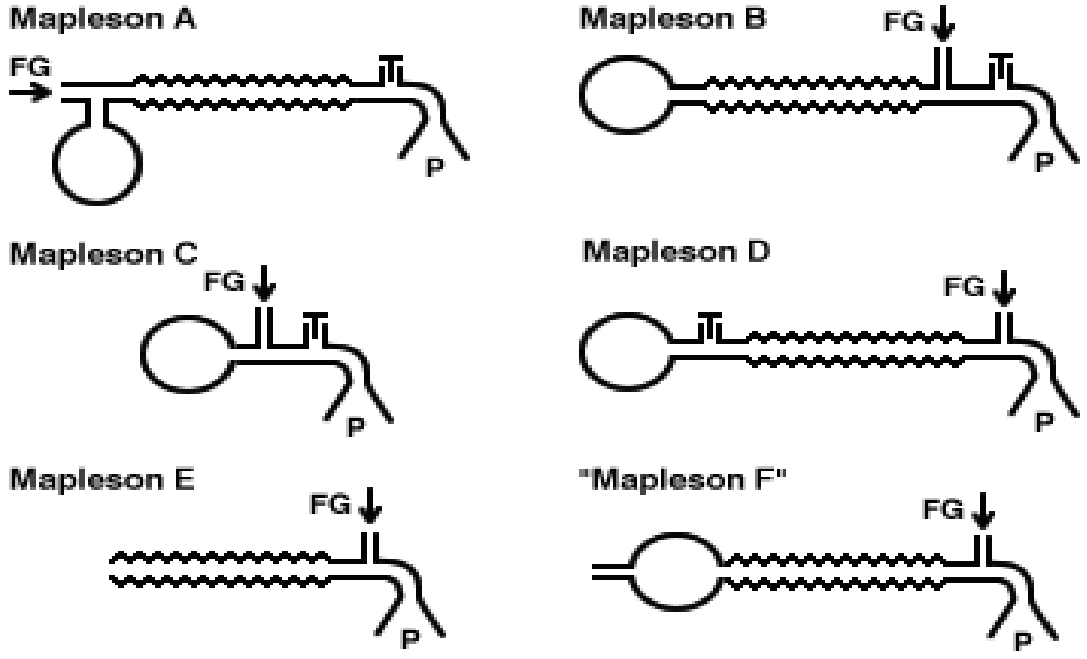
(Mapelson Circuits): 6 systems are there:

Type	Also k/as	Feature/ Advantage	Required fresh gas flow		Best suited for	Mnemonic
			Spontaneous	Controlled		
A	***Magill's circuit*** ^{Q}	**LACK'S system** is modification of 'A' with co-axial circuit (tube inside tube)	**Equal to minute volume** (80 ml/kg/min) ^{Q}	Very high and difficult to predict (3x **minute volume)** ^{Q}	o **Circuit of choice for spontaneous** ventilation. ^{Q} o **Should not be used for controlled** ventilation	**A** for m**A**gill
B		Obsolete	2 x minute volume	2.25 X M minute volume		
C	Water's to and Fro	Obsoelete	2 x minute volume	2.25X M minute volume	o **It is a coaxial system**	

D	**Bain's co-axial system**[Q]	Inspiratory limb is inside the expiratory limb	2.5x minute volume	1.6 X M minute volume	o **Circuit to choice for controlled ventilation.**[Q] o Most commonly used circuit o **Can also be used for spontaneo usventilati on**	**B-C-D** (Bain-**c**ontrolled ventilation for D circuit)
E	**Ayre's-T Piece**[Q]	Inlet is near the face mask/ETT, used for weaning	2.5x minute volume	3x **minute volume**	o **Circuit of 2nd choice in children**	**E** for ayr**E. and** childr**En**
F	**Jackson Ree's**[Q]	Modification of Ayer's T-piece/E. ***used in children <6 yr or <20 kg***	2 .5x minute volume	***1.5-2X*** **minute volume**[Q]	***o*** **Circuit of choice in children**[Q]	*F-for infant name Jack*

Note: Coaxial system means both fresh gas tube and exhaled gas tube are placed in same axis, i.e., coaxial. Fresh gases are delivered through inner tube and exhaled gases are expired through after tube so that mixing of fresh gases and exhaled gases does not occur.

- Efficiency grading of Mapelson system in :
  - Spontaneous ventilation A>DEF>C>B.
  - In controlled ventilation DFE>BC>A (A is least effective or not at all).
- Fresh gas inlet is nearer to patient end in D.E. and F.
- Valveless circuits are E and F.



FG = Fresh gas P = Patient

3. Closed circuit

□ In this system no gas escapes to atmosphere, ***exhaled gases are completely reused by the patient*** (after absorption of C02) —≫**Complete rebreathing.** Therefore this circuit is also known as **rebreathing system.**

Rebreathing system are : -

1. Circle system-C*ommonly used.*

2. To and fro (water's/Mapleson C) system more In use

Circle system:

□ The most commonly used ***closed circuit (rebreathing system)*** is circle system. It incorporates two main components : -

1. Unidirectional valves.

2. A means of absorbing C0 2 (Carbon dioxide absorbent).

l)Unidirectional valves

□ Unidirectional valves function as ***check valve*** — **Flow through these valves is possible only in one direction**; are two unidirectional valves.

A) **Inspiratory valve**

□ Present on the inspiratory limb of the circuit. These allow the gases to flow towards the patient; inhalation opens the valve, allowing the patient to breath a mixture of fresh and exhaled gas that has passed through the C02 absorber.

B) Expiratory valve (Rebreathing prevention valve)

□ **Present on expiratory limb .**They allow the exhaled gases to flow away from the patient and prevent rebreathing of exhaled gases as they are unidirectional valve. Therefore they are referred to as ***rebreathing prevention valve.*** **These valve should be near as possible from the patient** to prevent backflow into the inspiratory limb if a circuit leak develops.

2) Carbon dioxide absorbent

□ For reusing the exhaled gases, C02 in exhaled gases must be eliminated to prevent hypercapnia. **So, in this system** C0 2 **rebreathing is prevented**. For this following CO, absorbents are used: -

If we pass whole expired gas through sodalime, it absorbs CO_2,rest of gas can be re-used. Decreased Requirement of fresh gas flow, more economical. All anesthetic agents react with soda lime to produce CO (Carbon mono oxide toxicity).

· Indicator added to sodalime changes the color of sodalime. Indicators are -ethyl violet, mimosa-Z & phenoptalein.

· Mixture of 94% Ca $(OH)_2$ + 5% NaOH + 1% KOH

· Silicates are added to prevent powdering.

· Moisture 14-19% is also needed for efficient CO_2 absorption.

· It absorbs CO_2 and produces H_2O + heat, thus humidifies and warms inspired gases. 100 gm of soda lime can absorb 26 litre of CO_2 and temperature within the canister may increase up to 60°C.

· **Agents that should NOT be given with sodalime/closed circuit :**

- **Trichloroethylene (trilene) because** Qit generate phosgene which is neurotoxic.
- Sevofflurane
- Desflurane

· Barylime is alternative to sodalime

	Sodalime	Barylime
· Mesh size of granules	4-8	4-8
· Composition	**94% Ca $(OH)_2$ + 5% NaOH + 1% KOH**	**80% Ca $(OH)_2$ + 20% $Ba(OH)_2$**
· Absorption capacity	14-23 L CO_2/100g	9-18 L CO_2/100g
· Moisture	14-19%	Nil
· Hardness method	Silicates	Water crystallization
· Advantage		Less caustic

AIRWAY

The airway management seeks primarily to : -

1) ***Maintain and protect airway.***

iiPrevent aspiration of material into respiratory tract.

EQUIPMENTS USEDFOR AIRWAY MANAGEMENT

o Patient's airway is instrumented by either of the followings : -

i) ***Face mask***

ii) ***Supraglottic airway e.g., laryngeal mask airway (LMA)***

iii) ***Tracheal intubation (endotracheal intubation).***

Airways:

- The aim of airways is to prevent the tongue fall.
- The tip of airway gets inserted between tongue and posterior pharyngeal wall and thus prevent the tongue falling back on posterior pharyngeal wall.
- **Most commonly used** type **is Guedel airway**. Other commonly available **is Water's airway(it is metallic**).
- Nasal airways are also available which are inserted through nostril
- Langth of airway chosen (oral 0 is distance between tip of nose and tragus plus 1 cm.fig. 6.18. safar airway (used for mouth to airway breathing during resuscitation).
- Other type of airways: safar and brook, which can be used not only for preventing tongue fall but also for mouth to airway resuscitation.

FACE MASKS

- Face mask is the ***simplest and least invasive*** airway. Face mask is used to ventilate the patient without intubation.
- The use of a face mask can facilitate delivery of oxygen or of an anaesthetic gas from a breathing system to a patient by creating an airtight seal with the patient's face. **Face-mask significantly increases the amount of dead space.**
- These are available in sizes from 0 to 5 number. Face mask should be made of antistatic rubber. At the bottom of mask there is air filled cuff which has soft cushioning effect.
- A reservoir bag is attached to face mask to ventilate the patient. During **bag and mask ventilation** major portion of gasgoes into respiratory system, but some air can leak to esophagus which can increase the intragastric pressure and chances of regurgitation and aspiration. Therefore bag and mask ventilation is contraindicated when there are increased chances of aspiration like:- ***Full stomach, Intestinal Obstruction, Pregnancy, Hiatus hernia,*** **Diaphragmatic hernia . Tracheo-esophageal fistula \ Meconium aspiration syndrome .**

AMBU BAG RESUSCITATOR

AMBU = Artificial Manual Breathing Unit.

Used to ventilate the patient.

Ambu unit consist of one self inflating bag made up of rubber or silicone, Ruben non rebreathing type of valve and a mask. Non breathing valve closes the expiratory port when the bag is manually squeezed letting the air inside the bag to pass to face mask.

During expiration bobbin of valve comes to normal position letting the expired air to void to atmosphere.

- Maximum volume of bag is 1,200 ml.

- 100% oxygen can be delivered by Ambu bag by attaching oxygen source and oxygen reservoir.

RESERVOIR (BREATHING) BAG

- Reservoir bags (Breathing bags).
- These are attached to anaesthesia breathing circuits to ventilate the patient. Bags with different capacities are available for various age groups.
- Neonates : 250ml
- Children (up to 3 years) : 500 ml
- Children > 3 years : 1,000ml
- Adults : 2,000ml

LARYNGOSCOPES

Laryngoscope is used for visualizing the glottis to facilitate intubation.

It consists of a handle (which contains 2 batteries) and blade with a bulb (fig.6.24).

Type of Laryngoscopes

Based on different blade shapes laryngoscopes are:

- **Macintosh:** Most commonly used. It has curved blade and is available in 4 sizes. Smallest for children and larges for adults with long necks.
- **Miller:** it has a straight blade with curve at the tip only. It is also frequently used and again available in different sizes.
- **Fibreoptic laryngoscope:** it is useful in difficult intubations. Nasal intubation is easy and preferred method with fibreoptic laryngoscope.
- **Bullard laryngoscope:** it contains a fibreoptic channel which can visualize the laryngeal inlet directly.
- **McCoy laryngoscope:** it has got a movable tip.

Blades for Infants and Newborns

- Magill: straight blade used for neonates, neonatal epiglottis is large, leafy and more anterior therefore it need to be lifted by straight blade to visualize glottis. (adult's epiglottis just need to be pushed anteriorly therefore curved blade is used).
- Oxford infant blade: used for infants.

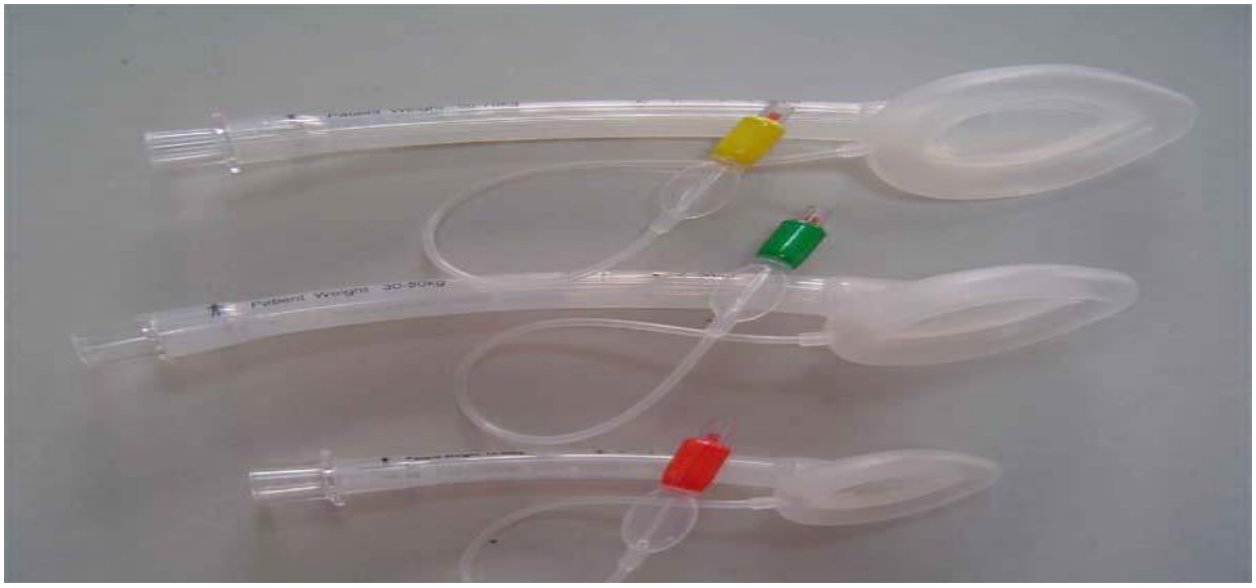
LARYNGEAL MASK AIRWAY:

- The LMA is a ***supraglottic airway.*** It is also referred as ***Brain mask*** as it was **invented by Dr. Archies Brain**.
- LMA provides an airway ***intermediate between the face mask and tracheal tube*** in terms of anatomic position (face mask is on the face, LMA is in the larynx around inlet and tracheal tube is in the trachea), invasiveness, security to protect airway, and facilitate gas exchange.
- The principle of LMA is that ***it provides an effective gas tight seal around the laryngeal inlet without anything having to pass through vocal cord.***
- LMA is very effective in **maintaining a patent airway** in ***spontaneously breathing patient.*** Positive pressure ventilation may be applied if necessory without tracheal intubation,

o **LMA is available in different size**

- Ranges of patient laryngeal mask airway sizes:

Size	Indication (is on basis of weight)	Cuff volume
1	Up to 5 kg	4 ml
1.5	5-10 kg	7ml
2	10-20 kg	10ml
2.5	20-30 kg	14 ml
3	30-50 kg	20ml
4	50-70 kg	30ml
5	>70 kg(or 70-100 kg if size 6 is available)	40ml
6(only available in few countries)	>100 kg	50ml



- After induction of anaesthesia with ***propofal (which depresses laryngeal reflexes)*** LMA is introduced blindly **(without laryngoscopy)** into the hypopharynx. One of the major disadvantage of LMA is that its **seal around laryngeal inlet does not always prevent aspiration. Therefore, LMA should not be used where there is an increased risk of aspiration of stomach contents, e.g., full stomach patient**.

Indications of LMA

- As an **alternative to intubation ,** where difficult **intubation is anticipated (difficult airway)**
- **To facilitate endo-tracheal intubation in a patient with difficult airways**
- Situations involving a difficult mask fit.
- Securing airway **(as cardiopulmonary resuscitation,)** in emergency where intubation and mask ventilation is not possible.
- For **minor surgeries (short surgeries) , where anaesthetist wants to avoid intubation .**
- As a conduit for bronchoscopes, small size tubes, gum elastic bougies
- **For extra and intra-ocular surgeries including retinopathy surgery in premature infants-**

- LMA is particularly useful in ophthalmic surgery as problems created by other two airways are eliminated : -

i) Face mask creates problem in surgical field access due to its size (LMA provides a better access).

ii) Endotracheal intubation may cause raised IOT (LMA has no effect).

Contraindications of LMA:

- **Conditions with high risk of aspiration** i.e., **full stomach patients** \ hiatus hernia, pregnancy.
- Massive thoracic injury
- Massive maxillofacial trauma
- **Oropharyngeal abscess or mass (tumor).**

ENDOTRACHEAL INTUBATION

- Tracheal intubation (endotracheal intubation) is the ***placement o f a flexible plastic tube (Tracheal tube or endotracheal tube) directly into the trachea*** to protect the patients airway and provide a means of mechanical ventilation. The tracheal intubation may be : -

1. Orotracheal (oral) intubation

It is the ***most commonly used*** tracheal intubation. In this, with the assistance of a laryngoscope, an endotracheal tube is **passed through mouth,** larynx and vocal cords into the trachea.

2. **Nasotracheal (nasal intubation)**

In this a tube is ***passed through nose,*** larynx, vocal cords into the trachea

Indications for endotracheal tubation

- Endotracheal intubation is used to **maintain a patent airway ,** in operation theater as well as outside the operation theater: -

Indications for Endotracheal Intubation in the operating room include: -

- ***The need to deliver positive pressure ventilation.***
- Protection of respiratory tract from aspiration of gastric contents.
- Surgical procedure involving the head and neck or in non-supine positions that preclude manual airway support.
- Almost all situations involving neuromuscular paralysis.
- Surgical procedures involving the cranium, thorax, or abdomen.
- Procedure that may involve intracranial hypertension

o **Some non-operative indications are**: -

- Profound disturbance in consciousness with the inability to protect the airways.
- ***Tracheobronchial toilet*** **(pulmonary toilet).**
- Severe pulmonary or multisystem injury associated with respiratory failure, such as sepsis, airway obstruction hypoxemia, and hypercarbia.

Indications of nasal intubation:-

- **Obstructing mass in oral cavity e.g., abscess or neoplasm**
- Improper mouth opening —Fracture mandible, temporomandibular (TM) joint ankylosis, trismus **— In theseconditions blind nasal intubation is indicated.**
- **Oral surgeries**
- Cervical spine injury — Nasal intubation is preferred over oral intubation.

- For awake intubation — Nasal intubation is preferred over oral intubation.

Blind nasal intubation:

- Usually nasal intubation is performed using direct laryngoscape or intubating fibrescope to visualize the laryngeal inlet. In conditions where ***mouth opening is restricted*** and where larynx cannot be seen on direct laryngoscopy, the intubation is done ***blindly.*** Such conditions are **temporomandibular joint ankylosis , *Trismus (tetanus, quinsy), Neck contracture.***

Contraindications for Nasal intubation.

- **Basal skull fracture,** (tube may reach the cranial cavity) and CSF **rhinorrhea** (Cerebral infection may occur).
- Coagulopathy and bleeding disorders.
- **Nasal polyp, abscess, foreign body**
- **Adenoid**

Contraindications for both nasal and oral intubation

- **Laryngeal edema**
- **Epiglotitis**
- **Laryngotracheobronchitis**

o Attempt to intubate can aggravate these conditions and can produce severe respiratory obstruction. So, in these conditions whenever there is severe respiratory distress, tracheostomy is preferred.

Technique for direct laryngoscopy and oral intubation (laryngoscopy assisted oral intubation)

There are five important components : -

1. Optimal head and neck position

- □ Optimal head and neck positioning is obtained by **flexion of the neck** and **extension of the atlanto-occipital joint. I**t js done by putting a small pillow under the occiput.

2. **Optimal muscle relaxation**

- Optimal muscle relaxation allows greatest exposure of the larynx and prevents glottic closure. ***For rapid(emergency) intubation succinylcholine is the agent of choice.***

3. **Optimal laryngoscope blade**

- ***Inserted from the right side of the patient's mouth*** to prevent the tongue blocking the view of the larynx, while watching the blade tip as it is advanced alongside of the tongue towards midline. When the epiglottis is seen, **the tip is inserted firmly** but not forcibly into the vellecula and **used to lift the base of the epiglottis** forward to reveal the cords. The curved laryngoscope blade may be easier to use and may cause less stretching of the faucial pillars than a straight blade.

4. **Optimal external laryngeal manipulation**

- Backward and lateral pressure on the larynx by the anaesthetist or assistant may help bring the cords into view.

The best manoeuvre is ***BURP (back wards, upwards and to the right pressure).***

- **Optimal use of introducer (bougie):** The gum elastic bougie (introducer) with coude tip is the single most useful aid for difficult direct laryngoscope.

It is introduced into the trachea and used as a guide to railroad a tracheal tube. **The goal is to position the end of endotracheal tube 5 ± 2 cm proximal to bifurcation of trachea i.e., carinam** when the head and neck are in neutral position. Neck flexion causes a 2 cm ascent. ***Therefore correct position of tip is 3 ± 2 cm from carina when neck is flexed and 7 ± 2 cm***

from carina when neck is extended.

Effect of Endotracheal intubation on dead space and airway resistance

- As nasal passage is bypassed and the lumen of endotracheal tube is less than that of natural airways, **intubation decreases dead space** Resistance to airflow depends primarily on diameter of airway : - ***Resistance is inversely related to diameter.*** If the radius (size) of air way is decreased airway resistance is increased. After putting the endotracheal tube, the diameter of airway is decreased — **Intubation increases the airway resistance.**

Physiological changes during intubation and laryngoscopy

- Laryngoscopy and tracheal intubation violate the patients protective reflexes. This results in some ***adversephysiological changes : -***

1. CVS: - **Hypertension , Tachycardia**r, Cardiac arrhythmias, cardiac arrest, Reflex bradycardia.
2. CNS : - **Increased** ICT . Increased crebral activity, blood flow and metabolic rate.
3. **Respiratory**: - Laryngospasm, Bronchospasm.
4. **Increased intraocular pressure .** Increased intraabdominal pressure.

Complications of Intubation

Perioperative	*Postoperative*	*Delayed Complications*
1. Esophageal intubation: this is a hazardous complication. If not detected in time can cause severe hypoxia and even death. 2. Ischemia, edema and necrosis at local site (especially with red rubber tubes). 3. cardiac arrest. 4. Aspiration (if cuff is not properly inflated). 5. Bronchial intubation and collapse of other lung. 6. Tracheal tube obstruction by secretions, kinking. Again if not detected in time can cause hypoxia. 7. Accidental extubation. 8. Trauma to gums, lip, epiglottis, pharynx, larynx and nasal cavity (in nasal intubation). 9. Reflex disturbances like laryngospasm, bronchospasm, breath holding.	1. Sore throat (pharyngitis, laryngitis): this is the most common postoperative complication. It usually subsides in 2 to 3 days without any treatment. 2. Lung atelectasis. 3. Laryngeal nerve palsies. 4. Surgical emphysema, mediastinal emphysema 5. Infection: Pneumonia, lung abscess, mediastinitis 6. Laryngeal edema (usually present after 1 to 2 hours	1. Vocal cord granuloma. 2. Laryngotracheal web 3. Tracheal stenosis 4. Tracheal collapse These complications are seen after prolonged intubation in intensive care patients. Maximum permissible time for which an endotracheal tube can be kept is 21 days. After this period there occurs subglottic edema so, if the requirement is more than this then tracheostomy should be done.

10. Cardiac arrhythmias, hypertension or even		

Endotracheal tubes

o Endotracheal tubes are mainly of two types.

Cuffed endotracheal tube	2. **Uncuffed endotracheal tubes**
• Most of the tubes used in anaesthesia are cuffed tubes. These tubes have ***inflatable cuffs*** which prevent leakage between the endotracheal tube and the trachea -> both leakage of gas outwards during IPPV and of gastric contents, blood & mucus into the lungs. **Cuff pressure should not exceed 30 cm HzO (22 mm Hg) to prevent ischemic damage to tracheal mucosa.** Cuffed endotracheal tubes may be of two types, based on cuff pressure and volume. • **Low pressure, High volume**; - In this cuff has high volume & low pressure. Because of low pressure these tubes ***produce less tracheal injury,*** therefore ***suitable for prolonged surgeries. More commonly used*** than high pressure low volume tube. These tubes are made up of ***polyvinyl chloride*** (PVC). • **High pressure, low volume** : . Because of high cuff pressure, chances of tracheal injury (ischemia) are high, therefore these tubes are not suitable for prolonged surgeries. This tubes are made up of ***red rubber.***	**In children (less than 10 years of age) uncuffed tubes should be used *and there should be slight leak on inspiratory pressure of 30 cm H2O*** (Tube should not be so tightly fit) —≫ This decreases the chances of post intubation croup.

Deciding the size of Endotracheal Tube

In a normal healthy male usually 9 number (means internal diameter 9 mm)tube is used and for normal healthy female usually 8 number tube is used. In children the size of endotracheal tube [in mm internal diameter (ID) is as follows:

- Prematures : 2.5mm ID
- 0 to 6 months : 3 to 3.5 mm ID

- 6 months to 1 year : 3.5 to 4 mm ID
- For children 1 year to 6 years the size is calculated by formula:

$$\frac{\text{Age (in years)}}{3} + 3.5\text{mm ID}$$

- For children >6 years:

$$\frac{\text{Age (in years)}}{4} + 4.5\text{ mm ID}$$

For example for a 5 year old child the tube size required will be:
$\frac{5}{3} + 3.5 = 1.6 + 3.5 = 5.1$ (means 5 number tube).
Smallest size of tube available is 2.5 mm and the largest size 10.5 mm.

Weight wise size of ET tube:

Weight in grams	**Internal diameter (mm)**
• **<1000**	**2.5**
• **1000 - 2000**	**3**
• **2000-3000**	**3.5**
• **>3000**	**3.5-4.0**

For calculating the Length of Tube

Clinically optimal length is the length at which air entry is equal on both sides of chest. Usually it is 23cm in adult males and 21cm in adult females (or in other words tip of the tube should lie 4 to 5 cm above the carina because distance between incisors and carina is 26 to 28cm). A rough guide is that length is twice the length from tip of nose to ear lobule.

- In children, the length for nasal intubation 3 cm is added to oral length.

Example: For 5 year old child length will be:

$= \frac{5}{2} + 12$
$= 2.5 + 10$ cm
$= 14.5$ cm

Some special types of ET tubes

- ***Spiral embedded*** (Flexometallic **armored tube** — Used for head & Neck, Maxillofacial and **neurosurgeries**
- **RAE (Ring, Adair, Elwyn) tube —Cleft lip and palate surgery**
- Microlaryngeal (MLT) laryngotracheal (LTS) surgery tube — Microlaryngeal surgeries,
- Coles tube — For children

o Endotrol tube — For nasal intubation
o **Double lumen tube — For thorasic surgery where one lung ventilation is required**

TRACHEOSTOMY

Indications

i. As an elective procedure where prolonged ventilation is required.
i. As a switch over procedure from intubation, if endotracheal tube is to be kept for more than 3 weeks. Keeping tube for more than 3 weeks can predispose to subglottic stenosis.
i. Excessive secretions leading to blockage or frequent change of endotracheal tube.
v. As an alternative when intubation is not possible
v. Upper airways obstruction due to:
   - Laryngeal edema
   - Impacted foreign bodies
   - Laryngeal trauma
   - Vocal cord paralysis
   - Ludwig angina, quinsy, laryngitis

i. For laryngeal surgeries like laryngectomy

Tracheostomy Tubes

- Silver tubes: Not used now-a-days.
- Cuffed plastic tubes: these are most commonly used. Cuffs should be high volume, low pressure, other tubes with automatic inflating cuffs are also available.
- Montgomery T tube or Olympic tracheal button: these devices have no cuff, so they produce less tracheal injury and allow air to pass through mouth for speech.
- Fenestrated tube for speaking.

Complications

Early Complications

- Malpositioning of the tube during insertion.
- Hemorrhage
- Surgical emphysema
- Pneumothorax
- Injury to trachea, larynx

Late Complications

- Blockage of tube due to secretions can cause severe hypoxia
- Infection
- Tracheal ulceration

Delayed

- Tracheal stenosis at the cuff site or at stoma: to avoid this complication, low cuff pressure (<15 mmHg) is advocated
- Tracheal web
- Tracheal dilatation

Care of Tracheostomy Tube

- Careful, aseptic suctioning of secretions at regular intervals should be done. Inner cannula should be changed every 4 to 6 hours.
- Adjustment of cuff pressure to keep it below 15mmHg
- Humidified oxygen.

- Strict asepsis at the time of change. First change should not be done before 5 days as stoma takes 5 days to establish completely and change before this time can create false tract.
- Conscious patient should be given a bell, pencil and paper.

DEFINITE AIRWAY

Definite airway is an airway that is adequately secured in trachea and it adequately **protect the airway from aspiration.**

The definite airways are:-

i) Endotracheal intubation:- **Orotracheal ,Nasotracheal**

ii) Surgical airway:- Tracheostomy, **Cricothyroidotomy .**

The airway that does not protect the airway from aspiration **are not definite airway.** Examples are:-

i) Nasopharyngeal airways, oropharyngeal airways

ii) Laryngeal Mask airway (LMA)

MEDICAL GAS THERAPY

Certain gases can be used for therapeutic purposes in certain conditions ***in non-intubated patients.***

o ***The therapeutic medical gases include.***

1. **Oxygen (ambient or hyperbaric)**: - Provided by ***oxygen delivery devices.*** Indications for use are : - ***Correcting hypoxemia, Acute MI, Severe trauma, Post anaesthetic recovery, Gas-gangrene (hyperbaric O2).***
2. **Helium - oxygen mixture (Heliox)**: - It used to treat the increased work of breathing (WOB) due to upper airway obstructing lesions.
3. **Nitric oxide** : - Used for its dilating effect on pulmonary vasculature.

Oxygen delivery devices

These are the devices which are used to supply oxygen to the patient as ***medical gas therapy.*** These are classified as

1) Low-flow (variable - performance) equipment

Oxygen (usually 100%) is supplied at a fixed flow that is ***only a portion of inspired gas, — it does not meet all the inspiratory flow demands of the patient.*** The performance of these device is affected by changes in patient's tidal volume and respiratory rate, i.e., ***performance is variable.*** Therefore these devices are also referred to as ***variable-performance devices.***

The ***disadvantage*** of these devices is that the delivered ***oxygen concentration (FiO2 accuracy can not be predicted,*** in contrast to high flow devices (venturimask) which deliver accurate concentration.

□ The ***advantage*** of these device is that these are ***very cheap, better tolerated; and can be used in wards, pre-and postoperative rooms***

Low flow Oxygen Delivery Systems

These include:

i. Nasal cannula
ii. Simple mask also called as Mary Carterall mask
iii. Oxygen tents

iv. Non rebreathing mask
v. Rebreathing mask
vi. Polymask

The advantage is that these are very cheap and can be used in wards, preoperative and postoperative rooms and these are better tolerated by patients as compared to high flow systems.

The disadvantages is that the delivered oxygen (FIO_2) occuracy can not be predicted (compared to venture mask which delivers accurate concentration).

These low flow systems are variable performance devices i.e., their performance is effected by changes in patient's tidal volume and respiratory rate.

Oxygen Mask

Very commonly used in wards. Also known as Mary Carterall mask.

Oxygen flow rate/minute	**Delivered oxygen(FIO_2)**
5-6 litres	40%
6-7 litres	50%
7-8 litres	60%

So maximum concentration of oxygen that can be delivered by oxygen mask is 60%. Increasing flow rate beyond 8 litres will not increase the (FIO_2) to more than 60%.Attaching reservoir bag can increase FIO_2 to 80%.

Nasal Cannula

The tip of nasal cannula should lie in nasopharynx.

Flow rate (litre/min)	**FIO_2**
1	24%
2	28%
3	32%
4	36%
5	40%
6	44%

So maximum oxygen which can be delivered by nasal cannula is 44%.

Non rebreathing Masks

Can deliver up to 80% of oxygen

Rebreathing Mask

When tightly fitted they can provide approximately 100% oxygen.

Oxygen Tents (Hoods)

Used for children. A lot of wastage of oxygen do occur and oaccurate concentration can not be predicted

2. **High flow (fixed - performance) equipment**

a ***Provide complete source of inspired O,.*** Performance of these devices is not affected by change in respiratory pattern (tidal volume, respiratory rate etc), therefore these devices are also referred to as ***fixed-performance devices.*** These high flow system ***deliver accurate inspired oxygen (FiO2,*** in contrast to low-flow system where accuracy cannot be predicted.

High Flow Delivery System

These are also called as fixed performance devices because their performance is not effected by changes in patient's tidal volume and respiratory rate and therefore deliver accurate oxygen concentration. High flow systems are more effective in treating hypoxemia then low flow systems.

Disadvantages

a. Low patient acceptance (due to high flow).
b. Increased cost (again due to high flow).

These work on venture principle which states that if a gas is passed through a narrow orifice at high pressure it creates shearing forces around the orifice which entrain room air in specific ratio.

The inspiratory gas flows should be 3 to 4 times of minute volume.

These high flow system deliver accurate inspired oxygen (FIO_2) [error is only 1 to 2%]. High flow system includes:

i. Venturi –mask: These are most commonly used high flow systems and are available in different colors.

Colour	Flow rate of O_2 (litre per min).	Delivered Oxygen(FIO_2)
Blue	02	24%
White	04	28%
Orange	06	31%
Yellow	08	35%
Red	10	40%
Green	15	60%

So maximum oxygen that can be delivered by venturi mask is 60%.

Other high flow systems available are

ii. Air entertainment nebulizers. There are special high flow nebulizers.
iii. High flow air- oxygen blunders
iv. Bag and mask ventilation is also considered as high flow system.

Hyperbaric oxygen therpy (HBOT)

- Hyperbaric oxygen therapy is a form of treatment in which a patient breates 100% 0 2 at higher than normal atmospheric pressure. When breathing 100% oxygen at sea level the dissolved oxygen concentration in blood is about 2.1 ml/dl.
- At 3 **atmospheric pressure** this increases to 6.2 ml/dl which exceeds the arterio-venous difference at rest (5ml/dl) and therefore satisfies tissue oxygen demand. This enhancement of dissolved O2 can be of ***therapeutic value.***

Important indications of HBOT

- **Anaerobic infections (i.e.g, gas gangrene)** o Osteoradionecrosis o Osteomyelitis
- **Compartment syndrome,** o **CO poisoning** o Decompression sickness

Hazard of oxygen therapy (oxygen toxicity):

- Oxygen therapy is like a two-edged sword, at one edge oxygen is essential for human survival, while at the other edge it may become toxic if given at ***an elevated partial pressure or for longer duration.***

The oxygen toxicity manifests as : -

- **Ocular effects** : **- Retrolental fibroplasia , (Retinopathy of prematurity)**

- **CNS toxicity (Bert effect)**: - The **acute oxygen toxicity** has predominant CNS effect. It may manifest as ***nausea, vertigo, convulsions.***
- **Pulmonary toxicity (Smith effect)**: - The ***chronic oxygen toxicity*** has predominant ulmonary effect. Oxygen toxicity causes damage to pulmonary epithelium and **vascular endothelium ,** inactivation of surfactant; interstitial edema and fibrosis. This may result in **decreased lung compliance**, Hypoventilation, **decreased vital capacity, absorption atelectasis.** Tracheobronchitis, Pulmonary interstitial fibrosis.

CHAPTER-3:PREOPERATIVE ASSESSMENT & MONITORING IN ANAESTHESIA

PREOPERATIVE ASSESSMENT

AMERICAN SOCIETY OF ANAESTHESIOLOGIST (ASA) CLASSIFICATION:

o ASA classification is for the Preoperative assessment to **quantify the risk** for patients who require anaesthesia for surgery. This is the simplest and most widely used system for describing **patient's physical status.** Based on physical status, the patients are ***classified into six categories.*** The ***morbidity and mortality is highest in grade V patients and minimum is grade I patients***

ASA-American Society of Anesthesiologists Physical Status Classification:

ASA 1	Healthy patient without organic, biochemical, or psychiatric disease
ASA 2	A patient with mild systemic disease, e.g., mild asthma or **well-controlled hypertension**.[Q] No significant impact on daily activity. Unlikely to have an impact on anesthesia and surgery
ASA 3	Significant or severe systemic disease that limits normal activity, e.g., renal failure on dialysis or class 2 congestive heart failure. Significant impact on daily activity. Probable impact on anesthesia and surgery
ASA 4	Severe disease that is a constant threat to life or requires intensive therapy, e.g., acute myocardial infarction, respiratory failure requiring mechanical ventilation. Serious limitation of daily activity. Major impact on anesthesia and surgery
ASA 5	Moribund patient who is equally likely to die in the next 24 hours with or without surgery
ASA 6	Brain-dead organ donor
"E" added to the classification indicates emergency surgery.	

AIRWAY ASSESSMENT:

ASSESSMENT OF DIFFICULT INTUBATION

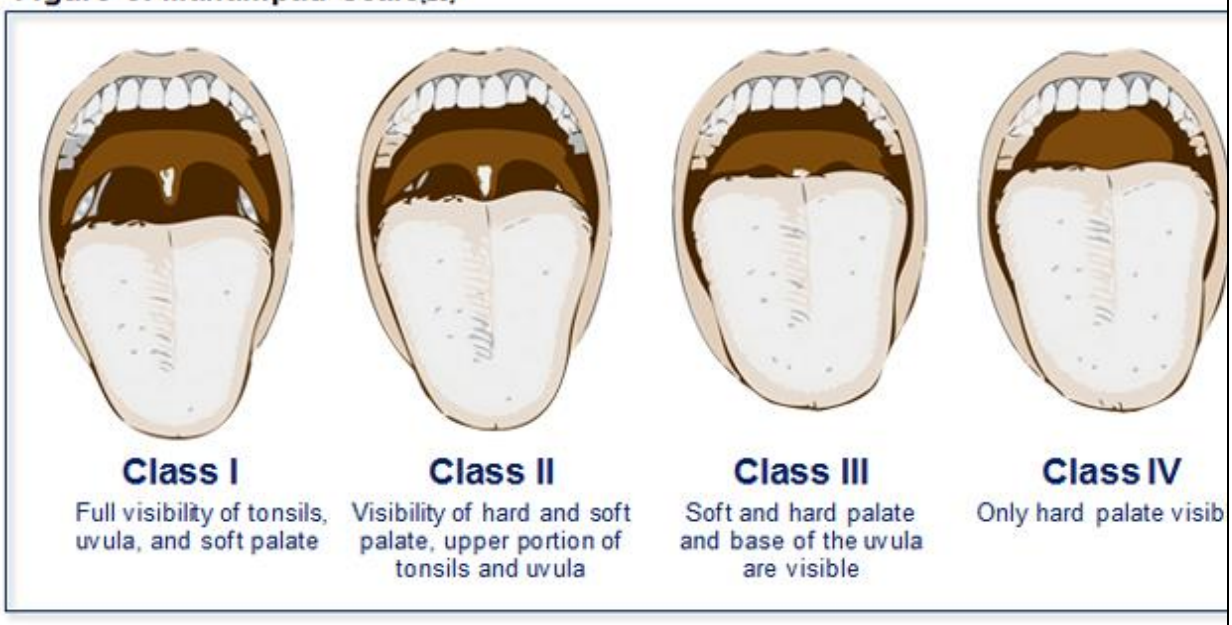
Commonly used grades and parameters for assessment of airway include:

1. **Mallampati grading:** It is done to assess **mouth opening.** Patients is asked to open the mouth as wide as possible and protrude the tongue. Depending on the structures seen by examiner the classification is as follows (.

Class I Faucial pillars, soft palate and uvuala seen.
Class II Faucial pillars and soft palate seen but not uvula.
Class III Only soft palate is seen.
Class IV Only hard palates is visible(modified Sampson and Young classification).

Intubation is difficult in Mallampatti grade 3 and 4.

Figure 9. Mallampati Scale[28]



2. **Thyromental distance** (distance between thyroid notch to mental prominence with fully extended neck):

Normal : 6.5 or more(> 3 finger breadth)
6.0-6.5cm : Difficult laryngoscopy.
<6.0 cm : Laryngoscopy may be impossible.

3. **Mentohyoid distance:** Normal > 5 cm (2 finger breadth).
4. **Assessment of TM joint function:** Inter incisor gap (mouth opening) should be at least 5 cm (2 finger breadth).
5. **Neck movements:** Normal range of flexion and extension varies between 165^0 to 90^0

Mallampati gradding, thyromental distance and neck movements are assessed in every case.

Grading of difficult laryngoscopy (Cotmack and Lehane)

Grade I	Glottis fully visible
Grade II	Only posterior glottis visible
Grade III	Only epiglottis visible
Grade IV	No recognizable structures

Difficult airway algorithm

Dr. Philip larson had developed a technique for ***managing a difficult airway.*** The method involves the use of four plans, which ***go in sequence:*** -

- **Plan** - A : - ***Standard laryngoscopy*** using a blade of choice and intubation. A second attempt with different blade is reasonable, but ***no more than two attempt should be made.***
- **Plan - B** : - ***Direct laryngoscopy and insertion of cook (Frova) catheter into the glottic opening*** followed by advancing ET tube on catheter. If plan 'B' fails, proceed to plan 'C'.
- **Plan** - C : - Insertion of a **laryngeal mask airway (LMA)** and attachment of anaesthetic machine. ***Mechanical ventilation is institued. Uncuffed tracheal tube*** is inserted onto the ***fiberoptic bronchoscope.*** Once ventilation, oxygenation and depth of anaesthesia are adequate, the LMA and tracheal tube are removed en-bloc, leaving only a catheter in trachea. The final tracheal tube is then inserted over this catheter. If plan C fails, proceed to plan 'D
- **Plan - D** : - This plan has two options : - ***(i) Cancel the operation*** and plan it for another day with awake fiberoptic intubation, ***(ii) Perform tracheostomy***

PRE-OPERATIVE MODIFICATION OF PRE-EXISTING DRUGS

Drug to be stopped	**Drug which can continue till the dav of surgery**
• **Aspirin — 1 week before surgery** • AT-II antagonist (Losartan, Valsarton) — 1 day prior • MAO inhibitors —3 weeks before surgery • Oral antigoagulant ***—>4*** days before and **switchover to heparin >** which is stopped 12 hours prior to surgery • Oral hypoglycemic (metformin) **— 48 hours before surgery, >** and switch to insulin • **Lithium: 24 hours prior to surgery**	• **Antiepileptics** • **Antihypertensives** (except AT-II antagonists) • Antianginal (except aspirin) • Digitalis • Tricyclic antidepresants • **Levodopa**

PREANAESTHETIC MEDICATION

Premedication (Preanaesthetic medication) refers to the use of drugs before anaesthesia to make it more pleasant and safe. The aims are :

1 ***.Relief of anxiety and apprehension*** pre operatively and to facilitate smooth induction.

2. ***Amnesia*** **for preoperative and postoperative events**
3. Supplement analgesic action of anaesthetics and potentiate them — **Reduce the dose of anaesthetic**
4. ***Decrease secretions*** and ***vagal stimulation*** **(undesirable reflex**
5. Antiemetic effect extending into postoperative period —**To prevent post-operative nausea & vomiting**
6. Decrease acidity and volume of gastric juice so that it is less damaging if aspirated.
7. **To decrease the chances of aspiration**

o To relieve anxiety, ***lorazepam is the benzodiazepine of choice.***
o To decreased the chance of aspiration
i) **Patient should be fasting for 6 hours for solid**
ii) Patient should be fasting for 3 -4 hours for water,
iii) Patient who are at high risk of aspiration (like hiatus hernia, pregnancy), gastric prokinetics/antacid/H2 blockers should be employed.
o To control secretion, anticholinergics (Glycopyrrolate, atropine or scopolamine) are used. **Gycopyrrolate is a preferred anticholinergic over atropine and scopolamine (hyoscine) because it does not crosses blood brain barrier and devoid of central side effects**
o To prevent nausea and vomiting, hyoscine, ondansetron or metoclopramide are used. **Hyoscine is the most potent antiemetic to be used as part of premedication.**
o **For elective surgeries, hemoglobin should be at least 10 gm/dl or more**

Drugs used in premedication
1. ***Sedative - antianxiety*** **Diazepam** Lorazepam/Midazolam.— Lorazepam is used most commonly **- Midazolam is used for day care surgery**
2. Opioids - **Morphine**r/Pethidine
3. ***Anticholinergics*** - **Atropine/Hyoscine /**Glycopyrrolate.
4. ***Neuroleptics*** Haloperidol/chlorapromazine/triflupromazine
5. H2 blocker or proton pump inhibitor - Ranitidine/Famotidine, omeprazole/Pantoprazole.
6. Antiemitics - Metoclopramide/Domperidone/Ondansetron/Hyoscine/Ondansetron

MONITORING IN ANAESTHESIA

1. **Basic monitoring** : - Basic monitoring is done clinically i.e., **clinical monitoring.** It includes monitoring of pulse rate, colour of skin, BP, inflation of chest, precordial & esophageal stethoscopy, urine output.
2. **Advance monitoring**: - It is done by instruments i.e., **instrumental monitoring.** Most important and widely used anaesthetic monitoring is done for CVS (cardiovascular monitoring) and respiratory system (respiratory monitoring).
Other monitoring are neuromuscular monitoring, Temperature monitoring etc.

RESPIRATORY MONITORING

1.Pulse oximetry

o Pulse oximetry is used to **measure the oxygen saturation in blood (SP02**. Probe is applied on pulsatile tissue beds like finger nail, toe nail, ear lobule, tip of nose to measure SpOr ***Normal SP02 is 97 to 98%.***

Principle of pulse oximetry: Works on principle of **Beer-Lambert Law**

· Sites of application of probe are: nail bed (fingers), toe, earlobe, nose, thenar and hypothenar eminence, sole of foot, wrist in neonates.

- It measures O_2 saturation. It also monitors pulse rate and perfusion gradient. **Recent studies show that pulse oximetry readings are unaffected by fetal hemoglobin**

Factors causing inaccurate reading in pulse oximeter

- **Methaemoglobinemia**
- **Carboxyhaemoglobinemia**
- Hypovolemia and vasoconstriction
- Vasodilatation
- **Nail polish**
- Shivering
- Sp02 below 60%
- **Skin pigmentation**
- Anaemia
- Poor peripheral pulsation

2.Capnographv: At a glance

- Capnography is the continuous **measurement of end tidal CO_2 ($ETCO_2$)** i.e. **CO_2 in exhaled air.**[Q]
- Normal value is ***35-45 mm Hg.***
- A beam of infrared light is passed across the gas sample to fall on to a sensor. The presence of CO_2 in the gas leads to a reduction in the amount of light falling on the sensor which changes the voltage in the circuit. So Capnography works on the principle that ***infrared light is absorbed by carbon dioxide.***

Uses of Capnography:

1. It is the surest confirmatory sign of correct intubation in trachea.

In esophageal intubation ET CO_2 = 0

$EtCO_2$ (by capnometer/capnography):Informations:

Absence of CO_2 in exhaled air or <10 mm Hg which is washed out within few breaths: Esophageal intubation.[Q]

Persistent detection of CO_2:

A. Endobronchial intubation: (Increased in peak inspiratory pressure (earliest sign), Unilateral breath sound.

B. Endotracheal intubation: (Bilateral breath sound, Absence of gastric gurgling).

Marked rise in *$EtCO_2$*	**Marked fall in *$EtCO_2$***
• Fever[Q]	• *Pulmonary/air embolism*[Q]
• Convulsions	• *Hypothermia*
• Increased muscle tone	• *Hyperventilation*
• Pain, anxiety	• *Hypotension*
• Shivering	• *Disconnection*

	• ***Malignant hyperthermia***^{Q} • *Thyroid storm*^{Q} • *Neurolept malignant syndrome*^{Q} • *Pneumoperitoneum* • *Hypoventilation* • *Rebreathing*	• *Esophageal intubation*^{Q} • *Increased dead space*	

3.Blood gas analysis

o ***Arterial oxygen is the better indicator ofpulmonary function*** on the other hand ***mixed venous oxygen is the best indicator of cardiac out-put i.e., tissue oxygenation.*** For blood gas analysis, usually sample is taken ***from radial or femoral artery*** for arterial gas analysis and from ***right atrium or pulmonary artery*** for venous gas analysis.

Blood gas analysis is particularly needed in ***thoracic surgeries, hypothermia and hypotensive anaesthesia***

CARDIOVASCULAR MONITORING

o Cardiovascular monitoring may be either Non-invasive or Invasive

Non-Invasive methods

1. ECG

- ECG is an excellent monitor to detect arrhythmia, ischemia or cardiac arrest. ***For detecting arrhythmia's lead II is chosen and for detecting ischemia lead V2 is the best.***

2. Non-invasive B.P. (NIBP)

- These instruments measure BP automatically at regular interval. The cuff size is very important: - **The cuff size should cover two third of length of arm. Too large cuff will under-read and too small cuff will over-read the actual value**

3. Transesophageal echocardiography

- **Two dimensional TEE is the most sensitive method to detect myocardial ischemia** and **air embolism in peri-operative period.** Detection of **regional wall motion abnormality -** a rapid and more sensitive indicator of myocardial ischemia than is the ECG.
- ***Decreased systolic wall thickening may be more reliable index for ischemia than endocardial wall motion abnormality alone.***

Invasive methods

1 .Invasive blood pressure (IBP)

- Blood pressure can be recorded by putting a transducer in the artery. ***Radial artery is used most commonly. In infants dorsal pedis artery*** is used for IBP.

2.Central venous pressure monitoring (CVP)

- CVP is monitored ***most commonly in right internal jugular vein.*** It can also be measured in ***subclavian, basilica andfemoral veins.*** Normal CVP is ***3-10 cm of Hg (2-8 mm Hg).***
- **CVP is increased** in fluid overload, **CHF** Cardiac temponade, pulmonary embolism,

IPPV with PEEP pieurai effusion, Hemothorax, **Valsalva maneuver** coughing & straining.

- **CVP is decreased** in hypovolemia, shock, **venodilators (nitroprusside) ,** Spinal/epidural anaesthesia, general aneasthetics.

o **Complications**: - **Air embolism**\ Thromboembolism, Cardiac arrhythmias, pneumothorax, **hemothorax** chylothorax, cardiac temponade, **Sepsis** \ trauma to cartoid artery (can cause **pseudoaneurysm** ***)*** brachial plexus.

Uses (indications) for CVP monitoring

1) Estimation of intravascular volume and a **guide to fluid therapy**- in patients with :-
a) Hemorrhage & shock
b) Sepsis
c) Trauma
d) Cardiovascular dysfunction
2) Fluid resuscitation
3) Perioperative period
4) **Blood transfusion** or **plasma transfusion**
5) Beside for monitoring, the same central venous line can be used for -
a) Parenteral nutrition
b) Aspiration of air embolus
c) Cardiac pacing

3.Pulmonarv artery catheterization

o Pulmonary artery catheterization is the insertion of a Catheter into pulmonary artery. The catheter used for pulmonary artery catherization is **Swan-Ganz catheter.**Pulmonary artery catherization (Swan-Ganz catheter) is used for: -

Direct simultaneous measurement of pressure in right atrium, right ventricle, pulmonary artery

ii) Indirect measurement of left atrial pressure through pulmonary capillary wedge pressure.
iii) Cardiac output,
iv) **Oxygen saturation of mixed venous blood** —≫Pulmonary artery is considered best site for mixed venous blood sample.
v) Titration of fluid infusion.

INTRA-ARTERIAL CANNULATIQN

Radial artery at wrist is the most common site for insertion of an intravascular cannula.
Other arteries which can be used for cannulation are ***brachial, axillary, femoraland dorsal pedis arteries.***

oUses of arterial cannulation

- **Arterial blood sampling (e.g.ABG measurement*)***
- **Intra-arterial BP measurement**
- **Drug injection**
- **Expected large blood or fluid loss**

o ***Thrombosis of radial artery is the most common complication*** which can cause ischemic damage.

CHAPTER-4: GENERAL ANAESTHESIA

- The term **anaesthesia** was given by **Oliver Wendell Holmes**.

TRIAD of general anaesthesia are:

1. Narcosis (and Amnesia)
2. Analgesia
3. Muscle relaxation

With the advancement of anaesthesia **amnesia was considered as separate** entity and **abolition of autonomic reflexes** was added as a component of anesthesia. This concept of anesthesia called **as balanced anesthesia was coined by John Lundy in 1926**.

Components of **balanced anesthesia** :

1. Narcosis
2. Analgesia
3. Muscle relaxation
4. Amnesia
5. Abolition of reflexes
6. Maintenance of normal haemodynamics and physiologic homoeostasis.

GENERAL ANAESTHESIA PROTOCOL

A. **Premedications**

- ***Benzodiazepine*** (Lora-zepam or diazepam) is given i.m., night before surgery to produce ***amnesia and sedation.***
- ***Opioid (Fentanyl: Preferred, or pethidine/fortwin)*** is given i.v., just before surgery to produce ***analgesia.***
- ***Anticholinergic*** (Glycopyruoate preferred over atropine) is given before surgery to ***reduce secretions(antisialogoues).***
- ***Antiemetic*** (metoclopramide or ondansetron or hyoscine) is given i.v., just before induction.

B. **Preoxygenation**

- Preoxygenation is done ***for 3 minutes*** because **99% of denitrogenation (nitrogen wash out) takes place in 3 minutes .**

C. Induction

- After improving the oxygen reserve by preoxygenation, induction is done by **intravenous anaesthetic agent (Thiopentone or propofol).** Usually induction is done by intravenous anaesthetic agent, However sometime either it is not possible e.g., where i.v., access is difficult to obtain or it is not accepted (by children). In these situations induction is done by an inhalational agent through face mask. **Inhalational agent of choice for induction is sevoflurane.**

D. Intubation

- Just before intubation laryngeal muscles are relaxed by succinylcholine, i.e., **succinylcholine is the musclebrelaxant of choice for intubation*(Rocuronium*** is an alternative). After muscle relaxation ***endotracheal intubation*** is done and ***intermittent positive pressure ventilation (IPPV)*** is started.

E Maintenance

- Maintenance of anaesthesia is done by ***inhalational anaesthetic agent*** (Induction is usually done by intravenous anaesthetic agent).

- Anaesthesia is maintained with a controlled mixture of **oxygen (minimum 33%)**+ ***Nitrous oxide (66%)*** + ***inhalational agent (most commonly halothane)*** + ***Non-depolarizing muscle relaxant (Pancuronium/Vecuronium/Atracurium).***
- Two i.v. anaesthetic agents can also be used for maintainance in minor surgeries: - **Propofol (In total intravenous anaesthesia with** alfentanil), and ketamine. So, ketamine & Propofol can be used for induction as well maintenance

So,During preoxygenation —> 1oo%o2
During maintenance of anaesthesia -> **Minimum 33% 0 2**

F. **Reversal**

- At end of surgery inhalational anaesthetic is discontinued. **Non-depolarizing muscle blockade is reversed with neostigmine**

E **Extubation**

- Extubation is done after thorough suctioning of oral cavity.

Stages of anaesthesia. **Described by Guedel (for ether anesthesia)**

STAGES OF ANAESTHESIA

o **Guedel described four stages of ether** anaesthesia dividing the third stage into 4 planes. With faster acting GAs these clear cut stages are not seen now days as induction with these agents is too fast.

A) **Stage** 1 **(Stage of a n a l g e s i a)** : - It extends from beginning of anaesthetic inhalation to the loss of conciousness.

B) **Stage** 2 **(Stage of delirium or e x c i tm e n t)** : - From the loss of conciousness to beginning of regular respiration.

There is **roving eye ball (maximum movement of eye) pupii is partially dilated eye l*ash reflex is lost — First reflex to be lost.*** However eyelid reflex remains present.

C.**Stage** 3 **(stage of surgical anaesthesia)** : - From beginning of regular respiration to cessation of spontaneous breathing. **Most surgeries are done in this stage .**it is divided into 4 planes : -

1) **Plane** 1: - From beginning of regular respiration to cessation of eye movement. There is roving eye ball. Eye lid
reflex is lost. **This plane ends when eye ball become fixed.** Pupil size is normal.

2) **Plane** 2: - From cessation of eye movement to respiratory Paresis. Eye ball is fixed. There is loss of corneal reflex.
Pupil starts dilating

3) **Plane** 3 : - From respiratory paresis to respiratory paralysis. Pupil 3/4 dilated. Swallowing reflex and laryngeal reflexes are lost.

4) **Plane** 4 : - Intercostal paralysis, there is only abdominal respiration. Pupil is fully dilated. ***Carinal reflex (Cough reflex) is lost — Last reflex to be lost***
Lacrimation is present in plane II & III and absent in Plane IV.

D) **Stage** 4 **(stage of medullary paralysis)**: - There is respiratory arrest and apnea. Pupil is fully dilated & fixed,

o During recovery, the return of reflexes is in opposite sequence, i.e., first to come is carinal reflex and last is eye lash. So theoretically it is cough which should come first but **swallowing comes first** than coughing because coughing also requires diaphram and respiratory muscles effort.

STAGES OF ANAESTHESIA:AT A GLANCE

	Respiration	**Tidal volume**	**Pupils**	**Eye position & ocular movement**	**Reflexes abolished**
STAGE-1(stage of analgesia): from analgesia to loss of consciousness	Irregular	Small	Constricted	Divergent(Normal)	Nill
STAGE- 2 (Stage of excitement): From loss of consciousness to rhythmic respiration	Irregular	Large	Dilated (due to sympathetic stimulation)	Divergent(Roving)	Eyelash
STAGE- 3 (Stage of surgical anaesthesia): PLANE -1 (From rhythmic respiration to cessation of eye movement)	Regular	Divided into four planes Large	Constricted	Divergent (Roving initially and fixed till the end)	• Conjunctival • Pharyngeal • Skin
PLANE-2(Cessation of eye movement to respiratory paresis)	Regular	Medium	½ Dilated	Fixed centrally	• Corneal
PLANE-3 (Respiratory paresis to paralysis)	Regular	Small	¾ Dilated	Fixed centrally	• Laryngeal
PLANE-4 (Diaphragmatic paralysis)	Jerky	Small	Fully dilated	Fixed centrally	• Carinal • Anal sphincter
STAGE-4 (Medually paralysis)	----------APNEA----------				

Monitoring the depth of anaesthesia:

o Monitoring of depth of anaesthesia is done mainly clinically

- **Tachycardia.** Movement on painful stimuli
- Hypertension
- Laryngospasm / Bronchospasm
- Lacrimation
- Tachypnea
- **Perspiration (sweating)**
- Eye movement Evoked responses
- Preserved reflexes (coughing)
- **Bispectal index**

Bispectal index: js the first scientifically validated and commercially available **monitor to check depth of anaesthesia.** It utilizes many parameters like EEG signals, eye blinks etc to calculate a score. A score of45-60 is considered as adequate depth (score of 100 is for fully awake state and O for completely silent brain).

INTRAVENOUS ANAESTHETICS

Intravenous anaesthetic agents are used for : -

- **Induction : - *It is the most important and most common use.*** IV anaesthetic agents are used for induction, i.e., to induce balanced unconciousness which is then usually maintained by an inhalational agent. ***Propofol is the most frequently used IV anaesthetic*** . ***Thiopentone*** is the second most commonly used agent for induction.
- **Analgesia** : - Opioids
- **Amnesia and sedation** : - Benzodiazepines
- As a sole anaesthetic agent for minor procedures: - For **Total intravenous anaesthesia *(TIVA), Propofol (Supplemented by fentanyl) is the agent of choice. Ketamine*** can also be used. So these two iv anaesthetic agents ***(Propofol and ketamine) can be used for induction as well as maintenance.***

Fast acting (inducing agents)	Slow acting	Dissociative anaesthesia
• **Thiopentone sodium** • Propofol • Etomidate • Methohexitone • **Ketamine**	o Benzodiazepines Diazepam, Lorazepam, Medazolam	**Ketamine**

BARBITURATES

Thiopentone:AT A GLANCE

- It is an ultrashort acting barbiturate.
- **It has short duration of action due to rapid redistribution**
- **It is poor analgesic- painful procedure should not be done**
- It produces ***hyperalgesia.***
- **It causes fall in BP** due to vasodilatation - Cardiovascular collpase may occur if hypovolemia, shock or sepsis are present —Contraindicated in hypovolemia & shock,
- Reflex ***tachycardia*** may occur due to hypotension & vasodilation.,
- It can cause respiratory depression, laryngospasm and bronchospasm.
- ***It has anticonvulsant action - agent of choice for neurosurgical procedures***
- ***It is the agent of choice for cerebral protection because it decreases ICT, cerebral perfusion, , consumption and cerebral metabolic rate*** — Can be used in the treatment of raised ICT.
- It has poor muscle relaxant property. Mild **muscular excitatory movement ,**such as tremer, twitching, cough, hiccup may occur.
- **IV injection of thiopentone is painful.**
- Inadeverent intra-arterial injection is a very dreadful complication. This complication is commonly seen when thiopentone is **injected in antecubital vein** because in 10% of the

cases brachial artery divides above elbow giving a very superficial abnormal ulnar artery which lies deep to antecubital vein. Therefore **thiopentone injection should be avoided at antecubital fossa it should be given in the veins over the outer aspect of forearm . Intra-arterial injection produces thrombosis, vasospasm ischemia, necrosis and finally gangrene . The first symptom is burning pain.** ***The first sign is blanching of the hand*** due to vasospasm.

The management of this situation includes : -

- **Leaving needle insitu in the artery**
- **Brachial block (stellate ganglion block)**
- **Heparin injection —> To prevent thrombosis**
- Dilution of thiopentol by injection of saline into the artery.
- **Papaverine or prostacycline injection —≫ to relieve spasm.**
- Urokinase, streptokinase, vasodilators, steroid and **Lignocaine can also be used** Uncompensated myocardial disease.

Uses of thiopentol: -

- As anticonvulsant
- Inducing agent in anaesthesia
- Medically induced coma
- Euthnasia —IV thiopental is rapid way to accomplish euthnesia.
- Phobia —For desensitization.
- Truth serum -Thiopental can be used to uncover the truth. Thiopental suppresses the higher cortical neurons which are involved in lying without affecting the neurons involved in telling the truth.
- To facilitate the recall of painful repressed memories.
- Cerebroprotection - To reduce ICT
- It decreases intraocular pressure .
- It can produce hypersensitivity —Rash angioedema, photosensitivity**.**

Contraindications:

o Acute intermittent prophyria.Cardiovascular instability or shock
o Respiratory obstruction
o No availibility of airway equipments
o Status asthmaticus
o Pericardial tamponade

METHOHEXITONE

It is not commonly used

- 2 to 3 times more potent than thiopentone
- Used as 1% solution with pH of 11.1
- Dose: 1.5 mg /kg
- Elimination half life is 4 hours
- It can be given intramuscularly and per rectally to produce sedation in children.
- It induces seizures (while thioperentone is anticonvulsant) and can produce myoclonus. Therefore it is the agent of choice for electroconvulsive therapy (ECT)
- Histamine release is much less than thiopentone so preferred barbiturate for asthma patients.

Rest of the pharmacology is similar to thiopentone.

Propofol—At a Glance

- Propolol is the most frequently used intravenous anesthetic today.
- Propofol consists of a **phenol ring** with isopropyl group attached **(2,6 di-isopropylphenol).**[Q]
- ***Mechanism of action:Similar to thiopentone i.e. it also mediated its action through GABA (GABA-A subtype).***
- ***It can be used for both induction as well as maintenance.***[Q]
- Dose–**2mg/kg.**
- Like thiopentone it is **cerebroprotective,** [Q] (Reduce ICT, cerebral metabolism, oxygen consumption and cerebral perfusion).
- It also ***decreases intraocular pressure.***[Q]
- It does not possess anticonvulsive action (unlike thiopentone), rather sometimes it can **produce muscle twitching and myoclonus.**
- It causes hypotension and **bradycardia**[Q] [Remember: pancuronium causes hypertension + tachycardia].
- **Propofol causes dose dependent myocardial depression.**[Q] **Used with great caution in cardiac patient.**
- ***Propofol possess significant antiemetic***[Q] ***and antipruritic***[Q] ***action.***
- ***It is a Bronchodialator also.***[Q]
- ***Propofol decreases polymorphonuclear leukocyte chemotoxis***[Q] ***but not phagocytosis and killing. (Thiopentone blocks all these) - Increased life threatening infections.***
- **Recovery from propofol remains rapid,** even after prolonged infusion.
- It is anesthetic of choice **for intubation in ICU** and for patients with malignant hyperthermia.
- Intermittent injection or continuous infusion of propofol is frequently used for total I.V. anesthesia (TIVA) when supplemented by fentanyl.
- **It is metabolized in liver** but significant extrahepatic metabolism also occurs in lungs, and excreted via kidney.
- It is ***oil based*** preparation containing soyabean oil, **egg lecithin,**[Q] and glycerol. The colour of solution is ***milky white.***[Q] Solution should be ***used within 6 hours*** after opening the vial because there have been ***death reports following the use of contaminated solution as egg lecithin is a good medium for bacterial growth.***[Q]
- To prevent this problem recently available propofol preparations have ***disodium edetate or sodium metabisulfite as antimicrobial agent.***
- Side effects – **pain on injection,**[Q] myoclonus, apnea, ***decrease*** BP and rarely thrombophlebitis,
- Propofol infusion syndrome: A lethal syndrome, associated with **infusion of propofol for 48 hours or longer.**[Q]
- **Contraindication: Obstetrics, lactation, children less than 3 years, patient at high risk of aspiration like full stomach.**
- **Since egg allergy is almost always from egg white (albumin) not from lecithin (prepared from yoke) therefore history of egg allergy is not a contraindication for propofol.**[Q]

ETOMIDATE

Chemically it is an imidazole derivative. It also acts through GABA.

Advantages

1. It is most cardiovascular stable agent among all IV agents
2. Minimal respiratory depression
3. No histamine release
4. Previously considered as neuroprotective but latest studies has proven that it may cause neuronal damage at cellular level.

Side effects (disadvantages)

1. **Adrenocortical suppression** on long term infusion. Single use only causes temporary adrenocortical suppression which recovers with vitamin C supplementation.
2. Nausea and vomiting: Incidence is 40% which is highest among all intravenous anaesthetics.
3. High incidence of myoclonus(30 to 60%)
4. Injection is painful
5. High incidence of thrombophlebitis
6. **It can cause vitamin C deficiency**
7. Hiccups are common
8. May cause inhibition of platelet function
9. No analgesia
10. It is only porphyrinoingenic in rats not in humans therefore can be safely used in poephyrias in human beings.

Uses

Intravenous anaesthetic of choice for aneurysm surgery and patients with cardiac disease.

Ketamine: At a Glance

- A phencyclidine derivative.[Q]
- Main mechanism of action is by inhibition of NMDA receptors.[Q] Primary site of action thalamoneocortical[Q] projection.
- *Induction dose of ketamine– 0.5-2 mg/kg I.V. or 4-6 mg/kg I.M.*[Q]
- It causes *dissociative anesthesia and profound analgesia.*[Q]
- ***Stimulation of the sympathetic nervous system so it causes:***

Stimulates Cvs (increase O_2 demand/Heart rate, cardiac out-put, BP)[Q]	***Increase in ALL pressures i.e. (intracranial, intraocular, intragastric and intravascular pressures)[Q]***	***Increases Muscle tone.[Q]***	**Potent Bronchodialator[Q]**

Avoided *in patients with ischaemic heart disease*[Q] *or vascular aneurysms.* *Agent of choice for shock*[Q]	Contraindicated in raised intracranial pressure[Q]	Causes myalgia	AOC of *Bronchial Asthma*[Q] It *preserves upper airway reflexes.*[Q] *Salivation is increased so atropine is always given in premedication*[Q]

- It is associated with *emergence psychomimetic side effects like delirium and hallucination. Benzodiazepines (lorazepam)*[Q] seem to be the most effective group of drugs to attenuate or treat ketamine emergence reactions.

OPIOID ANAESTHETICS

- Opioids compounds are frequently administered during anaesthesia to suppress autonomic responses to tracheal intubation and painful (noxious) surgical stimuli.
- Opioids anaesthetics used commonly are ***fentanyl, alfentanil, remifentanil, Sufentanil.***
- These drugs are **potent opioids analgesics** and are used i.v. at the beginning of painful surgical procedure,
- Fentanyl is frequently used with droperidol as ***neurolept analgesia,*** when N,0 is also added it is called ***neurolept anaesthesia.***
- **Alfentanyl is opioid of choice for day care surgery.**
- ***Alfentanyl is used with propofol for total intavenous anaesthesia (TIVA).***
- ***Sulfentanil is the most potent opioid.***
- **Order of potency (in decreasing order) -> Sufentanil > Fentanyl = Remifentanil > Alfentanil .**
- **Remifentanil is shortest acting opioid due to its metabolism by plasma esterase .Dose reduction is not necessary in hepatic or renal disease.**
- Use of fentanyl, sufentanil and alfentanil during induction anaesthesia can prevent increase in IOT.
- ***Tone of chest muscles may increase with rapid fentanyl injection*** —**All fentanyl cogneres can produce truncal rigidity on rapid i.v. injection**

NEUROLEPT ANAESTHESIA

- **When fentanyl (analgesic) is combined with a short acting neuroleptic (droperidol), it is referred to as neuroleptic analgesia .**

Droperidol produces : - Sedation (hypnosis), mental detachment, catatonia (absence of voluntary movement), antiemetic effect, **hypotension .**

- **Fentanyl produces** : - Analgesia, Bradycardia, respiratory depression, muscle rigidity,

o Side effects of Neuroleptic analgesia : -

- **Due to Fentanyl: - Muscle rigidity** respiratory depression, bradycardia.
- **Due to droperidol**: **- Hypotension .** Extrapyramidal side effects like dyskinesia, grimacing, trismus, torticollis, oculogyric spasms, malignant neuroleptic syndrome, **Acute muscular dystonia,** Hallucination & bizarre sensations.

o **When N20 is added (along with 0 2) ,**to neurolept analgesia (droperidol + fentanyl) it is referred to as neurolept anaesthesia (i.e., **N20 + droperidol + fentanyl**). It characterized by unconciousness, analgesia and amnesia.

Steroid anaesthetics:

o **Althesin** : - It is combination of two steroids ***alphaxolone and alphadolone.*** It raises the intracranial tension significantly. It can cause severe ***hypersensitivity reaction*** —≫ **Contraindicated in asthma .** Because of dangerous hypersensitivity, it is no more used.

o **Eltanolone** : - It is naturally occurring metabolite of progesterone. Eltanolone is new agent ***under trial***

INHALATIONAL AGENTS:

Inhalational
anaesthetic agents are : -

- **Gas** -Nitrous oxide, cyclopropane
- **Volatile agent (liquid)** —Ether, Halothane, Isoflurane, Enflurane, Sevoflurane, Desflurane, methoxyflurane,Trichoroethylene.

Inhalational agents are mainely used in anaesthesia:

i. For maintenance of anaesthesia but these can also be used as
ii. Induction agents especially in children (inhalational induction) and also
iii. As a sole agent for small procedures (especially ether).

MECHANISM OF ACTION OF INHALATIONAL AGENTS

Exact mechanism is not clear. The most acceptable mechanism is that they directly bind to cellular proteins altering their enzymes.

Other mechanism may be:

1. Theory of fluidization : By expanding cellular membrane they causes it's fluidization to block sodium channels was previously considered a smost acceptable mechanism.
2. Enhance GABA mediated inhibition of central nervous system
3. Inhalational agents decrease the concentration of adrenaline, noradrenaline, acetylcholine, serotonin (Excitatory neurotransmitters) and increase the concentration of GABA and adenosine (inhibitory neuro – transmitters).

Site of Action of Inhalational Agents

- These agents mainly act on central nervous system (producing unconsciousness, amnesia and muscle relaxation) and dorsal horn cells of spinal cord (producing analgesia).
- Mainly acts on synapses (in high doses can block axonal transmission).
- Acts at both pre and postsynaptic level.
- At molecular level all inhalational agents has common lipophilic (lipid soluble) site. This theory is called as unitary theory of narcosis.

POTENCY OF INHALATIONAL AGENTS

Minimal alveolar concentration (MAC)

- **Most important measure of potency is minimal alveolar concentration (MAC)**

MAC is the **lowest concentration of the anaesthetic in pulmonary alveoli needed to produce immobility in response to a painful stimulus (surgical incision) in** 50% **individuals.**

- Higher the MAC, less potent the anaesthetic agent.
- **Methoxyflurane has minimum MAC** (0.16%) — **The most potent inhalational agent,**
- N2O **has maximum MAC** (105) - **The least potent inhalational agent**
- ***Order of potency in decreasing order*** (MAC in increasing order): -

Methoxyflurane (MAC = 0.16 %) > Triiene (MAC = 0.2%) > Halothane (MAC = 0.74%) > > Chloroform (MAC = 0.8 %) >Isoflurane (MAC= 1.15 %) >Enflurane (MAC= 1.68%) > Ether (MAC = 1.92 %) > Sevoflurane (MAC = 2.0 %) > Desjlurane (MAC = 6.0%) Cyclopropane (MAC = 9.2%) > N /) (MAC 104%)

Oil : Gas partition Coefficient

- Another important **measure of potency** is oil: gas partition cofficient. It measures the **lipid solubility of the agent** and therefore solubility in the fat-rich tissues of the CNS. ***Higher the lipid solubility (Higher oil: gas partition coefficient) more is the potency of the agent.*** There is a direct relationship between the MAC value of inhaled anaesthetic agents and lipid solubility in terms of oil: gas partition coefficient,
- ***Methoxyflurane has maximum l: Gas partition coefficient — Most lipid soluble & most potent.***
- 0 ***N20 has minimum oil: Gas partition coefficient — Least lipid soluble and least potent.***

Factors Effecting MAC

Factors Decreasing the MAC	*Factors Increasing the MAC*	***Factors having no effect on MAC***
1. **Age:** Maximum MAC in human beings is at the age of 6 months thereafter decreasing steadily throughout the life (except a slight increase at puberty). 2. **Temperature:** Decreasing the temperature decreases the MAC (e.g., 5% decrease in halothane MAC/^{0}C decrease in temperature). Increasing temperature also decreases the MAC up to 420C after that there is increase in MAC. 3. **Anemia:** Hb<5 gm% only decreases MAC.	1. Hyperthermia > 420C 2. Chronic intoxication of alcohol and amphetamines 3. Cocaine, Ephedrine 4. Barometeric pressure: Increasing pressure increases the MAC (pressure reversal theory of anaesthesia) 5. Hypernatermia	1. Thyroid diseases: Both hypo- and hyperthyroidism have no effect on MAC 2. Sex: MAC is same for males and females 3. Obesity: MAC does not increase in obese patients

4. **Hypoxia, hypercarbia:** Hypoxia and hypercarbia decreases the MAC only if they are severe. (pO_2<40 mmHg and pCO_2 >95 mmHg). 5. **Alcohol:** Acute alcohol or acute administration of amphetamines decreases the MAC while chronic intoxication increases Mac. 6. **Pregnancy:** There is decrease in MAC so inhalational anaesthetics should be used in lower concentrations. 7. **Intravenous anaesthetics:** Decrease the Mac. 8. α_2 agonists 9. Local anaesthetics: Decrease the MAC (except cocaine). 10. Electrolytes: • Sodium: Hyponatremia decreases while hypernatremia increases the MAC • Calcium : Hypercalcemia decreases the MAC Magnesium: Hypermagnesemia decreases the MAC		

SPEED OF INDUCTION & RECOVERY

Blood : Gas partition coefficient (B : G cofficient)

- It is the measure of ***solubility o f the agent in the blood.*** Agent with low blood solubility (low B : G coefficient) will have high concentration in alveolar air as it will diffuse less through the alveolar capillary membrane because of low blood solubility. Since alveolar concentration determines the induction and recovery, ***induction & recovery will be fast with agent with less B : G partition coefficient; and induction & recovery will be slower with agents with high B : G partition coefficient.***

- **Desflurane has minimum B : G partition coefficient (least blood solubility) —> Has Fastest onset and recovery**

o Methoxyflurane has maximum B : G partition coefficient (Maximum blood solubility)

— Has slowest onset &recovery

- ***Speed of onset & recovery in decreasing order*** (Increasing order of B : G partition coefficient and blood solubility): -

B/G partition Coefficient of different agents are:

Agent	Blood gas partiion coeficient
Xenon	0.14
Desflurane	0.42
Cyclopropane	0.44
Nitrous ocide	0.47
Sevoflurane	0.69
Isoflurane	1.38
Enflurane	1.8
Halothane	2.4
Chloroform	8
Trielene	9
Ether	12
Methoxyflurane	15

It can be concluded from the table that although fatest induction is seen with xenon but xenon is not yet available for commercial use therefore among the agents used now a days induction is fastest with desflurane with B/G coefficient of 0.42 and slowest with methoxyflurane with B/G coefficient of 15 (among the agents used now a days slowest induction is with halothane)

Diffusion Coefficient:

- Diffusivity relates to the ability of an agent to be mobile within the substance of a ***membrane*** and is expressed as a diffusion coefficient.
- Agent with low diffusion coefficient (low diffusion capacity) will remain in alveolar air — Fast induction and recovery. So, diffusion coefficient has similar effect, i.e., Low diffusion coefficient — Fast induction & recovery; and high diffusion coefficient — Slow induction & recovery. Therefore order of diffusion coefficient is same as in above box —Desflurane has minimum and methoxyflurane has max. diffusion coefficient.

Second gas effect & diffusion hypoxia

- In initial part of induction, diffusion gradient from alveoli to blood is high and larger quantity of anaesthetic is entering blood. If the inhaled ***Concentration of anaesthetic is high (eg N2O),*** Substantial loss of alveolar gas volume will occur and it creates negative intra-alveolar pressure that leads to removal of more gas from cylinder to alveoli

Concentration effect.

- If another inhalation agent is (eg Halothane) is being given at the same time, it also will be delivered to lung from the cylinder (due to negative intraalveolar pressure) - ***Second gas effect.***
- ***During recovery*** - reverse occurs - N20 having low blood solubility, rapidly diffuses into alveoli and dilutes the alveolar air —- partial pressure of oxygen in alveoli is reduced,

o The resulting hypoxia is known as ***diffusion hypoxia (Fink effect).***

o **Diffusion hypoxia occurs in first 5-10 minutes of recovery .**

o **Diffusion hypoxia can be prevented by continuing 100% 0**2 **inhalation for a few minutes after discontinuing N**2**0 , instead of straight away switching over to air. Besides**

N20 , Xenon also causes diffusion hypoxia

SYSTEMIC EFFECTS OF INHALATIONAL AGENTS

Central Nervous System

Cerebral metabolic rate and oxygen consumption: All inhalational agents decreases cerebral metabolic rate and oxygen consumption at higher dose except isoflurane which produces these effects at clinically used concentrations.

Intracranial tension: all inhalational agents increases Intracranial tension. Minimum increase is seen with isoflurane.

Since isoflurane minimally increases: ICT and decreases metabolic rate of brain at clinically use concentrations, it is the agent of choice for neurosurgery.

Respiratory System

a. Ventilation: Initially all agents decrease the tidal volume and increase the frequency (respiratory rate) but with increasing dose, frequency also decreases so finally decreasing
b. Systemic vascular resistance (SVR): SVR is decreased by all agents used now a days. Since maximum decrease in SVR is caused by isoflurane agent of choice for controlled hypotension.
c. Myocardial Contractility: There is significant inhibition of myocardial contractility with halothane.
d. Baroreceptor reflex: All protective cardio vascular responses are blunted by inhalational agents, least with isoflurane (most cardiovascular stable)> Desfulrane> Sevoflurane> Halothane > Enflurane. Therefore, isoflurane is the agent of choice for cardiac patients (except patients with myocardial ischemia in which there is theoretical risk that it can cause coronary steal).
e. Sensitization of heart to adrenaline: Heart is sensitized to adrenaline which is exogenous to heart (may be exogenous or endogenous to body) by:
   i. Halothane
   ii. Trielene
   iii. Cyclopropane
   iv. Chloroform
   v. Enflurane

Haemtopoietic System

Nitrous oxide interacts with vitamin B12 and inhibits many pathways involved in one carbon moiety.

Nitrous oxide inhibits the enzyme methionine synthetase and hence the production of thymidate and DNA formation.

Due to these effects nitrous oxide can produce Megaloblastic and Aplastic anemia. These changes are seen only on prolonged exposure.

Liver

All agents produces some degree of hepatotoxicity by decreasing the blood supply to liver (indirect effect). Direct hepatocellular damage is seen with:

- Halothane
- Chloroform
- Fluroxene
- Methoxyflurane (only in hypoxia)

Hepatic blood flow: Generally hepatic blood flow is decreased in proportion to the decrease in cardiac output by inhalational agents but the direct effect of inhalational agents on hepatic and portal blood flow complicates this relation.

All inhalational agents significantly decreases portal blood flow. Isoflurane, sevoflurane and desflurane increases hepatic blood flow to compensate for decrease in portal flow but not sufficient enough to maintain total blood flow. Halothane and enflurane decreases hepatic blood flow also so total blood flow is significantly reduced.

Decrease in total hepatic blood flow in decreasing order is Halothane>> enflurane> isoflurane= desflurane> sevoflurane

To conclude it can be said that all inhalational agents decreases total blood flow, maximal decrease with halothane and least with sevoflurane.

Renal System

All inhalational agents can depress renal function by decreasing the renal blood flow.

Direct renal toxicity has been attributed to inorganic fluoride (F) produced by fluorinated compounds. Inhalational agents are Fluorinated to decrease their flammability.

Renal threshold beyond which fluoride levels are toxic is 50µm and the fluoride level produced by different agents is:

Agent	Fluoride (F-) level (produced after 2.5 to 3.0 MAC hours)
Methoxyflurane	50 to 80µm
*Sevoflurane	30 to 50 µm
Enflurane	20 to 25 µm
Isoflurane	4 to 8 µm
Halothane	Produces fluoride only in anaerobic conditions
Desflurane	Does not produce fluoride

*Sevoflurane although produces fluoride level up to renal threshold level but still does not causes nephrotoxicity because of its low blood gas coefficient (0.69) which allows its low blood gas coefficient (0.69) which allows its rapid elimination from body.

The nephrotoxicity produced by flurorinated agents is vasopressin resistant polyuric renal failure.

Spinal Cord

On prolonged exposure nitrous oxide by inhibiting the production of thymidate can impair myelin formation which can lead to subacute degeneration of spinal cord. This effect is only seen after prolonged exposure.

Neuromuscular System

All inhalational agents are centrally acting muscle relaxants (except nitrous oxide).overall maximum relaxation is produced by ether but among the agents now a say used maximum relaxation is seen with Desflurane.

Teratogenicity

Only some studies have shown increased incidence of spontaneous abortions and congenital abnormalities in females who underwent anaesthesia during pregnancy and females chronically exposed to inhalational agents (nitrous oxide), but exact data and and conclusive evidence to prove teratogenicity of inhalational agents is not yet available.

Uterus

All inhalational agents used now a days are equally effective uterine relaxants (contrast to previous consideration that halothane produces maximum relaxation).

Eye

All inhalational agents decreases infraocular pressure

Amnesia

All inhalational agents are good amnesic agents except nitrous oxide

Inflammability of inhalational Agents

Inflammable agents are:

1. Ether
2. Cyclopropane
3. Ethylene
4. Ethyl chloride

- Agents can be made non- inflammable by adding fluorine atoms.
- Cautery should not be used in vicinity of inflammable agents up to 25cms.

Analgesia

Inhalational agents used now a days are not good analgesics except nitrous oxide and xenon which are good analgesics. Previously used anesthetics like trielene and ether used to be good analgesic (maximum with trielene).

Reaction of Inhalational Agents with Sodalime

- Trielene can produce dichloroacetylene (which is neurotoxic) and phosgene gas [which is pulmonary toxic (ARDS)].
- Sevoflurane can produce toxic compound, compound A with sodalime and barylime
- Methoxyflurane (maximum), halothane and isoflurane (to lesser extent) is absorbed by the rubber tubing of closed circuit and can be used safely if rubber tubing is replaced by plastic tubing.
- Desflurane, isoflurane and enflurane can produce carbon monoxide by reacting with desiccated sodalime and barylime.
- Sevoflurane by reacting with desiccated sodalime can produce a compound called as hydrogen fluoride which can cause burns of respiratory mucosa.

Metabolic

Hyperglycemia is seem with:

Among the agents used today desflurane may cause hyperglycemia by sympathetic stimulation other agents causing hyperglycemia are ether (causes hyperglycemia by mobilizing liver glycogen), Cyclopropane (mild hyperglycemia), Chloroform (Causes most profound hyperglycemia).

INDIVIDUAL INHALATIONAL AGENTS
AGENTS IN COMMON USE

NITROUS OXIDE

NITROUS OXIDE

- It was first prepared by Joseph Pristley in 1774.
- Also called laughing gas
- Prepared by heating ammonium nitrate between 245-270 degree centrigrade.
- Colorless non irritating sweet smelling.
- 35 times more soluble than nitrogen.
- 1.5 times heavier than air.

- It is very good analgesic but weak anaesthetic agent havng high MAC.
- It is poor muscle relaxant.
- Color of the cylinder is blue
- Entonox is a mixture of 50% N2O+50% O2
- It is used in a concentration of 50-65% with 33% oxygen.
- N2O use is contraindicated in pneumothorax and volvulus.
- Methemohemoglobinemia and laryngospasm may occur due to the presence of impurites like nitric oxide and nitrogen dioxide.
- Vit12 can cause demyelinating lesion of spinal cord (sub acute combined degeneration of spinal cord), specially posterior column and latearal spinothalamic tract.
- Contraindicated in- pneumothorax, pneumoperitoneum,pneumoencephalum, middle ear surgery and tympanoplasty, posterior fossa surgery, laparoscopic surgery, acute intestinal obstruction and volvulas of gut , eye surgery and microlaryngeal surgeries.

Xenon

- It is a colourless, odourless, non flammable and **nonexplosive**
- Xenon (Xe) is a member of the so-called nobel or inert gases.
- Xenon is a heavy gas and is 4.5 **times heavier than air**
- Xenon is more potent than N20 (MAC 71%), but MAC is higher than other inhalational agents **— *Xenon is a weak anaesthetics (less potent)***
- **The blood gas partition cofficient is very low.Ev**en less than desflurane) —**Induction (onset) and recovery are very fast**

  - Xe does not **trigger malignant hypertermia.**
  - ***X***enon offers concentration effect, second gas effect and diffusion hypoxia, similar to N20.
  - It provides good ***hemodynamic stability with little change in blood pressure.*** It causes slight reduction in heart rate, otherwise it has no effect on heart — **Minimal cardiovascular side effects**
  - As it is radiodense, Xe-133 is used to ***enhance CT images of brain and to measure cerebral blood flow.***
  - Xenon produces a high regional blood flow in brain, liver, kidney and intestine — greatly reducing the dangers of tissue hypoxia and providing an ***alternative for transplant surgery.*** As Xe increases cerebral blood flow & ICT —to be used with caution in patients at risk for raised ICT.
  - For anaesthetic purposes, it was found very **close to the *"ideal agent"*.**
  - However, it is not used commonly because of high cost, unavailability, low potency, unavailability of commercially available anaesthesia equipment and its concentation can not be measured with conventional anaesthetic gas analyzers.

Xenon anaesthesia:

Advantages	**Disadvantages**
• ***Non explosive***^{Q} • ***Minimal cardiovascular effects.***^{Q} • ***Low blood solubility.***^{Q} • ***Rapid induction and recovery*** **(lowest blood gas partition coefficient)**^{Q}	• No commercially available anaesthesia equipment • High cost • Low potency

• Does not trigger malignant hyperthermia • Environmental friendly • Inert probably nontoxic with no metabolism • Unlikely to be involved in any biochemical events in the body. can be eliminated via lungs.	

TRILENE (Trichloroethylene)

- It is a potent **nerve poison, Vth & VIIth** CN are **m/c** involved, but damage to 3, 4, 6, 10, 12 CN can occur.
- Most potent analgesic agent because MAC is low 17%. Used for **trigeminal neuralgia** & for labour analgesia.
- Not used now a days
- Reaction with sodalime :- dischloroacetylene - neurotoxic-V, VII. Phosgene - pulmonary toxicity (ARDS)
- It is not used in closed circuit becoz it reacts with sodalime to form di-chlor acetylene (neurotoxic) and phosgene (pulmono-toxic)

- $C_2HCl_3 + NaOH = C_2Cl_2 + NaCl + H_2O$
- At 125°C or in presence of O2 as in cautery, it decomposes into **phosgene** ($COCl_2$) & HCl.
- Cardiostable. Does not depress myocardium/respiration.
- Disadvantage : Sensitizes heart to action of adrenaline (occasional dysthythmias), tachypnea, addiction liability.

CHLOROFORM

- 1st agent used for labour analgesia. Toxic agent.
- Cardiotoxic agent. Can cause death due to ventricular fibrillation.
- Highly emetic. Causes post op nausea/vomiting.
- Hepatotoxic. Causes profound hyperglycemia. Avoided in diabetic.

ETHER

- 1st public demonstra[n] on 16th Oct 1986 by W.T.G. Mortor. So 16th October is celebrated as World Anaesthesia Day.
- Pungent smelling (**unpleasant**).
- High potency (MAC 1.9).
- Agent with maxm skeletal muscle relaxation & good analgesia, so it is a complete anaesthetic agent.
- Safest anaesthetic in untrained hands.
- Only inhalational agent that stimulates respiration
- Both induction and recovery are slow.
- Inflammable/highly explosive. Not to be used with cautery.
- Does not sensitize the heart to the action of adrenaline.(BP & respiration well maintained)
- Highest incidence of nausea & vomitting among inhalational agent.
- Only inhalational agent that preserves/maintains cilliary function (All other agents decrease cilliary activity).

Cyclopropane

- Cyclopropane is an anaesthetic when inhaled. However, In modem anaesthetic practice it has been superseeded by other agents.

- It stimulates sympathetic system and blood pressure Can be used in shock. However, in emergence, cyclopropane it self causes shock, therefore should be tapered slowly,
- It can cause **hyperglycemia**
- **Cyclopropane tends to gravitate towards floor it is heavier than air**

FLUORINATED ANAESTHETICS

o Fluorine atoms are added to some agents to make them ***non-inflammable.*** Fluorinated anaesthetics are **Halothane isoflurane,** Desflurane, sevoflurane, **Enflurane *m,* methoxyflurane,** Note : All fluorinated agents has flurane as suffix in there name, except halothane).

Halothane

- Potent volatile anesthetic (non inflammable, non-toxic).
- **Sweet smelling** agent. Causes smooth inhalational induction in children.
- Only alkane among fluorinated inhalational agents.
- **Corrodes metals** in vaporizers in the presence of moisture.
- Stored in **amber colored bottles** to prevent degradation.
- Vaporiser colour is amber/red.
- 0.01% thymol is added as preservative
- **Metabolism** – 25% is metabolized, main metabolites →**Trifluroacetic acid**
- Undergoes maximum metabolism.

Effects:

- Bradycardia by delaying SA-AV nodal conduction.
- Hypotension by direct depression
- Sensitize the myocardium to dysarrythmic effect of catecholamines (adr). Adrenaline containing solutions should be avoided with halothane.
- Absolishes hypoxic drive even at 0.1 MAC.
- Decreases **IOP and BP, but ICT is** increas**ed**.

Advantages:

1. It is a powerful **bronchodilator, preferred in asthma**.
2. Uterine relaxant: DOC for **manual removal of placenta**. C/b used for internal version, tetanic uterine contraction.

Disadvantages:

1. **Malignant hyperthermia**
2. Significant relaxation of uterus can **increase PPH.**
3. Does not provide any pain relief. Hyperventilate the pt prior to halothane administration becoz it blunts cerebral autoregulation.
4. Causes shivering - **Halothane shakes** increase O2 requirement by 500%. Best antidote for shivering is pethidine/tramadol.
5. **Halothane hepatitis** (massive centrilobular necrosis) is a fatal condition in which mortality is 50%.

Can cause 5 'H' - **hyperthermia, hepatitis, hypotension, hypercapnia, decrease HR (myocardial depression).**

Should not be used within 3 month in the same pt.

Enflurane:

- It is a halogenated ether.
- It is a faster acting substitute of halothane
- Enflurane cause maximum respiratory depression.
- ***Because of its propensity to provoke seizures, it has been superseeded by isoflurane*** —**It is contraindicated in epilepsy**

Isoflurane:

- It is an isomer of enflurane with similar properties but 1 ***'A*** times more potent.
- BP falls due to vasodilation, **while cardiac output is maintained inhalation anaesthetic of choice in**
- **Cardiac surgery (intravenous anaesthetic of choice for cardiac surgery is etomidate)**
- It does not sensitize the heart to Adr **—** Safe in pheochromocytoma.
- **Isoflurane causes minimum increase in ICT — Preferred agent in increased ICT**
- It does not provoke seizures **—** ***preferred in neurosurgery.***
- Uterine and skeletal muscle relaxant action is similar to halothane - can be used for assisting version as an alternative to halothane.
- It causes significant respiratory depression.
- **Isoflurane is the volatile agent of choice in liver disease as it has least effect on hepatic blood flow**
- ***It can cause coronary steal phenomenon***
- It can be used for day care surgery (also sevoflurane and desflurane).
- It is also used to produce controlled hypotension, as it causes maximum decrease in systemic vascular resistance.

Desflurane:

- It is a newer ***all fluorinated congener of isoflurane ,*** which has gained popularity as an anaesthetic ***for out patient surgery ,.***
- **It is *fastest acting* inhalation anaesthetic with minimum blood** : **gas partition cofficient**
- It is ***highly volatile*** **—**\ a thermostatically heated special vaporizer is used to deliver a precise concentration of pure
- desflurane vapour in carrier gas (N20 + 0 2) mixture,
- **Desflurane has pungent odor** (In contrast to sevoflurane, which is sweet smelling).
- It is ***less potent than isoflurane,*** higher concentration has to be used for induction - may induce coughing, and laryngospasm because of **pungent odour—**\ ***Unsuitable for induction.***
- Degree of respiratory depression, muscle relaxation, vasodilation and fall in BP, as well as maintained cardiac contractility and coronary circulation are like isoflurane.
- **Desflurane is a safe anaesthetic for geriatric patients as its cardiovascular effects are similar to isoflurane but without coronary steal**
- **Desflurane is metabolically stable, only 0.2% is metabolized**
- Both isoflurane and desflurane do not provoke seizures, are not arrhythmogenic and do not have liver and kidney toxicity.
- Desflurane causes myocardial depression less than that of Enflurane or halothane —≫ **Myocardial depression is not severe.** (All inhalational agents cause myocardial

depression to some extent:- isoflurane, sevoflurane & desflurane has minimal effect).

Sevoflurane:

- It is fluorinated **isopropyl methyl ether** (Enflurane, desflurane & isoflurane are ethyl-methyl ether).
- **Sevoflurane is the inhalational agent of choice for induction** (usually i.v. anaesthetics are used for induction),
- So, it can be used for induction as well as for maintainance (Amongst the intravenous agent propofol & ketamine can be used for induction as well as maintenance).
- ***It is more potent than desflurane but less potent than isoflurane.***
- **Unlike desflurane it poses no problem in induction, acceptibility is good even by pediatric patients — inducing agent in children**
- **Sevoflurane is degraded by contact with the C02 absorbent (soda lime) in anesthesia machines- should not be used in closed circuit**
- Recent studies have suggested that **sevoflurane is associated with both activation of** EEG **and seizure activity**
- Seizure like movement and EEG recorded seizures have been noted during induction of anaesthesia with sevoflurane. However, ***the effects of sevoflurane is much less obvious than with enflurane.***

Summary systemic effects of inhalational agents

Agent	**Cardiovascular system**		**Central nervous system**			**Respiratory system**		**Hepato-toxicity**	**Nephro-toxicity**
	Heart	**Mean Arterial pressure**	**CM O_2**	**CBF**	**ICT**	**Ventiation**	**Bronchial muscles dilatation**		
Halothane	↓	↓↓	↓	↑↑↑	↑↑↑	↓	**+++(in asthmatics)**	**+++**	**-**
Isoflurane	**↑(reflex Tachycardia)**	↓↓↓	↓↓↓	↑	↑	↓	**+**	**–**	**-**
Enflurane	↓	↓↓	↓	↑↑	↑↑	↓	**+**	**-**	**-**
Nitrous oxide	**0**	**0**	**0/↑**	↑	↑	↓	**+/0**	**-**	**-**
Xenon	**0**	**0**	**0**	**0**	**0**	**0**	**Bronchoconstriction**	**-**	**-**
Sevoflurane	↓	↓	↓	↑↑	↑↑	↓	**+++ (in non asthmatics)**	**-**	**+/-**
Desflurane	↑	↓↓	↓	↑	↑↑	↓	**+**	**-**	**-**

Ether	↑	↑	↑↑	↑↑	↑↑↑	↑	++	-	-
Trielene	**0/↓**	**0/↑**	-	↑	↑	↑↑	+	-	-
Methoxyflurane	↓	↓	-	↑	↑	↓	+	+	+++
Cyclopropane	↑	↑↑	-	↑	↑	↓	+	-	-
Chloroform	↓	↓	-	↑	↑	↓	+	++	-

- = no effect
0 = negligible effect
↓ = decrease
↑ = increase
\+ = minimum
++ = moderate
+++ = maximum

CMO_2 = Oxygen consumption of brain tissue
CBF = Cerebral blood flow
ICT = intracranial tension

CHAPTER-5: MUSCLE RELAXANT

MECHANISM OF ACTION OF NEURO MUSCULAR BLOCKERS

Neuro-muscular blocker act at myoneural junction

1. Competitive (Non-depolarizing) blocker: -

- ***They compete with Ach for Nm receptor--- called competitive blockers.*** They prevent binding of Ach to Nm receptors — No opening of Na+ channels — No depolarization, so these are called nondepolarizing blockers.
- ***Competitive blockers reduce the frequency of channel opening but not its duration or the conductance of a channel once it has opened.*** When the magnitude of end plate potential falls below a critical level, it is unable to trigger propagated muscle action potential — muscle fails to contract.
- ***Neostigmine (anticholinesterases) antagonises competitive blockers*** as it increases the concentration of Ach by inhibiting its degradation by cholinesterase. Therefore, **Neostigmine is used for the reversal of competitive (nondepolarizing) blockers.**

2. **Depolarizing blockers (Succinylcholine, Decamethonium)**

- ***Depolarizing blockers have affinity as well as submaximal intrinsic activity on NM receptors.*** **They depolarize muscle end plates by opening of Na+ channels** and initially ***produce twitching and fasciculations*** (not full contraction as these drugs have submaximal activity) So, they are called depolarizing blocker.

These drugs do not dissociate rapidly from the receptor — ***Persistant partial depolarization*** —Na+ channels get inactivated —flaccid paralysis.

Neostigmine does not antagonise depolarizing blockers (Therefore neostigmine cannot be used for reversal).Infact neostigmine can potentiate the block as neostigmine and other anti-cholinesterase also inhibits pseudocholinesterase which metabolizes

Sch. Under certain conditions depolarizing agents produce dual mechanism of neuromuscular blockade which can be divided into two phases :

a) Phase I block

- Rapid in onset
- Result from persistant depolarization of muscle end plate — Typical mechanism of action of depolarizing blocker.
- Has classical features of depolarization block.

o ***Block is not antagonized by anticholinesterases (neostigmine).***

b) Phase II block (Dual block)

- Slow in onset
- Results from desensitization of receptor to ACh —> Ach can not act on Nm receptors (similar to competitive blocker).

o **Resembles block produced by competitive blockers** — Therefore, has characteristics similar to non-depolarizing (competitive) block.

o Block is partially reversed by anticholinesterases (Neostigmine).

- □ **In man, normally, only phase I block is seen — typical depolarizing block.**
- □ **Phase II block is seen when fluorinated anaesthetics have been given or when SCh is injected in high dose**
- □ **SCh also produces phase II block in patients with atypical or deficient**

pseudocholinesterase

Crux : -

o Non-depolarizing blockers produce flaccid paralysis,

o Depolarizing blockers (Sch) produce: -

i) Usually Phase I block which is characterized by fasciculation followed by flaccid paralysis.

ii) Phase II block occurs only when Sch is given in high doses (> **5mg/kg or** > **500 mg)** or given with fluorinated anaesthetic or when there is atypical (Non-functional) pseudocholinesterase. Phase II black is similar to non-depolarizing block.

Sequence of muscle blockade

o Neuromuscular blockade (both depolarized and non-depolarized) develops faster in centrally located muscles, i.e., face, jaw, pharynx, larynx, and muscles of respiration (including diaphrgm). Peripherally located muscles e.g., limb muscles (adductor pollicis) are involved later. ***Sequence of blockade is*** : ***Face —Jaw Pharynx —> Larynx —Respiratory (including diaphragm) — Trunk muscle — Limb muscle.***

Face muscles are involved earliest:-

i) ***In succinylcholine (depolarizing blocker) First clinical sign is fasciculation of eye lids.***

ii) **In non-depolarizing blocker (d-Tc) Ptopsis & Diplopia occurs earliest .**

- Sequence of recovery is same as the blockade. As blockade develop faster, lasts a shorter time and recovers more quickly in central muscle : - Face muscles recover earliest and limb muscles at last
- You should keep in mind that, **though diaphragm (centrally located muscle) involves early, it is the most resistant to Nm blockers**
- Clinical blockade of diaphragm (i.e., 60-70% of receptor occupation) do occur but to block it completely it is most resistant and complete blockade occur even after limb muscles

Classification:

<table>
<tr><th colspan="2">Peripherally acting</th><th>Centrally acting</th></tr>
<tr><td>Neuromuscular blocking agents</td><td>Directly acting agents</td><td rowspan="2">Mephenesin congeners
• Mephenesin
• Carisoprodol
• Chlorzoxazone
• Methocarbamol
Benzodiazepines
• Diazepam and other BZDs
GABA derivatices
• Baclofen, thiocholchicoside
Central a2-agonist
• Tizanidine</td></tr>
<tr><td>• Non-depolarising agent (NDMR)
• Depolarising agents (Non-competitive)</td><td>Dantrolene sodium
• Quinine</td></tr>
</table>

On the basis of duration of action **Non-depolarising** agent (NDMR) **(Competitive**) are classified as:

Long acting	**Intermediate acting**	**Short acting**
D tubbocurae Gallamine Pancuronium Pipecuronium Doxacurium **(longest acting)**	Vecuronium Rocuronium Atracurium Metocurine Cis- atracurium	Mivacurium Rapacuronium Gantacurium **(shortest acting)**

Depolarising agents (Non-competitive):

	Action	Example
· Depolarising agents (Non-competitive)	Shortest acting	Sch Decamethonium

Important facts about muscle relaxants:

- *Shortest acting competitive (nondepolarizing) neuromuscular blocker —Mivacurium (duration of action 12-18 minutes)*
- *Shortest and fastest acting neuromuscular blocker — Succinylcholine—duration of action 5-8 minutes, so it is DOC for endotracheal intubation*
- *Longest acting (120 min.) and most potent is doxacurium whereas least potent is gallamine*
- *Most commonly used muscle relaxant for routine surgery — Vecuronium*
- *Gantacurium—Nondepolarizing (competitive) neuromuscular blocker is new drug in phase 2 clinical trial with shortest duration of action, even shorter than succinylcholine*
- *Fastest acting nondepolarizing blocker — Rocuroniuim (can be used for endotracheal intubation*).R
- *Histamine release is caused by — D-TC (maximum tendency), succinylcholine, mivacurium, doxacurium, atracurium, tubocurarine — can cause bronchoconstriction.*
- *Virtually no histamine release—Pancuronium*
- *Rapacuronium has been withdrawn due to reports of severe bronchoconstriction.*
- *Atracurium and cis-atrcurium undergo Hoffman's elimination (spontaneous nonenzymatic molecular rearrangement) and are the DOC for renal or hepatic failure patients.*
- *Maximum ganglion blockade is caused by — d-TC*
- *Ganglion stimulation is caused by —Succinylcholine*
- *Maximal vagal block and tachycardia is caused by —Pancuronium*
- *Vagal stimulation is caused by —Succinylcholine*
- *Most potent skeletal muscle relaxant — Doxacurium*
- *Least potent nondepolarizing muscle relaxant — Rocuronium*
- *Gallamine has been withdrawn due to its nephrogenic and teratogenic potential*

Succinylcholine: At a Glance

- ***It is the shortest and fastest acting skeletal muscle relaxant.***[Q]
- SCh is a **depolarising**[Q] skeletal muscle relaxant.
- First introduced by Thesleff and Folds but first used **clinically by Bovet.**[Q]
- It causes sustained partial depolarization of muscle end plate —***initially produce twitching and fasciculation*** followed by flaccid paralysis.
- It can cause ***muscle fasiculations*** and soreness.
- ***It is the only muscle relaxant which stimulate autonomic ganglia and vagus.***[Q]
- ***SCh is the most commonly used muscle relaxant for passing endotracheal tube*** (mivacurium and rocuronium are alternatives).[Q]
- ***SCh is rapidly hydrolysed by plasma cholinesterase,*** some patients have genetically determined abnormality or deficiency of pseudocholinesterase, in them, **SCh causes phase II block.**[Q]
- It can cause change in BP and HR, arrhythmia, histamine release and K^+ efflux from muscles.
- SCh causes **increase in all pressures** —intraocular, intracranial, BP and intrabdominal—contraindicated in glaucoma, head injury.
- It can accentuate ***malignant hyperthermia caused by halothane***.[Q]

Systemic Effects

Cardiovascular system: It produces muscarinic effects similar to acetylcholine. Therefore can cause **bradycardia** (but at very high doses it may cause tachycardia due to the stimulation of nicotinic receptors at sympathetic gangalion).

Hyperkalemia: This is due to excessive muscle fasciculations. Ventricular arrhythmias can occur due to Hyperkalemia. In a normal subject serum potassium increases by 0.5 mEq/L

CNS: SCh increases intracranial tension [due to contraction of neck muscles, blocking venous outflow (jugular veins) from cranium].

Eye: Ocular muscles are multiple innervated muscles which undergo tonic contraction after Succinylcholine increasing the intraocular tension (IOT).

GIT

i. Intragastric pressure is increased due to contraction of abdominal muscles
ii. Increased salvation.
iii. Increased gastric secretions.
iv. Increased peristalsis.

Muscle pain (myalgias, muscle soreness): This is a very common problem in postoperative period; incidence is 40 to 50%. These are due to excessive muscle contractions. The incidence of postoperative myalgias can be reduced by:

i. Precrurarization

Precrurarization is the technique in which one tenth dose of Nondepolarizing muscle relaxant is given 3 minutes prior to succinycholine. This small dose of non depolarizes by blocking some of the receptors will decrease fasciculations and hence myalgias with

Suxamethonium.
This technique can also prevent the rise in intracranial and intragastric pressure but cannot prevent rise in intraocular pressure (due to multi innervation of ocular muscles)

ii. Self taming which means giving $1/10^{th}$ dose of Succinylcholine 30 to 60 seconds prior to full dose (not used now a days).

ii. NSAIDs: Use of NSAIDs also decrease incidence of myalgias (gut not used routinely for this purpose)

Malignant hyperthermia: SCh is the most commonly implicated drug.
Anaphylaxis: Severe hypersensitivity reaction can occur with Succinylcholine.

Masseter spasm: SCh can cause masseter spasm especially in children and patients susceptible for malignant hyperthermia.

Contraindications

1. **Hyperkalemia:** Serum K+>5.5 mEq/L is an absolute contraindication for use of SCh.
2. **Head injury:** It increases ICT.
3. **Newborns and infants:** These have extrajunctional receptors which are sensitive to depolarizing agents and SCh can produce severe Hyperkalemia by interacting with these receptors. Preferably it should be avoided in young children due to coexistence of undiagnosed muscular dystrophy.
4. Glaucoma and eye injuries (increases intraocular pressure)
5. Up to 2-3 *months after trauma.*
   Up to 6 months after hemiplegia/ paraplegia (stroke).
   Up to 1year after burns (the greatest risk is between 1 week to 2 months).
   In these conditions denervated/ regenerating nerve develops extrajunctional receptors which can produce Hyperkalemia.
6. Renal failure: If associated with Hyperkalemia.
7. Prolonged intraabdominal infection may be associated with Hyperkalemia.
8. Diagnosed case of atypical pseudocholinesterase and low pseudocholinesterase.
9. Duchene muscle dystrophy: Severe life threatening Hyperkalemia can occur if Succinylcholine is given to these patients.
10. Dystrophia myotonica: Permanent contractures may develop if Succinylcholine is given.
11. Tetanus.
12. Guillain Barre syndrome.
13. Metabolic acidosis: Acidosis is associated with Hyperkalemia.
14. Shock: Shock is associated with acidosis which in turn is associated with Hyperkalemia.
15. Spinal cord injury.

Prolonged Apnea After Succinylcholine

It can be because of:

1. Low pseudocholinesterase.
2. Atypical pseudocholinesterase.
3. Phase II block.

Low Pseudocholinesterase

It can be because of :

Pseudocholinesterase is a protein synthesized by liver and is present in plasma. Normal serum level is 80 units/ml and half life is 12 hours. Psedocholinesterase level should fall below 75% of normal to produce clinically significant prolongation of suxamethonium effect.

It's levels are reduced in:

- Liver diseases
- Uremia
- Hypoproteinemias
- Nephrosis
- Newborns.
- Alcoholics
- Cytotoxic drugs.
- Malignancies
- Alkalating agents
- **Cholinesterase inhibitors:** Neostigmine, pyridostigmine and Echothiophate inhibits pseudocholinesterase and can prolong apnea up to 60 minutes. So *cholinesterase inhibitors can reverse the action on non depolarizers and prolong the block of depolarizers.*
- Metoclopramide.
- Pancuronium.
- Oral contraceptives.

Treatment

1. Continue IPPV and wait for spontaneous recovery as spontaneous recovery occurs in almost all cases after a delayed period.
2. Fresh frozen plasma: It should be given only if patient is not recovering spontaneously but one must keep the risk of disease transmission in mind before giving FFP.
3. Heat treated preparation of cholinesterase is also available in western countries.

Atypical Pseudocholinesterase

Incidence: 1 in 3,000. This can be diagnosed by **Dibucaine number**.

- Dibucaine is a local anaesthetic which can inhibit 80% of normal enzyme and 20% of abnormal enzyme therefore dibucaine number for homozygous typical (normal person) is 70 to 80%. So Dibucaine number only indicates the genetic makeup of individual. It can not measure the concentration or efficiency of pseudocholinesterase
- Sodium fluoride can be used in place of dibucaine (**Fluoride number**)
- Usually apnea is for 1 to 2 hours.

Treatment

1. Continue IPPV as most of the patients recover spontaneously after prolonged period
2. Give fresh frozen plasma for the patients who do not recover spontaneously
3. Synthetic preparation of cholinesterase.

Phase II Block

Also called as **dual block**. This is prolonged block due to **excessive dose of SCh(>5 mg/kg or> 500 mg).** Exact Pathophysiology of phase II block is not understood but some of the

mechanism are:

i. Desensitization: Repeated SCh produces structural changes in receptor which undergoes desensitization (that means not sensitive to Ach).
ii. Channel blockade: SCh molecules enter the open channel and produce prolonged block.
ii. Calcium mediated injury to end plate.

Diagnosis: Succinylcholine showing fading on neuromuscular monitoring is pathognomonic of phase II block (normally fading is shown by non depolarizing muscle relaxants).

Treatment

- Maintain IPPV
- In 50% individual s block may reverse by itself in 10 to 15 minutes.
- In the remaining cases a trial of neostigmine can be given if there is no response even after 30 minutes. If neostigmine is given early it can worsen the block. Sufficient evidence stating the role of neostigmine in phase II block is still lacking.

Clinical characteristics of phase 1 and phase 2 neuromuscular blockade during succinylcholine infusion

Characteristic	**Phase 1**	**Transition**	**Phase 2**
Tetanic stimulation	No fade	Slight fade	Fade
Post-tetanic facilitation	**None**	**Slight**	**Yes**
Train-of-four fade	**No**	**Moderate fade**	**Marked fade**
Train-of-four ratio	**>0.7**	**0.4-0.7**	**<0.4**
Edrophonium	Augments	Little effect	Antagonizes
Recovery	Rapid	Rapid to slow	Increasingly prolong
Dose requirements (mg/kg) *	**2-3**	**4-5**	**>6**
Tachyphylaxis	No	Yes	Yes

Mivacurium

- ***Mivacurium is the shortest acting competitive blockert***
- It is metabolized rapidly by ***plasma cholinesterases*** —≫ Prolonged paralysis can occur in pseudocholinesterase deficiency.
- ***Mivacurium is the only nondepolarising (competitive) blocker that is metabolized by plasma cholinesterase (pseudocholinesteres).***
- It does not need reversal —≫ can be used as an alternative to **SCH for endotracheal intubation**.

Atracurium

- **The unique feature of atracurium is inactivation in plasma by spontaneous nonenzymatic degradation (Hofman elimination)** jn addition to that by alkaline ester hydrolysis.
- ***Consequently its duration of action is not altered in patients with hepatic/renal insufficiency or hypodynamic circulation —> Preferred muscle relaxant for such patients as well as for neonates*** and the elderly.

- ***Atracurium is metabolised to laudanosine that is responsible for seizures .***
- ***It can cause histamine release —> Hypotension, bronchoconstriction & flushing***

It is relaxant of choice in

- Renal failure
- Hepatic failure
- Neuromuscular disease
- Neonates'

Cisatracurium(5w89):

- This is R-Cis, R-Cis enantiomer of atracurium is nearly 4 times more potent, slower in onset but similar in duration of action. ***Like atracurium it undergoes Hofman elimination, but in contrast it is not hydrolysed by plasma cholinesterase. Most importantly it does not provoke histamine release*, therefore it is preferred over atracurium**
- As cisatrucurium does not provoke histamine release, ***there is no branchospasm, hypotension and reflex tachycardia.***

Cisatracurium does not affect heart rate or BP nor does it produce autonomic effect.

- **Cisatracurium produces less laudanosine than atracurium** (by Hoffman elimination). Therefore, Cisatracurium causes less CNS toxicity (seizures) than atracurium.
- Cisatracurium has more potency, and **longer duration of action than atracurium,** therefore requires less doses than atracurium. **Onset of action of both Cis-atracurium and atracurium is almost same**
- **Reversal of atracurium and cisatracurium by neostigmine is not required** because of spontaneous nonenzymatic degradation (Hofmann elimination) —≫ **So, Atracurium/cisatracurium can be used in patient with neostigmine hypersensitivity. *Other non-depolarizing agents can not be used as they require neostigmine for reversal.***

Vecuronium

- Vecuronium is a ***steroidal (amino-steroid)*** non-depolarizing neuro-muscular blocker with **intermediate duration (20-50 min) of action.**
- **Vecuronium is lipid soluble** and the lipophilic effect of single quaternary nitrogen enhances rapid uptake into hepatocytes.
- It is ***mainly metabolized in liver and excreted in bile.*** Only slightly (< 20%) excreted in urine —> **Not affected by renal failure**
- Vecuronium is **cardiovascular stable ,,** even at high doses, vecuronium is devoid of significant cardiovascular side effect. ***Therefore vecuronium is the most commonly used muscle relaxant during surgery.***

- **d-tubocurarine:** Maximum propensity for releasing histamine and ganglion blockade so causes severe hypotension whichcan be reversed by calcium'
  Bronchospasm due to histamine release
  Drug strongly concentrated in heart muscles
- **Metacurine**—Semi synthetic derivative of d-TC with less cardiovascular effects.
- **Gallamine:** Maximum propensity for vagal blockade, so cause tachycardia, excreted unchanged (80%) via kidney so it is
  contraindicated in renal failure. It is least potent, not used now because of significant

nephrotoxicity and teratogenecity.

- **Doxacurium:** Most potent and longest acting muscle relaxant.
- **Alcuronium:** Anaphylaxis very common.
- **Pancuronium:** It is steroid compound, only 10% is metabolized, excreted in bile so cautious use in biliary obstruction and renal diseases. It causes vagal blockade and release of noradrenaline, so tachycardia and T BP may occur, so it is muscle **relaxant of choice** in arterial surgeries where BP maintenance is required or in hypotensive patients.
- **Pipecuronium:** It is pancuronium derivative. No vagolytic or ganglion blockade action so cardiovascular stable
- **Rocuronium:** Fastest onset of action, so it is non depolarizer of choice for rapid sequence intubations/
- **Gantacurium:** Nondepolarizing (competitive) neuromuscular blocker is new drug in phase 3 clinical trial with **shortest duration of action,** even shorter than Succinylcholine and fastest onset of action. If approved, it can be used in place of SCh for endotracheal intubation.

Factors Prolonging NM Blockade:

1. Pediatric and elderly

2. Obesity

3. Renal disease *(except atracurium)*

4. Hepatic disease *(except atracurium*)

5. Hypothermia

6. Antibiotics:

- Neomycin
- Streptomycin
- Gentamicin
- Kanamycin
- Polymyxin
- Lincomycin
- Clindamycin
- Tetracycline

7. Local anesthetics

8. Ca2+ channel blockers, hypocalcaemia

9. Hypokalemia

10. Acidosis

11. Dantrolene

12. Centrally acting muscle relaxants

13. Magnesium

14. Lithium

15. Neuromuscular diseases

Reversal of block: Reversal of block is done by anticholinesterase, e.g. neostigmine, edrophoniumR, pyridostigmine.
Sugammadex: It is first selective relaxant binding agent **(SRBA). A** modified y-cyclodextrin that can be used to reverse neuromuscular blockade by *(rocuronium > vecuronium >pancuronium).*

o During rocuronium-induced neuromuscular blockade, the IV administration of sugammadex creates a concentration gradient

favoring the movement of rocuronium molecules from the neuromuscular junction back into the plasma, which results in a fast recovery of neuromuscular function **without producing autonomic instability,**

o It is safe and well tolerated.

o Side effects includes dysgeusia and rarely hypersensitivity reactions

DIRECTLY ACTING SKELETAL MUSCLE RELAXANT
Dantrolene Sodium
Mechanism of action: Dantrolene inhibits release of intracellular Ca+2 via inhibition of ryanodine receptors (RyR) — No excitation contraction coupling —> No contraction/R
Dantrolene is DOC for malignant hyperthermia. It can also be used in:
1. Neurolept malignant syndrome
2. To reduce spasticity in UMN disorders, hemiplegia, paraplegia, cerebral palsy and multiple sclerosis
Note: It is not effective in case of spasm due to musculoskeletal injuries.
Side effects

- Muscular weakness
- Sedation
- Malaise
- Diarrhoea
- Liver toxicity

Remember

- Procaine is the local anaesthetic of choice for malignant hyperthermia patients
- Propofol is the intravenous anaesthetic of choice for malignant hyperthermia patients

Quinine: Acts as directly acting muscle relaxant.
o It increases refractory period and decreases excitability of motor end plates,
o It can be used in nocturnal leg cramp.

CENTRALLY ACTING MUSCLE RELAXANT:

- These are drugs which reduce skeletal muscle tone by a selective action in the cerebrospinal axis
- They selectively depress spinal and supraspinal polysynaptic reflexes involved in the regulation of muscle tone without
- significantly affecting monosynaptically mediated stretch reflex
- All centrally acting muscle relaxants have some sedative property
- They have no effect on neuromuscular transmission and on muscle fibres, but reduce decerebrate rigidity, upper motor neuron spasticity and hypereflexia

These agents are: carisoprodol, chlorzoxazone, cyclobenzaprine, metaxalone, baclofen, benzodiazepines and methocarbamol.

- **Carisoprodol and chlorzoxazone** act on the spinal cord and subcortical levels of the brain to depress polysynaptic neuron
  transmission. Carisoprodol is metabolized to **meprobamate**(an anxiolytic).
- **Baclofen** is an analog of gamma amino butyric acid (GABA) and is thought to act by stimulating this inhibitory neurotransmitter.
  It is **GABAb receptor agonist.** It is used to relieve spasticity in multiple sclerosis and spinal injuries. It is not use in cerebral palsy.
- **Benzodiazepines:** Diazepam and clonazepam inhibits both monosynaptic as well as polysynaptic reflexes. They are mainly used in spinal card injuries and tetanus.
  Note: Additionally, the agents in this class have CNS depressant properties that may contribute to or are mainly responsible for the skeletal muscle relaxant activity.
- **Tizanidine** is classified as an alpha-2-adrenergic agonist and it is believed to act by increasing presynaptic inhibition of spinal motor neurons.
- **Cyclobenzaprine** is structurally related to the tricyclic antidepressants. It acts primarily at the brain stem and reduces tonic

somatic motor activity.

- **Metaxalone and methocarbamol** are thought to be due to general central nervous system depression.

CHAPTER-6-LOCAL ANAESTHESIA &REGIONAL ANAESTHESIA

Local Anaesthetics (LA)

- First local anaesthetic used **was cocaine** by **Carl Koller** for anaesthetizing cornea.

Classification:
Local anaesthetics are classified on the basis of the duration of action.and on chemical structure

Based on Duration of Action And potency:

Short duration, low potency (<30 min)	Intermediate duration, intermediate potency **(30-90 min)**	Long duration, high potency **(> 120 min)**
• Chloroprocaine: **Shortest duration** • Procaine	• Lignocaine • Mepivacaine • Prilocaine • Cocaine	• Bupivacaine • Levo bupivacaine • Tetracaine (Amethocaine) • Etidocaine • **Dibucaine: Longest duration** • Ropivacaine.

Based on chemical Structure:
Chemically local anaesthetics consist of a benzene ring separated from tertiary amide either by ester or amide linkage. Based on this intermediate chain these are classified as aminoesters and aminoamides.

Amino esters***(All esters contains single 'i)***	Aminoamides***(All Amides contains double'i')***
- Procaine - Chloroprocaine - Tetracaine (Amethocaine) - Benzocaine - Cocaine • Esters are metabolised by pseudocholinesterase (except cocaine which is metabolised by liver). • High incidence **of allergic reactions** which are because of **para aminobenzoic acid** • Solutions are not stable	- Lignocaine - Mepivacaine - Prilocaine - Bupivacaine - Etidocaine - Ropivacaine • Amides are metabolised primarily in liver • Low incidence of allergic reactions • Solutions are stable (not destroyed even by autoclaving).

Note: Bupivacaine is also called marcaine or sensorcaine

MECHANISM OF ACTION OF LOCAL ANAESTHETICS:

- Local anesthetics produce a local reversible block of nerve conduction with no permanent damage.These drugs can paralyze both sensory and motor nerves. They can block the nerve impulse at various sites along the neural pathway. The most common site of action for local anesthetics is the **axonal membrane.**
- Local anaesthetics block nerve conduction by reversibly binding with the a-subunit of the **voltage-gated sodium channels** in the nerve membrane. This site of action is intracellular, requiring local anaesthetic to diffuse across the lipophilic lipoprotein membrane. Local anaesthetics are weak bases and administered in an acidic solution that maintains the majority of the drug in the ionised soluble form. Once injected into the tissue it must be converted into the neutral unionised form in order to enter the nerve cell. The proportion of drug that is converted will depend upon the local anaesthetic pKa and the tissue pH. Once inside the cell the lower intracellular pH regenerates the ionized form, which blocks the receptor within the sodium channel.
- Sodium influx is reduced and the upsurge in the membrane potential slows. If a sufficient number of sodium channels are blocked the threshold potential will not be reached and impulse conduction stops. This inhibition of Na+ channel is frequency dependent
- Recent studies have proven that local anaesthetics not only act on sodium channels, the also block potassium and calcium channels in a manner that hypokalemia and hypercalcemia can antagonize the effect of local anaesthetics. They are also found to **block N methyl D aspirate (NMDA)receptors.**

o Small diameter axons like c fibers are more susceptible to local anesthetic block than large diameter fibers like Aa but myelinated are more readily blocked. Sequence of blockade is **B —> C —> A**

- Sequence of blockade—**Automatic —>sensory -> motor**
- Sequence of recovery—**Motor —> sensory —> automatic**
- In somatic (sensory) blockade order—**pain —> temperature (cold before heat) —> touch —> deep pressure —> propioception**
- Maximum absorption takes place via intercostals site and minimum by brachial plexus block

Potency, onset and duration of action:

1) **Potency correlates with lipid solubility** i.e., the ability of local anaesthetic molecule to penetrate membanes (ahydrophobic environment).

- ***Dibucaine is the most potent local anaesthetic.***
- ***Procaine and chlorprocaine are least potent***
- Order of potency in decreasing : - ***Dibucaine > Ropivacaine = Bupivacaine = etidocaine = Tetracaine > Lidocaine > Prilocaine > Mepivacaine = Cocaine > Procaine & chlorprocaine***

2) ***Onset of action*** depends on many factors, including ***lipid solubility and the relative concentration of unionized form.*** pKa is the pH at which a local anaesthetic is 50% ionized and 50% non-ionized. Since local anaesthetic are weak bases, agents with pka closer to physiological pH (7.4) will have more dmg in non-ionized form, because, ***weak bases are unionized at alkaline*** pH. For example: - ***Lidocaine has pka 7.8, i.e.,*** It is 50% ionized ***8c*** 50% ionized at pH 7.8. Physiological pH is 7.4 (more acidic than the pka of lidocaine), therefore at physiological pH more than 50% drug will

be in ionized form as weak bases are unionized at alkaline pH and physiological pH is towards the acidic side from pka.

ii***) Bupivacaine has pka 8.1,*** therefore at physiological pH ionized form will be greater than lignocaine because

physiological pH is far more on acidic side than pka of bupivacaine in comparison to pka of lignocaine.

(Note : Physiological pH is alkaline, i.e., 7.4, However in comparison to pka of local anaesthetics, it is on acidic

side).

Therefore, **the local anaesthetic with a pka closest to physiological pH will have a higher concentration of nonionized**

form that can cross the membrane easily and will have a more rapid onset .

3) ***Duration of action is generally correlated with lipid solubility.*** Highly lipid soluble local anaesthetic have a longer

duration of action, presumbly because they are less likely to be cleared by blood flow.

- **Dibucaine is the longest acting local anaesthetic**
- **Chlorprocaine is the shortest acting local anaesthetic**
- Decreasing order of duration **:** - Dibucaine **>** **Bupivacine**

Tetracaine,> = Ropivacaine = Etidocaine **>** Prilocaine = Lignocaine = Mepivacaine = Cocaine > **Procaine> > Chlorprocaine**

Addition of vasoconstrictors: Vasoconstrictors by decreasing the systemic absorption increases the duration of action. Vasoconstrictors used are:

a. **Adrenaline: In** a concentration of 1 in2,00,000(1 in 2 lakhs).Duration ofboth sensory and motor blockade is increased by addition of epinephrine to lignocaine but oly sensory block is prolonged if epinephrine is added to bupivacaine with no effect on motor blockade.
   Xylocaine with adrenaline should not be used for:

i. Ring block of fingers, toes, penis, pinna (absolute containrdication).

ii. When an inhalational agent especially halothane which sensititzes myocardium to adrenaline is used.

iii. Myocardial ischemia patients

iv. Hyperthyroid patient.

v. Severe hypertensives

vi. Intravenous regional anaesthesia (Beir's block).

b. **Phenylephrine** : In concentration of 1 in 20,000.
   Other vasoconstrictors which can be used are **noradrenaline and felypressin** (octopressin), a synthetic derivative of vasopressin.

2. Sodium bicarbonate: Although main advantage of sodabicarb is to increase the onset but duration is also increased because carbon dioxide released from sodium bicarbonate metabolism crosses the axonal membrane, changes the pH to more acidic making more drug to be available in ionized form to bind sodium channels.

So addition of sodium bicarbonate (1 ml of 8.4% to 10 ml of local anesthetic):

a. Enhances the onset of action (main advantage)
b. Increases the duration of action
c. Improves the quality of block
d. Decreases the pain of injection (by unknown mechanism).

Systemic Effects and Toxicity:

SYSTEMIC EFFECTS OF LOCAL ANAESTHETICS

Toxicity is proportional to potency. Due to diversion of blood CNS and CVS toxicity of local anesthetics gets increased in shock.

CARDIOVASCULAR SYSTEM

- **All local anaesthetics are vasodilators except cocaine, levobupivacaine and ropivacaine which are vasoconstrictors**.
- All local anaesthetics have negative inotropic action on myocardium. They causes depression of conduction system(prolonged PR interval and increased duration of QRS complex). At very high doses they may block conduction of sinus node producing bradycardia or even sinus arrest.
- In addition to the above effects bupivacaine (and to lesser effect levobupivacaine and ropivacaine) can also produce ventricular arrhythmias.
  Therefore, either the isolated or combined action like bradycardia, decreased myocardial contractility, ventricular arrhythmias, hypotension can produce cardiac arrest. Management of cardiac arrest is CPR with adrenaline or vasopressin (vasopressin preferred).
- **Cardiotoxic potential of bupivacaine is much higher than lignocaine**.

CENTRAL NERVOUS SYSTEM

Central nervous system is the first system involved in local anaesthetic toxicity. CNS: CVS dose ratio for lignocaine is 1:7 and for bupivacaine is 1:3 that means CNS is involved at much lower doses as compared to CVS. Therefore initial signs and symptoms of local anesthetic toxicity are related to CNS.

Typical sequence is excitation followed by depression of cerebral tissue (inhibitory neurons are more sensitive than excitatory neurons). Signs and symptoms are circumoral numbness, dizziness, tongue paresthesia, visual and auditory disturbances, muscle twitching, tremors, convulsions followed by coma and death.

Treatment

Maintain adequate ventilation and oxygenation. Convulsion can be controlled by diazepam or thiopentone.

Respiratory system: Lignocaine depresses hypoxic drive. Direct depression of medullary respiratory centre can occur at high dose.

Immunologic: Allergic reactions are very common with esters but rare with amides. The reaction with esters but rare with amides. The reaction with amides is because of the preservative (methylparaben) it contains. Cross sensitivity does not exist between classes (i.e., esters and amides) but exist between agents of same class.

Local toxicity: Not only when directly injected into nerve they cause neurotoxicity but otherwise also they may cause neurotoxicity. Although the most clinical example of local anaesthetic induced neurotoxicity is cauda equine syndrome seen with lignocaine and tetracaine (particularly if used through small bore continuous spinal catheters) but overall most neurotoxic is chloroprocaine.

When directly injected into muscle they are myotoxic.

Local anaesthetics with **adrenaline can cause necrosis and gangere If used for ring block of fingers, toes, penis or pinna** because these structures have end arteries:

Methemoglobinemia : Seen with **prilocaine, benzocaine and very rarely with lignocaine.**

Treatment: IV methylene blue 1% (1 to 2 mg/kg).

Malignant hyperthermia: Lignocaine can cause malignant hyperthermia in susceptible individuals.

COMMERCIAL PREPARATIONS

Although local anaesthetics are weak bases but their commercial preparations are made acidic (pH to around 6) to enhance their chemical stability so they are available as hydrochloride salts. Local anaesthetics containing adrenaline are made even more acidic (pH around 4) because adrenaline can become unstable at alkaline pH. Antimicrobial preservatives (methylparaben) is added to multi dose vials. For spinal and epidural anaesthesia preservative free preparations should be used.

METHODS OF LOCAL ANALGESIA

1. Topical (Surface anaesthesia): it includes topical application:
   i. At skin for which EMLA cream is used which is a eutectic (easily melted) mixture of prilocaine 5% and lignocaine 5% in equal amount (1:1 ratio).[2.5% EMLA cream (half strength) Is also available]. The major limitation of EMLA cream is its slow onset (30-60 min).
   ii. At mucous membranes of mouth, pharynx and larynx for which xylocaine spray 4% and 10% tetracaine and nbenzocaine lozenges are used.
   iii. For cathererization and proctoscopies xylocaine (lignocaine) jelly 2% is used.
   iv. For eye cocaine drops and tetracaine ointment is used
   v. For anal canal and rectum, lignocaine 4%, dibucaine 1% and benzocaine 5% ointment are used for anal fissure and painful piles.
   vi. For gastritis, oxethazaine (mucaine gel) 0.2% is used.
   So it may be seen that all local anaesthetics except mepivacaine, bupivacaine and ropivacaine can be used for surface (topical)analgesia (penetration of procaine and chloroprocaine is so poor after topical application that they are not recommended for topical application).
2. Infiltration anaesthesia: Local anaesthetic is infiltrated at operation site.
3. Nerve blocks: Drugs is injected around the nerve supplying the operation site.
4. Intravenous regional anaesthesia (Beir's block).
5. Central neuraxial blocks which includes spinal and epidural anaesthesia.
6. Refrigeration analgesia: it is topical analgesia produced by CO2 snow, ice cooling, ethyl chloride spray. It blocks the nerve conductions at local site.

INDIVIDUAL AGENTS:

ESTERS

Except for few topical applications esters are not used in clinical practice.

COCAINE:

o **Cocaine was the first local anaesthetic used by Carl Roller** It was used for anaesthetizing cornea,

o **It is the only naturally occuring anaesthetic** obtained from leaves of Erythroxylon coca,

o Cocaine is the only ester which is not metabolized by plasma esterase (It is metabolized in liver),
o The only indication for cocaine is in ocular anaesthesia.
o It should never be used with adr. due to its sympathomimetic property. For the same reason it should not be given i.v.
o Cocaine is unique among drugs of abuse - it does not produce tolerance.
o In periphery cocaine ***blocks the uptake of adrenaline and Noradrenaline in Adrenergic Nerve ending*** resulting in
higher concentration of sympathetic neurotransmitters (Sympathomimetic effect),
o The peripheral sympathomimetic action of cocaine produces following effect:
I. Mydriasis 2. Rise in B.P. 3. Local vasoconstriction 4. Tachycardia
o Therefore if the peripheral sympathetic system is paralysed it will lead to reverse of the above mentioned action

PROCAINE

- It should be stored in cool place to prevent hydrolysis. Like amethocaine (tetracaine) it inhibits the bacteriostatic action of sulphonamides and para amino salicylic acid. Metabolized by pseudocholinesterase.
- Not only it is the agent of choice in patients susceptible for malignant hyperthermia. Rather intravenously it had been used in the treatment of malignant hyperthermia in past.

CHLOROPROCAINE

- Shortest acting (Duration of effect 15 to 30 minutes).
- Most acidic (pH=3.3)
- Because of its high neurotoxicity it is contraindicated for spinal anaesthesia.

AMETHOCAINE (TETRACAINE)

- Like cocaine it can cause ventricular fibrillation
- Duration of action more than cocaine and lignocaine
- A lozenge containing tetracaine is available for bronchoscopies.
- It inhibits the action of sulphonamides and para amino salicylic acid.

BENZOCAINE

- It has low aqueous solubility
- Used as lozenges for stomatitis, sore throat.

AMIDES

LIGNOCAINE (XYLOCAINE, LIDOCAINE)

It is the most commonly used local anaesthetic

- First synthesized by Lofgen and first used by Gordh.
- Solution is very stable, not even decomposed by boiling. Contains preservative methyl paraben.
- pKa = 7.8.

Concentration used

Surface (topical) analgesia	:4% and 10%
Nerve blocks	: 1 to 2%
Urethral procedures (as jelly)	: 2%

Spinal	: 5% (heavy)
Epidural	: 1 to 2%
Intravenous regional analgesia (Beir's block)	: 0.5%
Infiltration block	: 1 to 2%

Metabolism

Metabolized in liver, excreted by kidney. T1/2:1.6 hrs.

Duration of Effect

Without adrenaline	: 45 to 60 minutes
With adrenaline	: 2 to 3 minutes

Maximum safe Dose

Without adrenaline	: 4.5 mg/kg (maximum 300 mg.)
With adrenaline	: 7 mg/kg(maximum 500mg).

- Systemic toxicity is much less than bupivacaine. CNS involvement occurs at much lesser dose than CVS involvement. (CNS to CVS ratio is 1:7)
- Lignocaine releases calcium from sarcoplasmic reticulum so should not be used in patients with history of malignant hyperthermia.
- Can cause cauda equine syndrome after sontinuous spinal.

Other Uses

1. Used for treating ventricular tachycardia. Preservative free lignocaine (Available as xylocard 2%) is used intravenously in dose of 2mg/kg.
2. Intravenous xylocard is used for blunting cardiovascular response to laryngoscopy and intubation.

MEPIVACAINE

Pharmacology is similar to lignocaine except duration of action slightly longer than lignocaine.

PRILOCAINE

Prilocaine because of it's extensive metabolism at hepatic as well as extrahepatic sites like kidney's lungs and by amidase is considered as safest local anesthetic.

Methemoglobinemia occurs at high dose (> 6mg/kg) and this is because of the accumulation of its metabolite ortholuidine which can vonvert haemoglobin to methaemoglobin.

Bupivacaine (sensoricaine, Marcaine):

o Bupivacaine is ***2nd most commonly used*** local anaesthetic (after lidocaine).

o Bupivacaine has the highest local tissue irritancy amongst local anaesthetics,

o **It is the most cardiotoxic local anaesthetic**

o ***Levobupivacaine*** (The S(-) enantiomer of bupivacaine) is less cardiotoxic and less prone to cause seizure,

o Concentrations used for bupivacaine are : - Nerve block: 0.5%, **Epidural**: **0.25 - 0.5** % and spinal: 0.5%.

o **Maximum safe dose is 2 mg/kg without adrenaline and 3mg/kg with epinephrine**

Newer Agent:

Articaine: It is unique due to thiophene, rather than a benzene ring, as well as an **additional ester group** that is subject to metabolism by plasma esterases. The modification of the ring serves to **enhance lipophilicity,** and thus improve tissue penetration, while inclusion of the ester leads to a **shorter plasma half-life** (approximately 20 minutes), **better therapeutic index.** These characteristics have led to widespread popularity in **dental anesthesia,** where it is generally considered to be more effective, and possibly safer, than lidocaine.

REGIONAL ANAESTHESIA (LOCAL ANAESTHESIA)

o Regional anaesthesia means loss of sensation in body part without the loss of consciousness or the impairment of central control of vital function,

Methods are : -

1. Topical anaesthesia (surface anaesthesia) 4. Conduction block (either field block or nerve block)
2. Infiltration anaesthesia 5. Central neuraxial block (spinal anaesthesia, epidural
3. Intravenous regional anaesthesia (Bier's block) anaesthesia)

TOPICAL ANAESTHESIA (SURFACE ANAESTHESIA)

o Topical anaesthesia is produced by topical application of local anaesthetics to mucous membrane or abraded skin,

o Surface anaesthetics are : -**Tetracaine (amethocaine),Lidocaine,**Oxethazone ***Cocaine,***__Dibucaine ,__Butamben,**Benzocaine ,** Benoxinate

Eutectic mixture of local Anaesthetics (EMLA)

o This is unique topical preparation which can anaesthetise ***intact skin.***

◦ **It is a mixture of 2.5% lidocaine and 2.5 prilocaine**

o **It acts slowly ,** and the cream must held in contact with skin for at least 1 hour.

o **EMLA** is used: to make venepuncture painless **especially in children** \ and for procedure like ***skin grafting*** & ***circumcision.***

o As systemic absorption of prilocaine can cause methemoglobinemia, **EMLA should not be used on mucocutaneous membrane** or ***in very small child.***

INFILTRATION ANAESTHESIA

- It is the injection of local anaesthetic directly into tissue without taking into consideration the course of cutaneous nerves. It can be so superficial as to include only the skin. It also can include deeper structure, including intraabdominal organs, when these too are infiltrated.
- ***Adrenaline*** can be used along with local anaesthetic to prolong its duration of action and to prevent its systemic absorption. However, **adrenaline containing solution should not be used into tissues supplied by endarteries, e.g., fingers, toes, ear, nose, penis**
- The most commonly used LAs for infiltration are ***lidocaine, bupivacine, prilocaine.*** Less commonly used LAs are Procaine, Chlorprocaine, etidocaine, ropivacaine & mepivacaine.
- Infiltration anaesthesia is used for minor surgeries, e.g., incision & drainage, suturing etc.

CONDUCTION BLOCK

o Conduction block may be of two types : -

A) **Field block**

- Is produced by subcutaneous injection of a solution of local anaesthetic in order to anaesthetize the region distal to the injection.

- For example, subcutaneous infiltration of the proximal portion of the volar surface of the forearm results in extensive area of cutaneous anaesthesia that starts 2 to 3 cm distal to the site of injection.

B) Nerve block

- LA is injected around a peripheral nerve of plexus. Example are: -

Upper limb — Brachial plexus and wrist block
Head & Neck —Stellate ganglion block, trigeminal nerve block, Phrenic nerve block.
Thorax & abdomen — Intercostal nerve & celiac plexus.

Brachial plexus block:

- This is the second most commonly practised block after central neuraxial block (spinal & epidural anaesthesia).
- Brachial plexus block is used for ***upper limb surgeries.***

o Brachial plexus can be blocked by 4 approaches : -

1. Interscalene approach

- Brachial plexus is blocked between anterior and middle scalene. This approach is not used routinely due to close proximity of vital structures. **Ulnar nerve is usually spared by this approach** because injection is given in **close proximity of upper nerve roots** and inferior nerve roots (C8-T1) may be spared.
- Complications include Homer syndrome (due to stellate ganglion block), phrenic nerve block, intravascular injection into carotids and epidural or intrathecal injections.

2. Supraclavicular approach

- This is the ***most commonly used approach.*** It involves the injection of local anaesthetic ***in close proximity to the trunks*** of the brachial plexus by **inserting the needle lateral to subclavian vessels ,** The supraclavicular block is performed where the brachial plexus is most compact, consequently, it produces reliable and rapid onset anaesthesia and is particularly useful in a fast paced ***ambulatory surgery*** centre.
- **Pneumothorax is the most common complication .** Other complications include phrenic nerve block, intravascular injection in subclavian artery or vein, Homer syndrome, hematoma formation.

3. Infra-clavicular approach

- Infraclavicular block involves the injection of local anaesthetic ***in close proximity of cords*** of the brachial plexus. The ***axillary nerve may be spared*** as this nerve exits the brachial plexus sheath proximal to the level of infraclavicular block.

4. Axillary approach

- Axillary block involves the injection of local anaesthetic ***in close proximity of terminal branches*** of the brachial plexus. The major disadvantage of this approach is that ***mucocutaneous and intercostobrachial nerves are spared.*** So arm surgery cannot be performed. In contrast to interscalene approach, most intense block occur in (C7-T1) ulnar dermatomes and least in C5-C6 dermatomes.

Stellate ganglion block

- Stellate ganglion is formed by fusion of lower cervical and first thoracic ganglion. It is blocked anterior to the **tubercle of transverse process of *C6* vertebra i.e., chassaignac tubercle at the level of cricoid cartilage**

- **Signs of successful block are** : - **Horner syndrome** (miosis, ptosis, anhydrosis, enophthalmos, absence of ciliospinal reflex), flushing of face, conjuctival congestion, **Nasal stuffiness (Gutman's sign),** Injection of tympanic membrane ***(muller's syndrome),*** Increased skin temprature and lacrimation.
- Stellate ganglion block is **indicated in** : -

i) Treatment of ***acute herpes zoster*** in the distribution of the trigeminal nerve, cervical and upper thoracic dermatomes.
ii) **Acute vascular insufficiency of upper limb** and face.
iii) Frost bite
iv) Reflex sympathetic dystrophy of face, neck and upper extremities.
v) Raynaud's syndrome of upper extremities.

Phrenic nerve block

- It is applied for **intractable hiccups.** Nerve is blocked 3 cm above the clavicle, just lateral to the **posterior border of sternocleidomastoid ,** Bilateral phrenic nerve block should never be performed.

Paravertebral block

- The paravertebral space is a wedge shaped compartment adjacent to the vertebral bodies, within this space, the spinal root emerges from the intervertebral foramen and divides into dorsal and ventral rami. In addition sympathetic fiber of ventral rami enter the sympathetic trunk. Injection of LA in this compact space produces ***unilateral motor, sensory and sympathetic blockade of multiple contiguous dermatomes above and below injection site.***
- The paravertebral space is contiguous laterally with the intercostal space and medially with the epidural space via the intervertebral neural foramina. **Anaesthetic injected for a paravertebral block may flow laterally into the intercostal space** as well as **up and down into the ipsilateral paravertebra space. Epidural spread is also possible if enough volume is injected .**
- Paravertebral block may be used to provide anaesthesia or analgesia or both, to patients undergoing ***thoracic, abdominal or pelvic procedures, as well as surgery on the breast. It may be useful in the diagnosis and treatment of certain chronic pain disorders,*** including post-thoracotomy and postmastectomy pain.

◦ **Complications include** : - **Epidural** or **subarachnoid ,** injection of local anaesthetic because of close proximity ofneuraxis to paravertebral space; **intravascular injection** in lumbar vessels, vena cava or aorta; **Pleural puncture** & **pneumothorax;** local **anaesthetic toxicity;** and hypotension.

Celiac plexus block

- The celiac plexus is situated retroperitoneally in the upper abdomen. It is at the level of T]2 and L; vertebrae anterior to the crura of the diaphragm. It contains visceral afferent and efferent fibers divided from T5 to T12 by means of greater, lesser and least splanchnic nerves. Celiac plexus innervates most of the ***abdominal viscera,*** therefore this procedure ***blocks the nerves which come from the pancreas, liver, gall bladder, stomach, intestine, spleen, kidney and adrenal glands.***
- A celiac plexus block can be combined with an intercostal block to provide anesthesia for ***intra-abdominal surgery.***
- Because celiac plexus block results in ***blockade of the autonomic nervous system,*** this block may help to reduce stress and endocrine responses to surgery. For the same reason, **the most common complication of celiac plexus block is postural hypotenstion** because of

blockade of lumbar sympathetic chain leading to upper abdominal vessel dilation and venous pooling.

o Celiac plexus block can be done by following three approaches : - ***Retrocrural (classic) approach, anterocrural approach and splanchnic nerve block.***

O Celiac plexus block is given to ***treat intractable pain in chronic pancreatitis, gastric & pancreatic malignancies.***

It can be combined with an intercostal block to provide anesthesia for **intra-abdomiual surgery.**

o **Postural hypotension is the Most common complication of classic retrocrural and splanchnic nerve block, Where as most common complication of Anterocrural approach is transient diarrhoea.**

Intercostal block

o An intercostal block involves the injection of local anaesthetic around the ***intercostal nerves*** that are located ***under each ribs.*** Intercostal blocks are rarely employed as the sole anesthetic technique for surgery. use: -

- *As supplements to general anesthesia*
- *For postoperative analgesia following thoracic and upper abdominal surgery.*
- *For relief o f pain associated with rib fractures, herpes zoster and cancer.*

The major complication is pneumothorax. Intercostal block result in the highest blood levels of local anesthetic per volume injected of any block in the body —> Systemic toxicity of local anesthetic may occur

Bier's block:

- Bier's block is the other name for intravenous regional block. [Q]
- It can be used for short procedures (< 90 minutes) involving the limb extremities.
- An intravenous cannula is placed as far distally as possible in the extremity to be operated.
- A double tourniquet is placed proximally in the same limb and inflated approximately 150 mmHg more than the systolic pressure.
- Local anaesthetic (**commonly lignocaine or prilocaine**)[Q] is then injected through the cannula (ofcourse after calculating the maximal allowable dose)
- This technique provides reliable anaesthesia within 5 minutes.
- Post procedure the tourniquet is deflated slowly, and care is taken to monitor for features of local anaesthetic toxicity.
- *Bupivacaine should not be used as it is more cardiotoxic*.[Q]
- The main disadvantages of Bier's block are that
  - It can be used only for short procedures
  - Premature release of tourniquet might lead to local anaesthetictoxicity.[Q]
  - It does not provide post operative analgesia.

CENTRAL NEURAXIAL BLOCK

- Central neuraxial block, as the name suggests, is the pertains to local anaesthetics placed around the nerves of the central nervous system. Examples are **spinal anaesthesia, Epidural anaesthesia and caudal anaesthesia.**

Mechanism of action

- ***The principal site of action for neuraxial blockade is the nerve root.***
- Local anaesthetic is injected into the **CSF in subarachnoid space** (space between pia matter and arachnoid matter) in **spinal anaesthesia** — Local anaesthetic acts on neve roots in subarachnoid space. As the injection is given directly into the CSF small dose of LA gives dense anaesthesia (in comparison to epidural anaesthesia).
- On the other hand, local anaesthetic is injected into ***epidural space*** (space outside the dura) in **epidural and caudal anaesthesia** — Local anaesthetic acts on nerve roots in epidural space. Large dose of LA is required (in comparison to spinal anaesthesia).

o It has already been explained previously that different nerve fibers have different sensitivity to LAs. **Sensitivity of block in decreasing order is : Autonomic (sympathetic) block > sensory block > motor block.**

Systemic manifestations

o Interruption of efferent autonomic transmission at the spinal nerve roots **produces sympathetic blockade** and sometimes parasympathtic blockade. **Sympathetic outflow** from the spinal cord is thoracolumber (T1-L2), whereas **parasympathetic outflow is craniosacral (Cranial nerve III, VII, IX, X, and spinal nerves S2, S3, S4).** Neuraxial anesthesia **does not block the vagus nerve (X cranial nerve).**

- **High spinal (Total spinal) anaesthesia** : - It occurs when the effect of spinal anaesthesia ascends to higher (cervical) levels. It can also occur **following attempted epidural/caudal anesthesia if there is inadvertent intrathecal injection**

- **Total spinal is a local anaesthetic depression of the cervical spinal cord and the brainstem.**
- It may follow excessive spread of an intrathecal injection of local anaesthetic, or inadvertent spinal injection of an epidural dose of local anaesthetic
- The onset is rapid as a large amount of drug enters the intrathecal space.
- ***The main clinical manifestations are***
    - ***Hypotension^{Q}***
    - Bradycardia
    - ***Apnoea^{Q}***
    - Weakness of all extremities
    - ***Loss of consciousness^{Q}***
    - Dilated pupils
    - ***Aphonia^{Q}***
- The treatment is mainly supportive
    - Immediate intubation and mechanical ventilation.
    - Iv fluids
    - Vasopressors(ephedrine, phenylephrine, dopamine etc.)
    - Atropine to treat bradycardia.

Choice of local anaesthetic for central neuraxial block

o Choice of local anaesthetic is the primary determinant of duration of spinal and epidural anaesthesia. **Lidocaine (Lignocaine/xylocaine) and Bupivacaine (marcaine/sensorecaine) are the the most commonly used local anaesthetics for spinal and epidural anesthesia .**

SPINAL ANAESTHESIA

o In spinal anaesthesia LA is injected into **subarachnoid space (space between pia matter and arachnoid matter)**

◦ **Structure pierced during SA (from outside in) - Skin - subcutaneous tissue - Supraspinous & intraspinous ligament —Ligamentum falvum — Durameter — Arachnoid matter.**

oSite of spinal anaesthesia:

- **L**2- 3 **or Lm intervertebral space in adult. (In adult spinal cord ends at lower border of L**1 **verteb r ae).**
- L4 5 intervertebral space in children (spinal cord ends at lower border L3 vertebrae in children).
- ***Spinal anaesthesia leads to creation of a zone of differential blockade, i.e., motor fibres are blocked two levels lower and autonomic fibres are blocked two levels higher than the sensory blockade*** due to different sensitivity of different fibres.

Complications :

Hypotension:

o **This is the most common complication of spinal anesthesia**

o It arises due to blocking of sympathetic root fibres and is ***usually accompnied by bradycardia***

o **Hypotension can be prevented by preloading the patient with colloids, Preloading with crystalloid does not prevent hypotension because large volumes of crystalloids quickly redistribute from intravascular to extravascular space. Beach chair position prevent hypotension .**

o **Treatment** of hypotension :

- **Trendlenburg (head low) position _** increases venous return.
- Intravenous fluids mainly ***crystalloids.***
- Sympathomimetic drug, **ephedrine provides more appropriate therapy** other sympathomimetic drugs used are mephentrine, phenylephrine, metraminol, **methoxamine dopamine**
- ***Atropine*** should be given for bradycardia.
- If hypotension and bradycardia persists ***epinephrine*** should be given.

Collapse (Vasovagal syncope)

o This is a harmless complication, which often occurs in young, nervous and anxious patients during injections in a sitting position. It involves a neurogenic, normovolemic shock state, which is characterized by **sudden and transient loss of consciousness. This complication occurs during injection of spinal anesthesia** (in contrast to hypotension and high & total anesthesia that occur immediately after injection).

Headache

- ***Post dural puncture headache*** **(PDPH)** ***is due to CSFleak .*** Typical location is **bifrontal** or occipital,
- Headache **gets worsen on sitting or upright posture and is relieved by lying down position and abdominal pressure**
- The hallmark of postdural puncture headache i.e., association with body position,
- **The onset of headache is usually 12-72 hours following the procedure, however, it**

may be seen almost immediately jn most Cases it lasts for 7-10 **days**

o **PDPH is believed to result from leakage of CSF from a dural defect *(* and decreased ICT .** Loss of CSF at a rate faster that it can be produced causes traction on structure supporting the brain, particularly dura and tentorium. Traction on cranial nerve (particularly 6th nerve) produces diplopia,

o Factors that increase the incidence of PDPH are ***young ag>, female sex, Pregnancy, large bore needle and multiple punctures.***

o **Use of small bore needle can prevent PDPH**

o Intially ***conservative treatment*** is given which includes analgesics (NSAIDs), oral or i.v., fluids, Sumatriptan, cosyntropin, caffeine and recumbent position.

o If conservative treatment fails, **epidural blood patch** can be used. It involves injecting 15-20 ml of autologus blood into the epidural space which stop leakage of CSF by coagulation and mass effect.

Position of the Patient during spinal anaesthesia

o Spinal anaesthesia can be done : -

- **Sitting position : -** This is the most commonly used position. Patients sit with ***flexion of the spine.***
- **Lateral**: - Some clinicians prefer lateral position with their knees flexed and pulled high against the abdomen or chest, ***i.e., fetal position.***
- **Prone position** : - This position may be used for anorectal procedures utilizing a hyporic solution.

Saddle block

- It is the ***spinal anesthesia given in sitting position and the patient remains seated for 5 minutes.*** Only sacral segments are blocked in saddle block.
- o It is used for **perianal surgeries** like hemorrhoids, fistula in ano, fissures.

EPIDURAL (EXTRADURAL) ANAESTHESIA

- Local anaesthetic is injected in **epidural space , i.e., outside the duramater with Tuohy's needle**
- In extradural space LA acts on the nerve roots.
- It is used in thoracic, lumbar and sacral (caudal) regions (in contrast to spinal anaesthesia which is given only in lumbar region).
- **The onset of analgesia is approximately 15-30 minutes in an epidural , *white it is approximately 5 minutes in spinal anesthesia.***
- Epidural anaesthesia is not as dense as spinal anaesthesia — ***Lower concentrations of local anaesthetic combined with an opioid*** can block the smaller sympathetic and sensory fibers with sparing of large motor fibers —≫**Analgesia**
- **without motor block** or epidural analgesia (not epidural anesthesia),
- Moreover a **segmental block** is possible because the anesthetic is not spread readily by CSF and can be confined to the level at which it is injected. A segmental block is characterized by a well defined band of anesthesia at certain nerve roots; nerve roots above & below are not blocked.This can be seen with thoracic epidural that provides upper abdominal anaesthesia while sparing lumbar and cervical nerve roots,
- Continuous analgesia is achieved by mixing the LA with an opioid, e.g., fentanyl.
- **It is mainly used to control post operative pain (by continuous epidural anaesthesia),**
- It can also be used for all surgeries which can be performed under spinal anaesthesia,

o **As the dura is not penetrated \ post dural puncture headache does not *Occur***

Methods to locate epidural space

o Following methods can be used to locate epidural space : -

- **Loss of resistance.** This is the most commonly used technique. There is sudden loss of resistance as soon as the needle enters the epidural space (because it pierces ligament flavum).
- **Hanging drop technique (Gutierrez's sign):** - If a drop of saline is placed on the hub of the needle it will be sucked in due to **negative pressure** ' o f epidural space.
- **Mecintosh extradural space indicator**
- Movement of bubble on ***Odom's indicator.***

Advantages of epidural anaesthesia over spinal anaesthesia

A) **Dural puncture is avoided** due to which : -

- **Chances of post dural puncture headache does not occur**
- **Chances of meningitis are very less .**
- **Arachnoiditis does not occur.**

B) Duration of action is longer

Can be used for surgery of upper abdomen, thorax & neck (in contrast to spinal anaesthesia which is used for lower part of the body)

CAUDAL ANAESTHESIA

- It is nothing else but the **epidural anesthesia which is given in caudal** space, i.e., sacral portion of epidural space.
- It is one of the most commonly used ***regional techniques in pediatric patient.*** It may also be used in ***anorectal surgery in adults.***

ANESTHESIA IN SPECIAL SITUATIONS

ANAESTHESIA FOR RENAL DISEASES.

Intravenous induction:

- ***Propofol and etomidate are safe.***
- As CNS is extremely sensitive to Barbiturates, the dose of ***thiopentone*** is reduced,
- ***Ketamine*** may further raise the BP in patients with renal failure who already have hypertension.

Inhalational agents

- **Desflurane is the inhalational agent of choice. Isoflurane is an alternative.** ***Halothane*** is also safe.
- **Methoxyflurane is contraindicated Enflurane,*andsevoflurane should also be avoided.***
- Anaesthesia is ***maintained*** with ***desflurane (or isoflurane) in N2o : 0 2 mixture.***

Muscle relaxants

- **Atracurium/cisatracurium are the muscle relaxant of choice** as there **elimination is not dependent on kidney** ***Mivacurium is an alternative*** as its elimination is also independent of kidney,
- **(Gallamine and metocurine are entirely dependent on renal excretion for elimination—Contraindicated in renal disease ,**
- **Pancuronium /pipecuranium/** Alcuronium and doxacurium are primarily dependent on renal excretion for elimination - Not contraindicated, however neuromuscular function should be closely monitored if these agents are used in patients with abnormal renal function.
- ***Vecuronium*** and ***Rocuronium*** are primarily excreted in Bile (hepatic elimination) but **some amount is eliminated in urine also**

So, **only three non-depolarizing blockers have no elimination through kidney** : - **Atracurium, Cisatracurium, Mivacurium**

Opioids

- Remifentanil, fentanyl and sufentanil are safe.

ANAESTHESIA FOR LIVER DISEASE

Intravenous induction

- ***Thiopentone*** or ***propofol*** are used for induction.

Inhalational agents

- **Isoflurane is the volatile agent of choice for maintenance** as it has the least effect on hepatic blood flow.
- Isoflurane in oxygen or oxygen-air mixture is used for maintenance. ***Desflurane and sevoflurane can also be used.***
- ◦ **Halothane should be avoided.** However, it should be kept in mind that halothane is not contraindicated in pre-existing liver disease. It should be avoided so as not to confuse the diagnosis if liver tests deteriorate post-operatively.

Muscle relaxants

O ***Cisatracurium/atracurium are the muscle relaxants of choice.***

NEUROPHYSIOLOGY AND ANAESTHESIA

Intravenous inducing anaesthetics

o ***All intravenous inducing agents excepts for ketamine (etomidate, thiopentone, methohexitone and propofol)decrease cerebral metabolic rate, cerebral blood flow and intracranial tension.*** **Maximum decrease in cerebral blood flow and cerebral protection is caused by thiopentone** -IV agent of choice for neurosurgery,

o **Ketamine increases cerebral metabolic rate, cerebral blood flow and intracranial ten sio n**

Inhalational agents

o All inhalational agents : -

i) Increase intracranial tension and cerebral blood flow

ii) ***Decrease cerebral metabolic rate*** -There by provide cerebroprotection.

- ***Amongst inhalational agents, isoflurane provides maximum cerebroprotection, therefore it is the inhalational agent of choicefor neurosurgery.***

Cerebral protection during cardiovascular surgery

o The brain is very vulnerable to ischemic injury because of its relatively high oxygen consumption and near-total dependence on aerobic glucose metabolism. As cardiopulmonary bypass causes ischemia to brain, it should be protected from ischemic injury. Methods of cerebral protection are : -

Hypothermia

- □ ***It is the most effective method for protecting the brain*** during focal and global ischemia. Indeed, profound hypothermia is often used for up to 1 hr of total circulatory arrest with little evidence of neurological impairment.

□ Hypothermia provides cerebral protection by decreasing basal and electrical metabolic requirments throughout the brain.

Electruencephalographic changes during anaesthesia:

Activation of EEG	Slowing of EEG
• **Hypoxia (early)** • **Nitrous oxide** • **Ketamine** • Inhalational agent (subanaestlietic dose) • Barbiturates (small doses) • Benzodiazepenes (small doses) • Etomidate (small doses) • Mild hypercapnia • Sensory stimulation	• **Hypothermia** • Hypocapnia • Marked hypercapnia • Hypoxia (late) ischernia • Barbiturates • Opioids • Propofol • Etomidate

ANAESTHESIA FOR ASTHMA

o Drugs often associated with histamine release should be ***avoided: - Curare, atracurium, mivacurium, suxamethonium, morphine and mepridine.***

o If patients is having **status asthmaticus:-**

- **Ketamine is the intravenous inducing anaesthetic of choice**
- Halothane is the inhalational agent of choice.
- ***Halothane or sevoflurane are the agent of choice in children.***
- Though ***thiopentone*** is used in simple Asthma, it is ***contraindicated in status***

asthmaticus.

o Ketamine should not be used in patients with high theophylline levels, as the combined actions of the two drugs can precipitate the seizure activity.

OBSTETRIC ANAESTHESIA

Cesarean section

o **Spinal or epidural or combination of both anaesthesia** is preferred to general anaesthesia for cesarean section.

o If there is massive bleeding (placenta previa, abruptio placentae or uterine rupture), umblical cord prolapse, and fetal distress; ***General anaesthesia (by rapid sequence induction is given.***

o Rapid sequence induction is done by ***propofol*** (in hypotensive & hypovolemic patients ***ketamine*** is DOC) along with ***succinylcholine.*** To prevent aspiration ***cricoid pressure (sellick***'s ***maneuver)*** is applied. ***Sevoflurane or desflurane or isoflurane*** is used in ***N,0 : O2 mixture*** for maintenance. A muscle relaxant of intermediate duration (mivacurium, atracurium, cisatracurium or vecuronium) is used for relaxation.

General anaesthesia in obstetrics

o **General anaesthesia is used for**: . Fetal distress, **manual extraction of retained placenta** \ reversion of an inverted uterus, repair of major laceration, bimanual massage of uterus, tetanic uterine contraction.

◦ **The most common cause of death during general anaesthesia in obstetrics is pulmonary aspiration of gastric content (Mendelson's syndrome) .** It can be prevented by : -

- *Proper starving for at least 4 hours if not longer.*
- *Reduction in gastric acid production i.e., H2 blocker (Ranitidne) plus antacids.*
- *Neutralization o f any acid produced by* ***sodium citrate*** *given just before anaesthesia.*
- *Increasing lower esophageal sphinctor tone by prokinetic drugs like* ***metoclopramide.***

o All fluorinated inhalational agents relax the uterus and cause PPH in dose related fashion. Halothane, isoflurane, desflurane, sevoflurane relax uterus to similar degree, as opposed to previous consideration that halothane causes maximum relaxation. However, ***traditionally Halothane is considered as best uterine relaxant.***

LASER AIRWAY SURGERY

Use of laser offer the surgeon excellent precision and hemostasis with minimal post-operative edema or pain. Unfortunately it also introduces some major hazards into the operating room, o The greatest fear during laser airway surgery is tracheal tube fire. Therefore, ***whenever laser airway surgery is being performed with a tracheal tube in place, the following precautions should be observed***

- Inspired oxygen concentration should be as low as possible.
- Nitrous oxide supports combustion & should be replaced with air or helium
- Tracheal tube cuff should be filled with saline dyed with methylene blue to dissipate heat and signal rupture.
- Laser intensity should be limited as much as possible
- Saline soaked pledgets should be placed in airway to limit ignition.
- A source of water should be immediately available in case of fire

o These precautions limit, but do not eliminate, the risk of an airway fire; anesthesiologist must always be prepared for

airway-fire protocol.

AIRWAY FIRE PROTOCOL

- ***Stop the procedure and extinguish fire with water***
- ***Stop ventilation & remove Endotracheal Tube (Submerge tube in water)***
- ***Turn off oxygen*** and disconnect circuit from machine
- Asses airway damage with bronchoscopy, serial chest X-rays & ABGs
- ***Consider bronchial lavage & steroids***
- vi) Ventilate with face mask and reintube.

PEDIATRIC ANAESTHESIA

ANAESTHETIC CONSIDERATION

Inhalational induction

o **Inhalational agent with mask is the induction method of choice in children**

o **Sevoflurane is the inhalation agent of choice for induction .Halothane is second choice inhalational agent for induction.** Isoflurane and desflurane are not used for induction as they are more pungent and associated with more coughing & laryngospasm.

Intravenous induction

o **Intravenous induction** is preferred when induction by mask is contraindicated i.e., in full stomach patients or of child comes in the operation theatre with IV line in situ.

o **Thiopentol or propofol** are commonly used agents. **Propofol is particularly suitable for out patient surgery.**

Ketamine is preferred in children with hypovolemia.

Muscle relaxants

Depolarizing blockers

o Children are more susceptible to cardiac arrhythmia, Hyperkalemia and rhabdomyolysis after administration of **succinylcholine.** If a child unexpectedly experiences cardiac arrest following administration of sucinylcholine, immediate treatment for hyperkalemia should be instituted. For this reason, ***succinylcholine is best avoided for routine elective surgery in children.***

o ***Children with muscular dystrophy are more prone to develop hyperkalemia:*** Arrhythmia and cardiac arrest may occur —> **Should be avoided in such patients**

Non-depolarizing muscle relaxants

o Functional maturation of NM junction is not complete until 2 months of age, therefore newborns are very sensitive to non-depolarizing muscle relaxants.

o Kidney and liver functions are immature in neonate —≫ ***Atracurium/cisatracurium is the muscle relaxant of choice in newborn*** as it does not require renal or hepatic elimination. For the same reason ***mivacurium*** can also be used.

Anaesthesia in Geriatic pt/Elderly

· Elderly persons require less dose of anaesthetic agent d/to age related physiological changes.
· Induction agent of choice : Etomidate, thiopentone.
· Inhalational agent of choice for maintenance of anaesthesia Isoflurane/desflurane.
· Methoxyflurane is nephrotoxic, so should not be used.
· More prone for post-operative delirium.

Anaesthesia in a patient of epilepsy

· Enflurane : Causes GTCS. So contra-indicated in seizure disorder.

- Sevoflurane : Can rarely cause convulsions.
- Atracurium : Its metabolite laudonosine can cause convulsions, avoided in epilepsy.
- Ketamine : Increased ICP- Convulsions.
- Recuronium : No effect on ICP Safe

Anaesthesia for Cardiovascular surgery

- Induction agent of choice fo R u L shunt (Cyanotic HD) --- Ketamine

(Because ketamine Ves systemic vascular resistance but does not Vsc pulmonary vascular resistance, and thus does not V R u L shunt)

- Induction in a pediatric patient with L u R shunt (Acyanotic HD) is done by --- Sevoflurane Or any other i.v. induction agent except ketamine
- Anaesthesia is maintained in cardiac patient with --- O_2 + N_2O + opioids

Anaesthetic consideration in special situations

- A patient with SCD (sickle cell trait) posted for surgery in left arm---

Torniquet should be avoided as it can produce vasocostriction and stasis of blood leading to hypoxia. IVRA (Beir's block) should be avoided.

- A patient with mitral stenosis is posted for survery. He is having some liver compromise--- Preferred inhalational agent for him is Xenon and sevo.
- Anesthesia in burn patient

Anectine safe in 1st 24 hrs. Ketamine for dressing changes & escharotomies.

Anesthetic (Induction) agents of choice for:

Condition	Drug
Daycare Surgery	Propofol[Q]
CHF	Ketamine[Q]
Shock	Ketamine[Q]
***Congenital heart disease* (Right to left shunt)**	Ketamine[Q]
***Congenital heart disease* (Left to right shunt)**	Isoflurane[Q]
Cardiac surgery	Isoflurane[Q]
Neurosurgery	Isoflurane[Q]
To produce deliberate hypotenion	Isoflurane[Q]
Epilepsy	Thiopentone[Q]
Ischemic heart disease	Etomidate[Q]

For neurosurgery preferred induction agent is isoflurane with thio/propo/eto+hyperventilation to maintain PaCO2 b/w 25-30 mmHg.

For CAD (IHD) surgery barbiturates, BZD's propo/eto are equally safe.

Drugs for day care surgery (OPD Anesthesia)

Drugs for day care surgery (OPD Anesthesia): At a glance		**Mnemonic: P**rime **M**inister's **DR**
Induction anesthetic of choice	**Propofol.**[Q]	**P**
Muscle relaxant	**Mivacurium,**[Q] atracurium	**M**
Inhalation agent of choice (for maintenance)	**Desflurane** (1st choice)[Q], sevoflurane (2nd choice).	**D**
Analgesic	**Remifentanyl**,[Q] **Alfentany**l,[Q] Fentanyl	**R**

SHOCK

Hypovolemic shock : Classification

	Class 1	Class 2	Class 3	Class 4
Blood loss	<15% (750 ml)	15-30% (.8-1 litre)	30-40 (1.5-2 litre)	>40% (>2 ltr.)
SBP	No change	No change	v	vv
Pulse rate	Slight	100-120	>120 week	>120, thready
RR	N	V	>20	20-30
Capillary refill	Normal 2, sec	> 2 sec.	> 2 sec.	Very delayed
Mental status	Alert	Anxious	Anxious + aggressive	Drowsy, confused unconscious

- Resuscitation of the trauma patient (pediatric/adult) begins with isotonic crystalloid, in a child 20 ml/kg.
- Urne output is the most important parameter of adequate tissue perfusion in a patient with shock.
- PCWP or CVP is used to assess volume replacement in hypovolemic shock.
- In children, hydrocortisone is indicated in septic shock in children with catecholamine resistance and suspected or proven adrenal insufficiency (chidren with severe septic shock and purpure, children who have previously received steriod therapies for chronic illness, and children with pituitary or adrenal abnormalities).

RESPIRATORY FAILURE

Type of respiratory failure	Subtype	ABG	Examplle
TYPE I (PaO_2 < 60 : $PaCO_2$ < 50 mm Hg)	Acute	PaO_2dec $PaCO_2$ normal pH normal or increase HCO_3normal	Asthma, Pulmonary embolus, Pulmonary edema, ARDS, Pneumothorax, Pneumonia
	Chronic	PaO_2dec $PaCO_2$inc HCO_3inc	Emphysema Lung fibrosis Lymphangitis carcinomatosa R - L shunts Anemia
TYPE II	Acute	PaO_2dec $PaCO_2$inc HCO_3inc	Severe acute asthma Acute epiglottis FB inhalation, Respiratory ms paralysis, Flail chest injury Sleep apnea Brain stem lesion Narcotic drugs
	Chronic	PaO_2dec $PACO_2$inc HCO_3inc	Chronic bronchitis, Primary alveolar HTN, Kyphoscoliosis, Ankylosing spondylitis

Type III respiratory failure

- Is the result of lung atelectasis. Also called perioperative respiratory failure.
- Seen **after G.A. dec** in FRC leads to collapse of dependent lung units.

Type IV respiratory failure

- Occurs bec/of hypoperfusion of respiratory muscles in patients of shock.

Patient of shock often suffer resp. distress d/to pulmonary edema, lactic acidosis & anemia.

CPR

- M/c type id ECG rythm at the time of cardiac arrest
  - in children --- Pulseless electrical activity
  - and in adults --- VT without pulse
- M/c cause of cardiac arrest in children is --- hypoxia (rescue breaths are more effective)
- M/c cause of cardiac arrest in adult is --- cardiac causes (chest compression are more effective)
- In hospital setting, tracheal intubation is the preferred method of maintaining a patent airway in an unconscious patients with cardiac arrest. Prior to intubation an

oropharyngeal airway can be used to prevent fall of tongue. Outside hospital settings BMV is still preferred.

- The standard ventilation bags used during CPR have a volume of 1600 ml.
- To mininize the circulatory adverse effects of hyperventilation, avoid lung ventilation > 10 breaths/min.
- Any destrose containing fluid should be avoided. In CPR
- DOC for asystole in CPR : Adrenaline
- DOC for bradycardiac in CPR : Atropine
- The first step in CPR is circulation now a days (C---A---B Circulation-airway-breathing sequence)

AHA guidlines for CPR:

	Neunates & <2 months	Infants/children	Infant/children	Adult
Compression	90/min	-100/min	-100/min	j100/min
Compression to ventilation ratio	3:1 (2 rescuer)	30:2 (single rescuer)	15:2 (if two rescuer present)	30:2 (or 15:1)

CARDIOPULMONARY RESUSCITATION:

SUMMARY OF CHANGES AS PER 2010 (AHA)GUIDELINES

1. Sequence of management changed to C (Circulation)→ A (airway) → B (breathing) from A → B→ C.
2. BLS survey steps instead of primary A, B, C, D are now numbered as 1, 2, 3, 4, and ACLS survey steps instead of secondary A, B, C, D, are simply numbered as A, B, C, D.
3. No listening, looking and feel for respiration.
4. No mouth to mouth or mouth to nose breathing.
5. Ensure high quality CPRI i.e.

I. Push hard means sternum must be depressed by 2 inches in adults, 1.5 inches in children and 1 inch in infants (no range).
II. Push fast means rate of compression in adults in 100 (not around 100)
III. Allow full chest recoil
IV. Minimize interruption in chest compressions. Any procedure should not interrupt massage more than 10 sec.,
V. Rotate the person giving compression every 2 minutes to avoid fatigue.
VI. Avoid excess ventilation.

6. For common man-hands only
7. Defibrillation energies

All shocks of 360 J with monophasic defibrillators and 120-200 J with biphasic defibrillators.

For infants and children preferably defibrillate with pediatric attenuator but if defibrillator does nto have this facility then standard energy regimes [i.e.2J/Kg (first shock) and 4J/Kg subsequent shocks) should be employed.

8. Capnography is a mandatory monitor not only to confirm the position of endotracheal tube but also to see the performance of CPR-improve CPR if pco2 less than 10 and diastolic pressure less than 20.
9. Intraosseous route is preferred route over endotracheal and can be employed for all ages (contrary to previous recommendation of intraosseous route only or children <6 years)
10. Drugs

I. No atropine for Asytole/pulseless electrical activity.
II. Only the standard regime of adrenaline (1mg every 2-3min.) should be followed.
III. Dopamine and adrenaline infusions are as good alternatives to transcutaneous pacing for bradycardia refractory to atropine.
IV. Adenosine recommended for regular monomorphic wide complex ventricular tachycardia.

PALS GUIDELINES: Pediatric advanced life support:

Change in CPR Sequence(C-A-B Rather Than A-B-C)

2010 (New):

Initiate CPR for infants and children with chest compressions rather than rescue breaths.

CPR should begin with 30 compressions (any lonerescuer) or 15 compressions (for resuscitation of infantsand children by 2 healthcare providers) rather than with 2ventilations.For resuscitation of the newly born, see the

Neonatal Resuscitation section

2005 (Old):

Cardiopulmonary resuscitation was initiated with opening of the airway and the provision of 2 breaths before chest compressions.

Chest Compression Depth

2010 (New):

To achieve effective chest compressions,rescuers should compress at least one third of the anteriorposteriordiameter of the chest.

1½ inches (about 4 cm) in most infants

2 inches (5 cm) in most children

2005 (Old):

Push with sufficient force to depress the chestapproximately one third to one half the anterior-posterior diameter of the chest

Elimination of "Look, Listen, and Feel for Breathing"

2010 (New):

"Look, listen, and feel" was removed from thesequence for assessment of breathing after opening the airway.

2005 (Old):

"Look, listen, and feel" was used to assess breathing after the airway was opened.

Pulse Check Again De-emphasized

2010 (New):

If the infant or child is unresponsive and not breathing or only gasping, healthcare providers may take up to 10 seconds to attempt to feel for a pulse (brachial in an infant and carotid or femoral in a child). If, within 10 seconds, you don't feel a pulse or are not sure if you feel a pulse, begin chest compressions.

(It can be difficult to determine the presence or absence of a pulse, especially in an emergency, and studies show that both healthcare providers and lay rescuers are unable to reliably detect a pulse.)

2005 (Old):

If you are a healthcare provider, try to palpate a pulse. Take no more than 10 seconds.

PEDIATRIC ADVANCED LIFE SUPPORT(PALS)

Many key issues in the review of the PALS literature resulted in refinement of existing recommendations rather than new recommendations;

Defibrillation Energy Doses

2010 (New): It is acceptable to use an initial dose of 2 to 4 J/kg for defibrillation, but for ease of teaching, an initial dose of 2 J/kg may be used.

For refractory VF, it is reasonable to increase the dose. Subsequent energy levels should be at least 4 J/kg, and higher energy levels, not to exceed 10 J/kg or the adult maximum dose, may be considered.

2005 (Old):

With a manual defibrillator (monophasicorbiphasic), use a dose of 2 J/kg for the first attempt and 4 J/kg for subsequent attempts.

Limited evidence is available about effective or maximum energy doses for pediatric defibrillation, but some data suggest that higher doses may be safe and potentially more effective

Limiting Oxygen to Normal LevelsAfter Resuscitation

2010 (New):

Once the circulation is restored, monitor arterial oxyhemoglobin saturation.

In general it is appropriate to wean the FIO2when the saturation is 100%, provided the saturation can be maintained 94%.

2005 (Old):

Hyperoxiaand the risk for reperfusion injury were addressed in the 2005 AHA Guidelines for CPR in general, *but recommendations for titration of inspired oxygen were not as specific.*

Recent data from an adult study demonstrated worse outcomes with hyperoxiaafter resuscitation from cardiac arrest.

Management of Tachycardia

2010 (New): Wide-complex tachycardia is present if the QRS width is >0.09 second.

In a recent scientific statement, QRS duration was considered prolonged if it was >0.09 second for a child under the age of 4 years, and ≥0.1 second was considered prolonged for a child between the ages of 4 and 16 years.

2005 (Old): Wide-complex tachycardia is present if the QRS width is >0.08 second.

Medications During Cardiac Arrest and Shock

2010 (New): The recommendation regarding calcium administration is stronger than in past AHA Guidelines:

Etomidatehas been shown to facilitate endotrachealintubation in infants and children with minimal hemodynamic effect but is not recommended for routine use in pediatric patients with evidence of septic shock.

2005 (Old): Theroutine administration of calcium does not improve the outcome of cardiac arrest.

Etomidatewas not addressed in the 2005 AHA Guidelines for CPR

Advanced Trauma Life Support (ATLS®): The ninth edition
Journal of Trauma and Acute Care Surgery 2013; 72(5): 1363–1366

ATLS Protocol of trauma patient:

- **RESUSCITATION**
  - ✧ To reverse immediately life-threatening situations and maximize patient survival

TREATMENT PRIORITY	NECCESSARY PROCEDURE
Airway	1. Jaw thrust/chin lift/ 2. Suction **3. Intubation** 4. Cricothyroidotomy (with protection of C-spine)
Breathing/Ventilation/oxygenation	1. Chest needle decompression 2. Tube thoracostomy 3. Supplemental oxygen 4. Seal open pneumothorax
Circulation/hemorrhage control	1. IV line/ central line 2. Venous cutdown 3. Fluid resuscitation/Blood transfusion 4. Thorocostomy for massive hemothorax 5. Pericardiocentesis for cardiac tamponade
Disability	1. Burr holes for trans-tentorial herniation 2. IV mannitol
Exposure/**E**nvironment	1. Warmed crystalloid fluid 2. Temperature

  - ✧ **Q : What are the indications for definite airway ?**

Indications For Definite Airway

Need for Airway Protection	**Need for Ventilation**
Unconscious GCS ≤ 8	Apnea Neuromuscular paralysis Unconscious
Severe maxillofacial fractures	Inadequate respiratory effort

	Tachypnea Hypoxia Hypercarbia Cyanosis
Risk for aspiration Bleeding Vomiting	Severe closed head injury with need for hyperventilation
Risk for obstruction	

- ✧ **Maintain the cervical spine** in a neutral position with manual immobilization as necessary when establishing an airway
- ✧ **Immobilization of the c-spine** with appropriate devices after establishing an airway.
- ✧ **Important Notes:**
  - Assume a cervical spine injury in any patient with multisystem trauma, especially with an altered level of consciousness or a blunt injury above the clavicle

Major Changes In The ATLS® 9th Edition:

Chapter	Subject	9thed
Initial Assessment	Team training	Preparation of the team, along with team dynamics and debriefing, are important parts of team-based care that are highlighted in the Initial Assessment chapter. one team member should assume the role of team leader
Airway	Cuffed pediatric tubes	Previous concerns about cuffed endotracheal tubes causing tracheal necrosis are no longer relevant due to improvements in the design of the cuffs. Ideally, cuff pressure should be measured as soon as it is feasible and, 30mm Hg is considered safe.
	Use of video laryngoscopy	The use of additional advanced airway techniques is highlighted, along with the use of videolaryngoscopy
Shock	Crystalloid	Hypertonic saline has no benefit over standard crystalloid resuscitation.
	Fluid Resuscitation	a.The concept of balanced resuscitation is further emphasized, and the term aggressive resuscitation has been eliminated. The standard use of 2 liters of crystalloid resuscitation as the starting point for all resuscitation has been modified to initiation of 1 liter of crystalloid. b.Early use of blood and blood products for patients in shock is also emphasized, without mandating or suggesting any specific ratio of plasma and platelets
Abdomen & Pelvis		More emphasis is placed on the pelvis as a source of blood loss. This has been done by moving all of the content to the abdomen and pelvis chapter and the shock and surgical skills stations. The new Focused Assessment with Sonography for

		Trauma (FAST) skill station must be taught; one way of assessing the abdomen as a source of potential blood loss remains mandatory.

Note:In ATLS protocol there is no change in sequence of resuscitation sequence of trauma patient.(ABC)

But in ACLS protocol the sequence have been changed. Now it is (CAB)

MISCLANEOUS TOPICS

REPLACEMENT FLUIDS

Thomas graham in 1861 coined the terms colloid and crystalloid.

Crystalloid:Solutes that will pass through semipemeable membrane and molecular wt is < 10000 Dalton

Colloid : solutes that will not pass through semipemeable membrane and molecular wt is >10000 Dalton

Crystalloids

- Ringer lactate
- Normal saline
- 5% dextrose
- DNS
- hypertonic saline
- for 1 ml loss of blood 3ml of crystalloid is required (1:3 ratio)

Colloids: required in 1:1 ratio

Natural	Synthetic
Albumin	Dextran
FFP	Gelatin
	Hydoxyethyl starch

Albumin

Available in 5%, 20%& 25%

Albumin has intravascular half life of 10-15 days

Uses

Extensive burns

Cirrhosis

Protein losing nephropathies

Side effects: pulmonary edema, anaphylaxis & transmission of infection

Fresh frozen plasma

Obtainedby separating from a unit of whole bllod with in 6 hrs of collection and frozen at -30^{o}C.

May be stored up to one year

Factor V & VIII deteriorate to minimal extent during storage

Once thawed it should be used with in 2hrs to prevent ↓ in coagulation factor VII.

FFP should be ABO compatible as Anti-A and Anti-B in FFP can destroy recipient RBCs

Uses

Abnormal bleeding with deficient coagulation factors

To reverse the effect of warfarin

Side effect

Hypersentivity

Transmission of infection

Plasma Expanders: At a Glance

- These are high molecular weight substances that exert osmotic effect and retain fluid in blood vessels when infused I.V.
- These are used to correct hypovolemia due to blood loss as in trauma.
- The agents used are: **Albumin, Dextran, Polygeline and Hetastarch. Polyvinylpyrrolidone.**[Q]
- Plasma expanders are *contraindicated in severe anemia, heart failure, pulmonary edema, liver and/kidney failure.*[Q]

Albumin	• It **does not interfere with blood grouping or coagulation** and is free of risk of transmission of hepatitis (as it is heat treated)[Q]. • Apart from hypovolemia, burns and shock, it can be used for hypoalbuminemia also. • It is highly expensive.[Q]
Dextran	• Dextran is a **polysaccharide**[Q] obtained from sugar beat. • Two form. *Dextran-70 (MW 70000) is longer acting (24 hours) whereas dextran-40(MW 40000) is rapid but short* acting. • It is a plasma expander and have all properties of an ideal plasma expander except: a. May interfere with blood **grouping and cross matching.**[Q] b. Some polysaccharide reacting antibodies if present in patients may cross-react with dextran and trigger an anaphylactoid reaction. c. They coat the platelets and coagulation factors and may interfere with coagulation and platelet function, thus prolong bleeding time. It is not used when hypofibrinogenemia, thrombocytopenia or bleeding is present. • Dextran prevents roleaux formation of RBCs and has anti-sludging effects, thereby increases microcirculation.
Polygeline or degraded gelatin polymer	• **It is a polypeptide with average MW 30000 which exerts oncotic pressure similar to albumin and is not antigenic, hypersensitivity reaction is rare, but should be watched for.** • It does not interfere with blood **grouping and cross matching.**[Q] • Not metabolized by body excreted slowly by kidney. • Expansion of plasma volume lasts for 12 hours. • More expensive than dextran. • Used for priming of heart lung machine and dialysis machine.
Hydroxyethyl starch (HES)	• It is a mixture of ethoxylated amylopectin of various sizes. • MW: 4.5 lac. • The colloidal properties of 6% HES approximate those of human albumin. • Plasma volume expands slightly in excess of volume infused. • Adverse effect: ***Flu like symptoms, salivary gland swelling.***
Polyvinyl pyrrolidone	It is a synthetic polymer (MW 40000) used as a 3.5% solution. It interferes with blood **grouping and cross matching.**

TRANSFUSION

Indications:

	1.	Blood loss greater than 20% of blood volume when more than 100 mL
	2.	Hemoglobin level less than 8 g/dL
	3.	Hemoglobin level less than 10 g/dL with major disease (e.g., emphysema, ischemic heart disease)
	4.	Hemoglobin level of less than 10 g/dL with autologous blood
	5.	Hemoglobin level less than 12 g/dL and ventilator dependent

SOLUTIONS USED FOR BLOOD STORAGE

CPD -21 days
CPDA-35 days
ADsol-42 days (adenine, glucose, mannitol & NaCI)
Nutricel-42 days (adenine, glucose, citrate, phosphate, & NaCI)
Opticel-42 days
Citrate as anticoagulant
Phosphate as buffer
Dextrose – energy for red cells by glycolysis
Adenine to RBC survival substrate for ATP

Blood is stored at 4 degree C which slows the rate of glycolysis

→ 1 unit of blood ↑es Hb by 0.8gm%

→ Hct. Of stored blood 40% (Hb 12gm%)

→ 1 unit of blood = 350 ml (out of this 49ml is anticoagulant)

Changes in stored blood

1. pH of CPD solution is 5.5. so when blood is added to this solution the pH of blood ↓to 7.0 to 7.1& further ↓ is because of lactic acid/pyruvic acid & ↑ in $PaCO_2$ (plastic bag prevent escape of CO_2)
2. PH = ↓ 6.98 at 35 days)
3. Hb conc. (70% at 35 days)
4. K+↑
5. 2,3 DPG -↓
6. Platelets – only 50% after 6-8 hrs. Of storage & only 5% after 24-48 hrs.
7. Coagulation factors –
   V-only 15% after 21 days
   VIII – 5o% after 21 days

Complications

Immune	**Non immune**
Acute hemolytic transfusion reaction	hypothermia
Delayed hemolytic transfusion reaction	electrolyte toxicity
Febrile hemolytic transfusion reaction	infection
Anaphylactic reaction	Fe overload
Alloimmunization	fluid overload

TRALI
Allergic reaction

1. **Heamolytic reactions** (1 in 5000)

S/S

1. Fever with rigor & chills
2. Chest pain / flanks pain
3. Nausea
4. Flushing
5. Dyspnea
6. Hypotension @
7. Bledding from surgical site @
8. Haemoglobinuria

@ S/S observed under anaesthesia

Steps in the Treatment of a Hemolytic Transfusion Reaction

1. STOP THE TRANSFUSION.

2. Maintain the urine output at a minimum of 75 to 100 mL/hr by the following methods:

- **a.** Generously administer fluids intravenously and possibly mannitol (12.5 to 50 g, given over 5 to 15 minutes).
- **b.** If intravenously administered fluids and mannitol are ineffective, administer furosemide (20 to 40 mg) intravenously.

3. Alkalinize the urine; because bicarbonate is preferentially excreted in the urine, only 40 to 70 mEq of sodium bicarbonate per 70 kg of body weight is usually required to raise the urine pH to 8, whereupon repeat urine pH determinations indicate the need for additional bicarbonate.

4. Assay urine and plasma hemoglobin concentrations.

5. Determine platelet count, partial thromboplastin time, and serum fibrinogen level.

6. Return unused blood to blood bank for repeat crossmatch.

7. Send patient's blood and urine sample to blood bank for examination.

8. Prevent hypotension to ensure adequate renal blood flow.

2. Delayed hemolytic transfusion reaction: 2 to 21 days. This type of reaction occurs mainly in recipient sensitized to RBC antigens by previous blood transfusions or pregnancy. The level of antibody at the time of transfusion is too low to be detected or too low to cause RBCs destruction. Antibodies commonly involved in this reaction are Rh & kidd systems rather than the ABO system. RBC destruction occurs only when the level of antibody is ↑ after second stimulus (anamnestic response)
3. Febrile – associated with chills, rigor & rise in temperature. Antibody directed against donar leucocyte & HLA antigen is responsible.
   no hypotension & sign of haemolysis

Rx – no Rx required

Severe – stop transfusion

4. Allergic – mild

   Rx- Diphenylhydramine + steroid

   - Slowing the rate of delivery

   - Severe

   Immediately stop transfusion

   Epinephrine

5. Alloimmunization cellular blood elements and plasma proteins bear a number of antigens to which the recipient may become alloimmunized. Alloantibodies to RBC antigens are detected during pretransfusion testing. Women of child bearing age who are sensitized to certain RBC antigens i.e D,C,E,Kell or duffy are at the risk for bearing a fetus hemolytic disease of newborn. Alloimmunization to antigens on leucocytes and platelets can result in refractoriness to platelet transfusions. Hence to prevent sensitization leucocyte reduced components & judicious used of bllod & its components are used.
6. Transmission of viral diseases

   Hepatitis – incidence is 1 in 3000

   - 90% is non A non B
   - 70% are anicteric
   - 75% of anicteric results in subclinical cases
   - 40% develop chronic hepatitis out of these 0.5% die

   - AIDS (incidence 1:60000-20000)

   - Cytomegalovirus

   - HTLV type 1

Other diseases

- Syphilis
- Malaria
- Yersinia enterocaolitica
- Herepes, toxoplasmosis, infectious mononucleosis, filariasis, leishmaniasis, brucellosis.

7. Acid base abnormalities

   Variable results

   Decrease pH of blood causes acidosis

   Citrate once metabolized in body causes alkalosis

8. Hyperkalemia } especially, if rate of infusion is high
9. Hypocalcemia }
10. Coagulation abnormalities

    And decrease coagulation factors

    Rx-fresh blood transfusion is the best management & Component therapies
11. Infusion of microaggregates – to reduce this microfilters with pore size of 20-40 μms should be used instead of conventional filter with size of 170 micron
12. Immnosuppression
13. Endotoxemia mainly because of Pseudomonas

Massive blood transfusion

Bleeding requiring more than 10 units/ patients volume over a 24hrs period OR

Replacement of 50% of blood volume in 3 hrs OR blood loss of more than 150ml/min

Complications

Rate related	volume related
Hyperkalemia &	dilutional thrombocytopnea
Hypocalcemia& hypomagnesemia citrate chelate Ca &Mg	dilutional procoagulant factors
Hypothermia	dilutional anticoagulant factors
Acidosis	
DIC – usual cause of death	
ARDS	

BLOOD COMPONENT THERAPY

1. Packed cells – volume 300ml
   Hct – 70%
   To be diluted in isotonic solutions only
2. Frozen RBC,s
   - Expensive
   - ↓ Chances of reactions
   - ↓ Chances of disease transmission
3. Platelet concentrate (50ml

Platelet concentrate usually contain WBC & RBCs & for this reason it should be of correct blood group
Stored at room temp (survival 4-5days). While at 4 degree C survival is 24-48hrs.
1 unit increase platelet by 7000- 10000

4. Fresh frozen plasma (volume 225ml)
   Contain all procoagulants
5. Cryoprecicipate contains factor VIII, fibrinogen, vWillibrand factor.
6. Granulocytes

Synthetic O_2 carriers

1. Blood substitutes : perflourocarbons e.g Fluosal DA, oxygen, oxyfluor
2. Hb based O_2 carriers
   - Free Hb solutions. Hb is derived from human RBC, Bivine RBC, Recombinant Hb in Ecoli
   - Liposomal encapsulated Hb solution