Manual of Anaesthesia

Arun K Paul

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To
my wife, Kanyakumari
and
daughter, Sushmita
for the love, support and encouragement

Preface

The *Manual of Anaesthesia* is intended to provide a convenient, concise, readable and rapid source of information relevant to anaesthesiology. The book uses a point-wise format for easy reading and better understanding of the text.

The subject matter is discussed in some details and made interesting as well as practicable to grasp the fundamentals of clinical anaesthesia. On the whole, the text will serve as primer and the students, trainee and practitioners will find it suitable.

I wish to thank Mrs Kanyakumari Paul and Sushmita Paul for their cooperation and support in the preparation of this book.

I am also indebted to Shri Jitendar P Vij, (Chairman and Managing Director) and Mr Tarun Duneja (Director-Publishing) of Jaypee Brothers Medical Publishers (P) Ltd, New Delhi who offered the concept of the book with enthusiasm and published the volume.

Arun Kumar Paul

Contents

CHAPTER

1 Preanaesthetic Evaluation

OBJECTIVES

1. History and physical examination of the patient
2. To review medical records including past anaesthetic records
3. To get laboratory studies
4. To determine physical status and anticipate difficulties
5. For planning of anaesthesia management
6. To ensure obtaining consent
7. To develop anaesthetist-patient rapport
8. To make advanced preparation relating facilities, equipment and expertise, to enhance patient safety and minimise the chance of errors.

HISTORY

1. Patient's medications: Aspirin, insulin, antihypertensives, MAO inhibitors, lithium, anticoagulants, etc.
2. Any allergy
3. Past hospitalisation, any anaesthesia/operation
4. Family history
5. Any addiction: Smoking, alcohol, drugs
6. Any associated illness: Metabolic, endocrinal, renal, hepatic, cardiac, pulmonary disease, sexually transmitted disease, hepatitis, HIV
7. Menstrual history in case of females.

ASSOCIATED ILLNESS NEEDING FURTHER INVESTIGATIONS

a. Central nervous system: Cerebrovascular insufficiency, convulsion.
b. Cardiovascular system: Chest pain, myocardial infarction, hypertension, rheumatic fever, palpitations, dysrhythmias.
c. Respiratory system: Dyspnoea, cough, bronchospasm, pneumonia, smoking, upper respiratory infection.

d. Liver: Alcoholism, hepatitis, jaundice
e. Kidney: Polyuria, pyuria
f. Endocrine system: Diabetes mellitus, adrenal dysfunction, thyroid dysfunction.
g. Miscellaneous: Allergy, bleeding tendency, myalgia, arthritis, osteoporosis, strabismus, etc.

COMMON MEDICATIONS AND ANAESTHETIC IMPLICATIONS

1. Aspirin: Bleeding tendency, platelet dysfunction
2. Alcohol abuse: Resistance to anaesthetic drugs
3. Antibiotics: Potentiation of muscle relaxants
4. Antihypertensives: Impaired sympathetic nervous system activity, hypertensive crisis
5. Beta blockers: Bradycardia, bronchospasm
6. Benzodiazepines: Potentiation of muscle relaxants, resistance to anaesthetic drugs
7. Calcium channel blockers: Interaction with muscle relaxants, hypotension
8. MAO inhibitors: Increased response to sympathomimetic drugs
9. Lithium: Potentiation of muscle relaxants, impaired thyroid function
10. Digitalis: Dysrhythmias
11. Diuretics: Hypotension, hypovolaemia, hypokalaemia
12. Anticoagulant therapy: Excessive bleeding.

PHYSICAL EXAMINATION

1. **Vital signs**: Pulse, respiration, blood pressure, body temperature
2. **General**: Weight, weakness
3. **Airway examination**:
   Cervical spine: head mobility, Mobility of temporomandibular joint, Teeth : Central incisor prominency, Artificial teeth, if any, loose teeth, Attempt of visualise uvula, any lesion in mouth, hyromental distance (Normal more than 6.5 cm)
   Nose and throat: Sore throat, sinusitis, epistaxis, deviated nasal septum, dysphagia, sunken cheeks, patency of nares opening of mouth. Appearance of neck (long or short).
4. **Respiratory**: Breathing rate and pattern, any moist sound, wheezing, cough, sputum, emphysema, pneumonia, tuberculosis, bronchitis.
5. **Cardiac**: Heart rate, rhythm, murmur, blood pressure, pulse, peripheral oedema, dyspnoea, orthopnoea, veins, heart failure.
6. **Central nervous system**: Level of consciousness, numbness, paralysis, skeletal muscle dysfunction, convulsion.
7. **Gastrointestinal system**: Nausea/vomiting, constipation, diarrhoea, jaundice, hepatitis.
8. **Haematologic**: Bruising, anaemia, bleeding.
9. **Endocrine system**: Diabetes, thyroid dysfunction.
10. **Urinary system**: Nocturia, dysuria, haematuria, incontinence.
11. **Prosthesis, if any**: Eye glasses, contact lens, hearing aid, ornaments, ring

12. **Miscellaneous**: Examination of eye; examination of ear, extremities: Claudication, thrombophlebitis, arthritis; skin examination: rashes, wounds, infection; psychiatric problems, anxiety.
    - **Breath holding test**: It is the time to hold his breath after full inspiration. Normal more than 25 seconds. Less than 15 seconds indicates severely diminished cardiorespiratory reserve.
    - **Match test**: Patient is asked to blow off the lighted match stick with his open mouth at a distance 15 cm. Failure indicates low maximum breathing capacity.

PREOPERATIVE DIAGNOSTIC INVESTIGATIONS

1. Blood examination
   TC, DC, haemoglobin, haematocrit
2. Blood biochemistry
   Glucose, urea, nitrogen, creatinine, electrolytes, liver enzymes
3. Urine analysis
4. Coagulation studies
   Prothrombin time, platelet count, partial thromboplastin time
5. Chest X-ray
6. Electrocardiogram
7. Pulmonary function tests
   FEV_1, vital capacity, peak expiratory flow rate
   Arterial blood gas study, pH
   [**Normal Values** :
   Vital capacity 5 lits.
   FEV_1 4 lits.
   PEFR 600 lits/min.
   PaO_2 75 to 100 mm Hg.
   $PaCO_2$ 36 to 46 mm Hg.]

ASA PHYSICAL STATUS INDEX

Grade 1: Normal healthy patient

Grade 2: Patient with mild/moderate systemic disease

Grade 3: Patient with severe systemic disease that causes functional limitation

Grade 4: Patient with incapacitating systemic disease that causes a constant threat to life

Grade 5: Moribund patient not expected to survive 24 hours without operation

Emergency Operation E: Any patient in whom emergency operation is required. Here the suffix E is added.

FACTORS FOR SELECTION OF ANAESTHETIC TECHNIQUE

1. Safety of the patient
2. Coexisting systemic disorders
3. Site of operation
4. Elective or emergency procedure
5. Age of the patient
6. Preference of the patient, if any
7. Ability of the anaesthetist concerned
8. Convenience of the surgeon.

PREANAESTHETIC ROUTINE PREPARATION

1. Psychological support, reassurance
2. No food/drink for at least 6 hours before anaesthesia
3. Urinary bladder should be emptied before taken to OT
4. False teeth, artificial limbs, artificial eyes, contact lenses, shoes, ornaments, etc. should be taken off
5. No tight clothing, no lipstick, no nail vernish
6. Adequate oral hygiene
7. Identification label should be checked
8. Consent for anaesthesia/surgery is mandatory
9. Resuscitative drugs, fluids, etc.
10. Night sedation
11. Preanaesthetic medication. It should be given in adequate dose and at proper time.

- No routine preparation is needed in extreme emergencies :
  i. Rupture of major vessels
  ii. Severe obstetric emergencies: ectopic rupture
  iii. Acute upper airway obstruction
  iv. Surgery on patients trapped and immobile.

COMMON CAUSES OF POSTPONEMENT OF OPERATION

1. Acute respiratory infection
2. Coexisting systemic illness not under optimal control
3. Lack of adequate resuscitation
4. Full stomach
5. Nonavailability of written consent
6. Failure to obstain recent investigation reports.

ROUTINE REQUIREMENT BEFORE INDUCTION OF ANAESTHESIA

A. Anaesthesia machine
Anaesthesia breathing system
Gas cylinders
Soda lime
Vaporisers
Mechanical ventilator
Suction apparatus
Monitoring equipment.

B. Drugs
Local anaesthetic drugs
iv inducing agents
Muscle relaxants
Opioids and opioid antagonist
Benzodiazepines and its antagonist
Anticholinergic drugs
Vasopressor drugs
Bronchodilators
Catecholamines.

C. Miscellaneous
Infusion set, fluids
Suction catheter, oral/nasal airway
Laryngoscope, endotracheal tubes
Nasogastric tube, Magill forceps.

D. Blood should be crossmatched and available in time.

CHAPTER

2 Preanaesthetic Medication

AIMS OF PREANAESTHETIC MEDICATION OR PREMEDICATION

1. To relieve anxiety, fear and tension
2. To provide a degree of autonomic block
3. To produce sedation, analgesia and amnesia
4. To reduce salivary secretions and secretions of respiratory tract
5. To reduce metabolic rate
6. To depress unwanted vagal reflex activities
7. To potentiate anaesthetic drugs
8. To protect the patient from the toxic effects of anaesthesia
9. To reduce the incidence of postoperative complications.

CRITERIA FOR IDEAL PREMEDICATION

1. It should be anxiolytic, analgesic, sedative and anesic
2. It should facilitate smooth anaesthesia
3. It should depress salivary and respiratory secretions
4. It should prevent nausea/vomiting
5. It should be safe and can be easily administered
6. There should not be undue depression of cardiovascular, respiratory and central nervous system.

FACTORS FOR PROPER SELECTION OF PREMEDICANT DRUGS

1. General condition of patient, age and weight, psychological status, level of anxiety, presence of pain, etc.
2. Proposed operation: Nature of surgery, site of operation, posture during surgery, duration of operation
3. Elective/emergency surgery
4. Inpatient/outpatient

5. Availability of nursing care
6. Availability of adequate surgical and anaesthetic management and care
7. Tolerance of depressant drugs
8. Previous history of adverse reaction of drugs
9. Presence of allergy.

COMMON DRUGS USED IN PREMEDICATION

1. Sedatives : Barbiturates, benzodiazepines, phenothiazines
2. Narcotic analgesics: Opioid drugs
3. Neuroleptic drugs: Droperidol
4. Anticholinergic drugs: Atropine, hyoscine, glycopyrrolate
5. Anxiolytic drugs: Diazepam, midazolam, lorazepam
6. Phenothiazine drugs: Promethazine, trimeprazine, prochlorperazine
7. Antiemetic drugs: Metoclopramide, ondansetron
8. H_2 antagonists: Ranitidine, cimetidine famotidine
9. Antacids
   - These drugs are being used eiher alone or in combination according to the need of the individual patients.

MORPHINE SULPHATE

1. Alkaloid of opium, a standard potent analgesic
2. Sedative, hypnotic, anxiolytic
3. Overall depression of central nervous system
4. CSF pressure raised
5. Depression of respiration, decreased response of chemoreceptors to anoxia, depression of cough reflex, increased bronchial muscle tone
6. Direct myocardial depression, hypotension, reduction of cardiac output and stroke volume, peripheral vasodilation
7. Nausea/vomiting, constriction of sphincters, diminished peristalsis, constipation
8. Passes through placental barrier
9. Constricted pupils
10. May cause hyperglycaemia
11. May cause addiction
12. Antidiuresis
13. Pruritus
14. Dose: About 0·2 mg/kg im.

PETHIDINE HYDROCHLORIDE

1. Synthetic opioid agonist one-tenth as potent as morphine
2. Dose: 1 to 2 mg/kg

3. Analgesic, sedative, euphoric, anxiolytic
4. Respiratory depressant, raise CSF pressure
5. Atropine like effect: dry mouth
6. Direct effect on smooth muscles of bronchioles, intestines, ureters and arteries causing reduction of tone
7. Can cause addiction
8. Does not cause constipation
9. May release histamine
10. Passes through placental barrier
11. Side-effects: Nausea/vomiting, hypotension, vertigo, tremor, limb tingling.

PENTAZOCINE

1. Synthetic narcotic analgesic, a benzomorphan derivative. A partial agonist of μ-receptors
2. It is short-acting and induces less respiratory depression
3. Dysphoria is common. Less addiction liability
4. Sympathomimetic action
5. Nausea/vomiting : less ; constipation : less
6. It crosses the placental barrier less
7. It is less cumulative
8. Dose: 20 to 60 mg by injection, 25 to 100 mg orally.

DIAZEPAM

1. Benzodiazepine group of drug with main pharmacological actions:
   a. Sedative, hypnotic, anxiolytic, amnesic
   b. Muscle relaxation
   c. Anxiolytic
   d. Anticonvulsant.
2. Not analgesic, does not cause nausea/vomiting
3. May decrease blood pressure and increase heart rate
4. Respiratory depression is less
5. Potentiates nondepolarising muscle relaxants
6. Dose: In premedication 10 to 20 mg orally or im; for induction of anaesthesia 0.5 mg/kg iv.

ATROPINE SULPHATE

1. Anticholinergic, parasympatholytic drug
2. It crosses the blood-brain barrier and stimulates higher cortical centres and medulla
3. In therapeutic doses atropine can cause stimulation of vagal centre and initially cause bradycardia. Later on this is overcome by antimuscarinic action on sinoatrial node causing tachycardia
4. Bronchiolar dilatation, may increase rate and depth of respiration

5. Salivary and bronchial secretions diminished
6. Diminishes tone and Peristalsis of gut
7. Can reduce the tone of lower oesophageal sphincter and lower oesophageal pressure
8. Can raise body temperature, stimulate heat regulating centre, increase basal metabolic rate, diminish sweating
9. Dilates pupil, causes paralysis of accommodation (cycloplegia), significant effect on intraocular pressure in cases with narrow angle glaucoma
10. Reduces motor activity and tone in detrusor muscle of urinary bladder
11. Dose: 0·65 mg ; in children 0·02 mg/kg ; for vagolytic action 1·5 to 3 mg.

HYOSCINE

1. Levorotatory alkaloid, anticholinergic, parasympatholytic, tertiary amine
2. Crosses the blood-brain barrier and placental barrier easily
3. Marked sedation, amnesia, antanalgesic
4. Restlessness and delirium—common
5. Pronounced antisalivary effect
6. Can cause rise of body temperature
7. Effects on heart and gut : Weaker than atropine
8. Marked mydriasis and cycloplegia
9. Dose: 0·3 to 0·6 mg ; in children 0·015 mg/kg.

- **Atropine/hyoscine should be used cautiously**
  1. Thyrotoxicosis
  2. Febrile patients
  3. Glaucoma
  4. Some cardiac patients: Mitral stenosis
  5. Elderly patients
  6. Tachycardiac patients.

- **Unwanted effects of anticholinergics**
  1. CNS toxicity
  2. Mydriasis and cycloplegia
  3. Rise of body temperature
  4. Tachycardia
  5. Drying of airway secretions
  6. Relaxation lower oesophageal sphincter.

GLYCOPYRROLATE

1. Synthetic quarternary ammonium compound with anticholinergic parasympatholytic activities
2. Strong vagal bloking effect on heart
3. Strong antisalivary effect
4. Antagonises the muscarinic effects like bradycardia, bronchospasm, intestinal motility

5. Can suppress gastric fluid volume and its acidity
6. Does not cross blood-brain barrier and placental barrier
7. Dose: 0.1 to 0.3 mg; in children 0.004 mg/kg im.

PROMETHAZINE

1. Phenothiazine group of drug
2. Sedative, antihistaminic
3. Mild atropine like activities
4. Depression of upper airway reflexes
5. Potentiates the effects of hypnotics, narcotics and anaesthetic drugs
6. Mild hypotensive effect
7. When used alone, it increases the sensitivity of pain (antanalgesic)
8. Reduces the incidence of nausea and vomiting
9. Marked local analgesic effect
10. Usual dose: 25 mg ; in children 1 mg/kg
11. May produce extrapyramidal side effects.

TRIMEPRAZINE

1. Phenothiazine derivative
2. Sedative, antihistaminic, antiemetic
3. Potentiates the effects of sedative and narcotics
4. Spasmolytic, antipruritic effect
5. Mild anticholinergic effects
6. Dose: 1.5 mg/kg, in children 1mg/kg im
   3 to 4 mg/kg orally.

PROCHLORPERAZINE

1. Phenothiazine derivative
2. Antiemetic effect is profound
3. Weak antihistaminic and spasmolytic effect
4. Does not produce hypotension
5. Dose: 12.5 mg, in children 2.5 to 5 mg orally.

METOCLOPRAMIDE

1. Derivative of procainamide
2. Potent antiemetic effect
3. Increases the rate of gastric emptying, relaxes pylorus, dilates the duodenal bulb, increases the peristalsis of gut
4. Inhibits vomiting centre, depresses cortex and reticular activating system

5. No significant effect on gastric secretion and its acidity
6. No significant effect on cardiovascular and respiratory system
7. Dose: 10 mg
8. Side-effects: Spasm of muscles, abdominal cramps
9. Caution: Atropine, opioids and antacids should be avoided during its use.

ONDANSETRON

1. It is a selective antagonist of the actions of 5-HT, serotonin at 5-HT_3 receptor
2. Highly effective for prevention and treatment of postoperative nausea/vomiting
3. Dose: 4 mg iv. Prophylactic use 16 mg orally
4. No serious side effects.

ROUTES OF ADMINISTRATION OF PREMEDICANT DRUGS

1. Parenteral
   a. Subcutaneous or intravascular route. It takes 45 to 60 minutes to get the optimum effect.
   b. Intravenous route: Immediate effect
      Advantages: Early effect
      More certain in effect
      Disadvantages : Pain, discomfort, infection, bleeding, broken needles, disliked by most patients particularly children.
2. Oral route
   In takes at least 90 minutes to get the optimum effect.
   Advantages: No pain, no discomfort, liked by all.
   Disadvantages: Effect is not certain, little risk of vomiting and aspiration, late and prolonged effect.

CHAPTER

3 Conduct of Anaesthesia

The conduct of general anaesthesia is broadly divided in various stages such as induction of anaesthesia, maintenance of anaesthesia and recovery from anaesthesia.

Before administering anaesthesia, one should check the availability of anaesthetic machine and all other equipment for ready use.

1. Anaesthetic machine and its accessories, gas cylinders, face masks
2. Laryngoscope
3. Set of endotracheal tubes
4. Endotracheal tube connection, catheter mount
5. Stilette, bougie
6. Magill forceps
7. Syringes, indwelling iv needles, infusion set
8. Airway tubes
9. Adhesive tape, bandage
10. Lignocaine spray 4%
11. Vaseline
12. Throat packs
13. Suction apparatus
14. Common drugs, anaesthetic drugs, drugs for resuscitation.

INDUCTION OF ANAESTHESIA

Inhalational Induction

Here the inhalational anaesthetic agents are administered through face mask. This is mostly indicated in:

1. Children, uncooperative patients
2. Upper or lower airway obstruction
3. Bronchopleural fistula
4. Where iv induction is risky.
   A. Procedure should be explained to the patient beforehand

B. Select the gas mixture
C. Initially 70% nitrous oxide in oxygen is given, then the anaesthesia is deepened by the gradual administration of volatile anaesthetic
D. Halothane 1 to 3% is being popularly used
E. Maintenance of anaesthesia can also be done
F. Other agents used:
   i. Cyclopropane
   ii. Enflurane.

Problems

1. Slow induction
2. Salivation
3. Airway obstruction, bronchospasm
4. Laryngospasm, hiccups
5. Wastage of anaesthetic vapours
6. Pollution.

Intravenous Induction

1. IV anaesthetic agents are used for induction
2. It avoids most complications of inhalational induction
3. It is mostly pleasant, can cause rapid induction
4. Can be used even in emergency surgery
5. Note:
   i. Drug should be selected carefully
   ii. Dose should be calculated properly
   iii. IV access is essential
   iv. Suitable aesptic skin preparation is needed
   v. IV entry must be confirmed with blood aspiration
   vi. Slow injection should be given
   vii. Avoid subcutaneous, intraarterial injection
   viii. Monitoring the effects of drug on CVS and respiratory system is important.
6. Common drugs:
   i. Thiopentone sodium 4 to 5 mg/kg
   ii. Methohexitone 1 to 1.5 mg/kg
   iii. Etomidate 0.3 mg/kg
   iv. Ketamine 2 mg/kg
   v. Propofol 2.5 mg/kg
   vi. Midazolam 0.2 mg/kg.
7. Complications:
   i. Regurgitation, vomiting, aspiration pneumonitis
   ii. Intraarterial injection of thiopentone
   iii. Perivenous, subcutaneous injection
   iv. Cardiovascular depression

v. Respiratory depression
vi. Histamine release
vii. Drug interaction
viii. Porphyria in susceptible individuals by barbiturates
ix. Pain on injection
x. Muscular movements
xi. Hiccup.

MAINTENANCE OF ANAESTHESIA

1. Inhalational agents
2. IV anaesthetic agents
3. IV opioid
4. The above agents can be used alone or in combination.

- Inhalational anaesthesia with spontaneous ventilation.
  1. $N_2O + O_2$ + Halothane/enflurane/trichloroethylene
  2. $N_2O + O_2$ + Cyclopropane.

Signs of Anaesthesia

The stages and planes of anaesthesia are most precise in patients breathing ether in air. These are **Guedel's classical signs**.

Stage 1: Analgesia.
It is the period from the beginning of anaesthesia until loss of consciousness. Respiration is irregular and of small volume. Pupils are small and reflexes are mostly intact.

Stage 2: Excitement:
The period from the loss of consciousness to the starting of rhythmic respiration. Respiration is of large volume and irregular. Eyelash reflexes are absent, but other reflexes are intact. Patient is struggling, restless.

Stage 3: Surgical anaesthesia
The period extends from the onset of regular rhythmic respiration upto respiratory paralysis. It includes 4 planes:
Plane 1: Starts from onset of regular respiration and ends when eyeball comes in rest on central position.
Plane 2: Starts from cessation of eyeball movement and ends when intercostal muscle paralysis starts.
Plane 3: Progressive intercostal paralysis till its completion. Only diphragmatic respiration continues.
Plane 4: Respiration ceases.

Stage 4: Medullary paralysis, apnoea, intense muscular relaxation. Pupils dilated and fixed. This is due to excessive anaesthesia. Patient is endangered.

Light general anaesthesia

1. Low blood concentration of anaesthetics
2. Stimulus of low intensity — anaesthesia, but high stimulus causes muscle movements
3. Respiration regular, smooth, pupil fixed but not dilated. Muscle relaxation is not adequate.

Deep general anaesthesia

1. High blood concentration of anaesthetics
2. Strong stimulus: No muscular movements
3. Respiration regular, pupils fixed, absent reflexes. Profound muscular relaxation.

Signs of lightening of anaesthesia

1. Lacrimation, tears
2. Eye movements, pupils reactive
3. Rate of respiration increases, irregular
4. Reflex muscle movements on stimulus
5. Pulse rate increases
6. Poor muscle relaxation
7. Sweating, swallowing, coughing
8. Awareness.

Signs of too deepening of anaesthesia

1. Overdose of anaesthetics
2. Pupils dilated widely
3. Respiration — shallow, irregular
4. Poor muslce tone
5. Collapsing
6. Cold skin
7. Operative field : Pale and dry.

Endotracheal Anaesthesia

Anaesthetic gases and vapours are administered through a tube inserted into the trachea through the nose or mouth or transtracheal route.

Objectives

1. To ensure ventilation/oxygenation
2. To ensure airway patency
3. To protect against pulmonary aspiration
4. To provide separate ventilation to each lung
5. To protect the airway from contamination
6. To facilitate tracheobronchial toilet.

Indications for Endotracheal Intubation

A. Head/neck surgery, major surgery, abdominal/thoracic surgery, long operation, operation in the oral cavity, difficult airway
B. Risk of aspiration, abnormal position: Prone position, needing profound muscle relaxation
C. Technique involving artificial ventilation, resuscitation of newborn, cardiac arrest, respiratory arrest.

Choice of endotracheal anaesthesia depends on:

1. Nature of surgery
2. Patient factors
3. Anaesthetic factors.

Advantages

1. Securing the airway, provides free, unobstructed patent airway
2. Patient's respiratory effect diminished
3. Ventilation can be controlled/assisted
4. Aspiration of lungs prevented
5. Muscle relaxants can be used
6. Stomach is not inflated
7. Resuscitation better performed
8. Anaesthetist and apparatus kept well away from surgical field
9. Tracheobronchial toilet possible
10. Anaesthesia: Certain in effect
11. Mostly safe.

Hazards of endotracheal intubation

1. Trauma during laryngoscopy and intubation
   tooth/lips/gum/larynx/epiglottis/pharynx/trachea
2. Reflex disturbances: Breath holding, apnoea, bronchospasm, laryngospasm, cardiac arrhythmia hypertension, tachycardia.
3. Obstruction: By mucus, blood, vomitus, foreign bodies, kinking/biting of the tube, bevel against the tracheal wall.
4. Position and type of the tube: Too long tube may enter in one bronchus, too short tube may come out during change of posture. Narrow tube may cause undue resistance.
5. Oesophageal intubation, gastric distension, barotrauma, pressure effect on tracheal mucosa, disconnection, accidental extubation, etc.
6. Postanaesthetic complications:
   i. Sore throat
   ii. Laryngitis/laryngeal ulceration
   iii. Tracheitis/tracheobronchitis
   iv. Oedema glottis

v. Infections: Pneumonia, aspiration pneumonitis, atelectasis, lung abscess.
vi. Nonspecific granuloma of larynx
vii. Surgical emphysema
viii. Vocal cord paralysis
ix. Dislocation of arytenoid cartilage
x. Tracheal stenosis.

Disadvantages of endotracheal anaesthesia

1. Needs adequate knowledge of anatomy and physiology. Needs experience and skill
2. Done in deeper plane of anaesthesia
3. Hazards of endotracheal intubation
4. Unconscious patient needs constant monitoring and special care
5. Pharmacological depression of body systems
6. Needs heavy and costly machine and equipment.

Nasotracheal intubation

Here the trachea is intubated through the nasal route.

Indications

1. Where orotracheal tube comes in the surgical field as in surgery inside the mouth
2. Where laryngoscopy is difficult
3. When endotracheal tube is to be kept for prolonged period.

Complications

Unique to nasotracheal intubation

1. Injury to nasal mucosa: Epistaxis
2. Dislodgement of adenoids
3. Eustachian tube obstruction
4. Infection: Maxillary sinusitis
5. Bacteremia
6. Gastric distension.

Advantages of nasotracheal intubation

1. Tube is secured, no chance of spontaneous extubation
2. Comfortable in awake patient
3. No chance of tube biting
4. Oral feeding possible
5. Good oral hygiene can be maintained.

Disadvantages

1. Needs small sized tube
2. Chance of infection more, bacteremia
3. Sinusitis
4. Epistaxis.

Technique of endotracheal intubation

1. Keep the head upon a head rest (about 10 cm high), supine position
2. Head elevation and neck flexion to bring the pharyngeal and laryngeal axis into line. Extension of head and cervicooccipital joint helps alignment of the oral axis with the other two
3. Open the mouth with your fingers
4. Laryngoscopic blade is introduced along the right margin of tongue. The tongue is displaced to the left by rotating the blade
5. The curved blade is advanced to the midline in the glossoepiglottic fold
6. The glottis is exposed by displacing the tongue and epiglottis anteroinferiorly
7. Glottis can be better viewed by applying backward, upward and rightward pressure on the thyroid cartilage. A good assistant is always helpful
8. The endotracheal tube should be introduced from the right side
9. The proximal margin of the cuff of the endotracheal tube should lie 3 to 4 cm beyond the vocal cords.

Caution

1. Sniffing position should be proper
2. Muscular relaxation should be adequate
3. Mouth should be opened widely
4. The blade should not go too far to the left
5. Epiglottis should be identified
6. Laryngoscopic blade should be introduced to proper depth
7. Assistant should give the proper pressure on thyroid cartilage.

Technique of blind nasotracheal intubation

1. Patient's head should be placed in exaggerated sniffing position
2. Lubricated endotracheal tube (0.5 mm smaller diameter tube than usual) is gently and slowly introduced along the nasal floor
3. If there is resistance, the tube is withdrawn a little and rotated to advance again
4. Listen the breath sounds at the proximal end of the endotracheal tube. One can use one hand to advance the tube and the other to palpate the thyrohyoid membrane
5. Position of the tube can be ascertained by the intensity of breath sounds, lateral bulging produced by the tip in the priform fosa, resistance to pass when it is in vallecula and no breath sounds, if it is in oesophagus
6. Tube should be adjusted by twisting the tip from side-to-side, extending or flexing the neck to move the tip anteroposteriorly
7. Tube inserted into the trachea can be judged by coughing, aphonia, and a normal capnograph tracing.

CHAPTER

4 Inhalational Anaesthetic Agents

CRITERIA FOR AN IDEAL INHALED ANAESTHETIC DRUGS

1. Causes rapid, smooth pleasant induction, amnesia and anaesthesia readily
2. Adequate muscular relaxation
3. Safe, potent, easily reversible. Absence of flammability, nonexplosive
4. Readily acceptable by the patient
5. Cheap, readily available
6. Easy to administer
7. Nontoxic, no side effects/complications
8. Safe for the vital organs like brain, heart, lungs, liver and kidneys.

Desirable Features

1. Low blood-gas solubility. Insolubility causes quicker induction of and recovery from anaesthesia
2. High potency and volatility
3. Resistance to biotransformation
4. Ether structure conveys cardiac stability
5. Halogenation reduces flammability
6. Compatible with adrenaline.

True Anaesthetic Gases

Nitrous oxide, Cyclopropane.

Their saturated vapour pressure are above ambient pressure and exist as liquid under pressure. Other agents are volatile liquids with SVP below ambient pressure and these need special calibrated vaporisers for their use.

Following Factors Increase the Rate of Anaesthetic Induction

1. Increased anaesthetic concentration
2. Increased fresh gas flow
3. Increased alveolar ventilation
4. Reduced cardiac output
5. Second gas effect: When nitrous oxide is administered with a volatile anaesthetic agent, the rapid uptake of nitrous oxide increases the effective minute ventilation during anaesthetic induction. Moreover the uptake of N_2O from the alveoli decreases the volume of gas remaining in the alveoli and increases the concentration of remaining gases within the alveoli and thus anaesthetic induction is enhanced. At the end of N_2O anaesthesia, the reverse effect occurs and *diffusion hypoxia* may develop. This can be prevented by supplemental oxygen therapy
6. Use of nonrebreathing anaesthetic circuit
7. Low blood gas solubility coefficient.

Following factors increase the rate of recovery from anaesthesia

1. Increased fresh gas flow
2. Increased alveolar ventilation
3. Use of nonrebreathing circuit
4. Low blood gas solubility
5. Low tissue gas solubility
6. Decreased anaesthetic duration.

Minimum alveolar concentration (MAC)

1. A standard measure of the potency of inhaled anaesthetics
2. It is the partial pressure of an inhaled anaesthetic at 1 atmosphere that prevents skeletal muscle movement in response to noxious stimuli in 50% cases
3. Factors increase MAC:
   (i) Young age (ii) hyperpyrexia (iii) alcoholics (iv) infants (v) hypernatraemia (vi) CNS stimulants like MAO inhibitors, tricyclic antidepressants, cocaine, amphetamine
4. Factors decrease MAC:
   (i) Hypothermia (ii) IV anaesthetics (iii) premedicants (iv) neonates (v) elderly (vi) pregnancy (vii) lithium (viii) CNS depressants like benzodiazepines, barbiturates, propofol, etc. (ix) Alpha 2 adrenergic agonists like clonidine.
5. MAC is not affected:
   (i) Sex (ii) duration of anaesthesia (iii) metabolism of anaesthetics (iv) hyper/hypokalaemia (v) thyroid dysfunction, etc.
6. MAC values for combinations of inhaled anaesthetics are additive.
7. Administration of nearly 1.3 MAC prevents skeletal muscle movement in almost all patients during surgery.
8. MAC of common inhaled anaesthetics :
   (i) Nitrous oxide 110 (ii) halothane 0.75 (iii) isoflurane 1.15 (iv) enflurane 1.68 (v) desflurane 7.25 (vi) sevoflurane 2.05 (vii) ether 1.92 (viii) trichlorethylene 0.2 (ix) methoxyflurane 0.16 Cyclopropane 9.2.
9. Agent with minimum MAC will be the most potent.

Nitrous Oxide

1. Nonirritant sweet smelling gas supplied in blue colour coded cylinders. It is stored as a liquid at room temperature
2. First anaesthetic use in 1844
3. Low blood gas solubility
4. Smooth and rapid induction of anaesthesia
5. Weak anaesthetic agent, cannot produce surgical anaesthesia when used alone
6. Excellent analgesia
7. Nitrous oxide 50% in oxygen is used for painless labour
8. Causes mild depression of cardiovascular system
9. May cause megaloblastic changes in bone Marrow in prolonged use
10. Prolonged N_2O anaesthesia may cause diffusion of the gas into the body cavities
11. At the end of anaesthesia high percentage of expired volume may consist of N_2O, so that onward diffusion of gas lowers alveolar partial pressure of oxygen (Diffusion hypoxia).

Entonox

1. A mixture of 50% nitrous oxide in oxygen.
2. Stored as a gas in cylinders whose body is blue and shoulder in white / blue quarters under a pressure of 1987 lb per sq. inch
3. Under pressure some parts of mixture may remain in gaseous phase at temperature and pressure at which N_2O is normally in liquid phase (Poynting effect)
4. It is stored horizontally at least above 10°C
5. It liquefies at–7°C
6. In cold climate there may be liquefaction and separation of the components. This may lead to uneven delivery of gases. To prevent this, the cylinder should be inverted several times to ensure adequate mixing. Rewarming in a water bath may also be helpful
7. Uses :
   a. For relief of pain in labour
   b. Burn dressing
   c. Management of chronic pain, cancer pain, etc.

Cyclopropane

1. Supplied in an orange cylinder as liquid at a pressure of 75 lb per sq. inch
2. Pleasant smell, nonirritant, potent. Not metabolised
3. Rapid induction of anaesthesia, potent anaesthetic gas
4. Sympathomimetic action. Arterial pressure is maintained and may increase
5. Can cause salivation, increased bronchial secretion and occassional bradycardia
6. Flammable, highly explosive
7. Expensive
8. Respiratoy depression, bronchospasm
9. Post-cyclopropane hypotension can occur (Cyclopropane shock)

10. Emergence delirium can occur
11. Contraindications
    i. Use of diathermy
    ii. Use of adrenaline
    iii. Asthmatic patients
    iv. Pheochromocytoma.

Diethyl ether

1. Colourless, pungent volatile liquid
2. Relatively nontoxic, safe, potent anaesthetic agent
3. Produces good muscular relaxation
4. Causes an increase in sympathoadrenal activity. Heart rate and blood pressure may increase a little
5. Excessive salivation, cough, laryngospasm due to irritant vapour
6. Bronchodilation
7. Raises blood sugar level
8. Raises CSF pressure
9. Reduces body temperature
10. Postoperative nausea/vomiting is common
11. Induction is slow, unpleasant stage of excitement
12. Explosion risk
13. Ether convulsion can occur
14. Passes through placental barrier
15. Cheap and can be used without sophisticated apparatus and compressed gas cylinders.

Trichloroethylene

1. Colourless liquid but coloured with waxoline blue dye for identification
2. Highly lipoid soluble, nonexplosive
3. Potent agent with considerable analgesic effects
4. Blood pressure is well-maintained but cardiac arrhythmias are common
5. Nonirritant to tracheobronchial tree
6. Prolonged induction and recovery rate
7. Muscular relaxation is not good
8. Reacts with soda lime, cannot be used in closed circuit
9. Cheap and mostly safe in adequately ventilated patient.

Halothane

1. A halogenated hydrocarbon (not an ether as it lacks etheric bond)
2. Heavy, colourless volatile liquid with sweet smell. Needs thymol for stability
3. Potent and nonflammable, nonexplosive
4. Well-tolerated, provides rapid and smooth induction of anaesthesia

5. Causes dose related fall in blood pressure, myocardial depression, sensitizes the heart to circulating catecholamines causing arrhythmias
6. Potentiates competitive muscle relaxants
7. Post-operative shivering can occur
8. May be associated with nonspecific hepatotoxic damage. It may be due to its breakdown products either causing damage directly or by immunological toxic response
9. Causes bronchodilation
10. May cause hypotension
11. Salivation and other secretions are not increased
12. May cause marked uterine relaxation leading to postpartum haemorrhage
13. May trigger malignant hyperpyrexia
14. Early postoperative restlessness is common
15. Special calibrated vaporiser is needed.

Methoxyflurane

1. Clear colourless, volatile anaesthetic with characteristic fruity smell
2. Potent anaesthetic and good analgesic
3. Slow induction due to its low volatility. Slow recovery
4. Excellent muscular relaxation
5. Diminishes cardiac output and causes hypotension
6. May cause cardiac arrhythmia
7. No sensitisation of myocardium to catecholamines
8. Uterine muscles inhibited
9. Causes high output renal failure due to fluoride ion containing metabolites. Extensive metabolism (more than 30%)
10. May cause postoperative headache, emergence delirium
11. May trigger malignant hyperpyrexia.

Enflurane

1. Potent volatile anaesthetic liquid
2. Clear, colourless, pleasant ethereal smell
3. Noninflammable, nonexplosive, noncorrosive
4. Produces rapid smooth induction of anaesthesia
5. Depresses cardiovascular and respiratory systems. Myocardial depression is dose dependent
6. Nonirritant to respiratory tract, does not increase tracheobronchial secretions
7. Good muscular relaxation, potentiates nondepolarising muscle relaxants
8. Relaxes uterine muscles
9. Depresses central nervous system, but in high concentration may cause epileptiform fits
10. Increases intracranial pressure and cerebral blood flow
11. Only about 2% undergoes biotransformation in liver and metabolites are excreted in urine as organic or inorganic fluorides. But nephrotoxicity is extremely rare

12. No major liver and kidney dysfunction
13. Little risk of teratogenesis.

Isoflurane

1. An isomer of enflurane, clear colourless volatile liquid. Noninflammable
2. Somewhat pungent and irritant, causes coughing
3. Induction and recovery are mostly rapid. Low blood gas coefficient
4. Causes profound respiratory depression
5. Produces hypotension, myocardial depression, reduction in cardiac output, fall in peripheral vascular resistance
6. Potentiates muscle relaxants
7. Uterine relaxation can occur
8. Decreases cerebral metabolism, and increases cerebral blood flow. Intracranial pressure may rise. Does not cause seizure activity
9. Only 0.2% is metabolised in liver, no significant toxic metabolites are formed.

Desflurane

1. Fluorinated ether, potent volatile anaesthetic liquid
2. Induction is rapid, recovery is prompt
3. Pungent, irritant to airway; breath holding and laryngospasm can occur
4. Dose dependent fall of blood pressure, fall in peripheral vascular resistance
5. Respiratory depression can occur
6. Metabolism of desflurane to trifluorocretic acid and inorganic fluoride is about 10 times less than that of isoflurane.

Sevoflurane

1. Fluorinated methyl ethyl ether
2. Potent anaesthetic
3. Nonirritant to airway
4. Respiratory and cardiovascular effects are mostly similar to those of halothane
5. Induction is rapid and recovery is prompt
6. Does not sensitise the myocardium to catecholamines
7. Instability in soda lime.

Fluroxene

1. Fluorine containing ether, potent volatile anaesthetic liquid
2. Good analgesic
3. Induction and recovery mostly smooth and rapid
4. May cause profound respiratory depression
5. May cause uterine relaxation

6. Cardiac output and blood pressure are well-maintained
7. Passes through placental barrier readily
8. Increases intracranial pressure.

Note:

Volatile anaesthetic agents are mostly divided in two groups:

1. Halogenated hydrocarbons: Halothane, trichlorethylene, chloroform
2. Ethers: Enflurane, isoflurane, methoxyflurane, diethyl ether, etc.

Some physical properties of inhalational anaesthetic agents are shown in Table 4.1.

Table 4.1. Showing some physical properties of inhalational anaesthetic agents

	Mol. Wt.	*Boiling Point*	*Vapour pressure at 20°C mm/Hg*	*Oil/Water solubility*	*Blood/gas solubility*	*MAC*
Diethyl ether	74	35°C	460	3.2	12	1.92
Trichlorethylene	131	87°C	60	400	9	0.17
Halothane	197	50°C	243	220	2.5	0.75
Methoxyflurane	165	105°C	23	400	13	0.16
Enflurane	184	56°C	180	120	1.9	1.68
Isoflurane	184	49°C	250	174	1.4	1.15
Cyclopropane	42	– 33°C	78	34.4	0.45	9.2
Nitrous oxide	44	– 88°C	680	3.2	0.47	105

- Hepatotoxic volatile anaesthetics : Halothane, chloroform
  Nephrotoxic volatile anaesthetics : Methoxyflurane, sevoflurane
  Epileptogenic: Enflurane
- Inflammable and can cause explosion : Diethyl ether, cyclopropane.

CHAPTER

5 Intravenous Anaesthetic Agents

Criteria for an Ideal Intravenous Anaesthetic Agent

1. It should provide smooth, pleasant and rapid induction of anaesthesia
2. Effect is evident in one arm brain circulation
3. Rapid recovery with little hangover systems
4. Negligible effect on cardiovascular and respiratory effects
5. Stable in solution, water solubility
6. Nonirritant even if injected extravascularly
7. No untoward reactions like nausea/vomiting, emergency delirium, hallucinations, tremor, allergy, laryngospasm and so on
8. Produce no accumulation.

Use of iv Anaesthetics

1. For induction of anaesthesia
2. For maintenance of anaesthesia
3. Often combined with other inhaled anaesthetics

Common iv Anaesthetics

1. Barbiturates Thiopentone
2. Eugenols: Propanidid
3. Steroids: Althesin, etanolone
4. Phencyclidine: Ketamine
5. Imidazole: Etomidate
6. Di-isopropyl phenol: Propofol
7. Benzodiazepine : Diazepam, midazolam
8. Opioids : Fentanyl, alfentanil, sufentanil.

Pharmacokinetics of iv Anaesthetics

Factors determining the anaesthetic effect:

1. Blood flow to the brain

2. Body pH and pKa of the drug
3. Lipoid solubility
4. Protein binding
5. Redistribution to other tissues
6. Metabolism
7. Excretion.

- Only nonionised fraction of the drug is able to penetrate the blood-brain barrier
- A protein bound drug is unable to cross into the brain
- All IV anaestheics are to some extent protein bound
- The degree of ionisation depends on body pH and pKa of the drug.

Following IV injection of drug, it will reach the site of action quickly in high concentration and produce rapid onset of action. Vital centres in medulla, vasomotor and respiratory centres are more likely to affect.

Distribution of drug depends on lipoid solubility and blood flow to body tissues. As the drugs are all highly fat-soluble and the heart and viscera belong to vessel rich groups, drug will rapidly enter the brain and produce unconsciousness.

Well-perfused organs will subsequenty be depleted of the drug by redistribution to lean tissues (muscle, bone). The blood supply of fat is so poor that it plays little role in the initial distribution of the drug which results in early awakening.

Though this is the principal mechanism of recovery after a single dose of thiopentone, hepatic metabolism also plays some role.

With nonbarbiturates (etomidate, propofol) redistribution plays a prominent role in recovery, but metabolism is also of greater importance. The rapidity of metabolism makes them suitable for continuous infusion and still with good recovery.

Biotransformation of iv Anaesthetics

1. Barbiturates: Slowly metabolised, stored in muscles and fat for hours, produces prolonged mild sedation.
2. Propanidid, alphaxalone and etomidate: Removed from circulation mainly by biotransformation, more rapid in case of propanidid.
3. Ketamine and diazepam: Converted to metabolites which themselves have sedative action, may give prolonged duration of action.
4. Diazepam: Undergoes enterohepatic recirculation—produces prolonged action.
5. Midazolam does not have these characteristics of diazepam, thus gives it a shorter duration of action.

BARBITURATES

Mechanism of action:

- Depresses reticular activating system
- Decreases rate of dissociation of GABA from its receptors
- Selectively decreases transmission of impulses through sympathetic ganglion
- No specific antidote for overdose.

Thiopentone

1. Most commonly used iv induction agent
2. Rapidly acting thiobarbiturate
3. Dose: 3 to 5 mg/kg (2.5% solution)
4. Induction is rapid, smooth and quiet
5. Metabolism in liver is slow (10–15% per hour)
6. Effects:
   - Sedation, hypnosis, anaesthesia
   - Depression of respiration
   - Peripheral vasodilation
   - Direct myocardial depression
   - Cumulative effect
   - Acute tolerance
   - Antanalgesic.
7. Complications:
   - Laryngospasm, bronchospasm
   - Hypotension
   - Intraarterial injection
   - Extravascular injection
   - Histamine release, anaphylactic reaction.
8. Contraindications:
   - Porphyria
   - Airway obstruction
   - Fixed cardiac output disorders
   - Severe shock
   - Adrenocortical insufficiency
   - Nonavailability of resuscitative equipment.

Methohexitone

1. Oxybarbiturate
2. Dose: 1 to 1.5 mg/kg (1% solution)
3. White powder, water-soluble
4. Duration of action: 2 to 3 min
5. Recovery: Smooth, rapid
6. Effects:
   - Sedative, hypnotic, anaesthetic
   - Circulatory depression
   - Respiratory depression
   - Abnormal muscle movements
   - Antanalgesia
7. Indications:
   i. Inducing agent
   ii. Sole anaesthetic agent in short procedures, in day-care surgery.

8. Contraindications:
   Epilepsy
   Porphyria
   Hypersensitive patients.

Propanidid

1. Oily liquid derived from oil of cloves
2. Insoluble in water, solubilised in cremophor EL
3. Ultrashort acting with rapid recovery within 5 to 8 min
4. Dose: 6 to 7 mg/kg iv
5. Initial hyperventilation, then marked hypoventilation.
6. Involuntary muscle movements, coughing
7. Mild rise of pulse rate, fall of blood pressure
8. Detoxicated by plasma cholinesterase
   Action of suxamethonium prolonged
9. Uses: Inducing agent
   Sole anaesthetic agent for short surgical procedures, outpatient anaesthesia
10. Anaphylactic reaction: Common
11. Not used now a days.

Althesin

1. A mixture of alphaxalone 9 mg/ml and alphadolone 3 mg/ml
2. Steroid anaesthetic with no hormonal effect
3. Dose: 0.05 to 0.1 ml/kg
4. Rapid induction, recovery in 5 to 10 min
5. Painless injection, no hangover effect
6. Mild hypotension and respiratory depression
7. Postoperative nausea/vomiting, excitement and euphoria can occur
8. Anaphylactic reaction: Common
9. Uses: Inducing agent
   Sole anaesthetic agent for short procedures
10. Contraindications:
    Porphyria
    Liver diseases
11. Not used now a days.

Etanolone (Pregnanolone)

1. Naturally occurring metabolite of progesterone
   — latest steroid anaesthetic
2. Insoluble in water 0.4% emulsion in 10% intralipid
3. 3 times more potent then propofol

4. Less pain during injection
5. Dose: 0.6 mg/kg iv
6. Rapid induction, rapid recovery
7. Dose-related reduction of blood pressure
8. Mild respiratory depression
9. Postoperative nausea/vomiting—less.

Ketamine

1. Dissociative anaesthesia: Intense analgesia with only superficial sleep. EEG evidence of dissociation between thalamus and limbic system.
2. Dose:
   i. 2 mg/kg iv—effect within 60 sec and lasts for 5 to 8 min
   ii. 5 to 10 mg/kg im—effective in 3 min and lasts for 20 to 30 min
   iii. 50 µg/kg/min in continuous infusion.
3. No cardiorespiratory depression, heart rate and blood pressure may increase
4. Side effects:
   Hypertonus
   Salivation
   Nausea/vomiting
   Emergence delirium
   Hallucinations.
5. Indications:
   Inducing agent
   Sole anaesthetic agent.
6. Contraindications:
   Hypertension
   Chronic alcoholism
   History of cerebrovascular accident
   Raised intracranial pressure
   Raised intraocular pressure
   Recent penetrating eye injury
   Psychotic patients
   Thyroxine treatment
   Severe cardiac disorders.

Etomidate

1. Carboxylated imidazole derivative
2. Dose: 0.2 to 0.3 mg/kg iv
3. Rapid iv induction within 30 sec
4. Rapid recovery within 6 to 8 min
5. Broken down by hydrolysis by esterases in liver and plasma
6. Maintains cardiovascular stability

7. No histamine release
8. Disadvantages:
   Pain during injection
   Involuntary muscle movements
   Nausea/vomiting
   Adrenocortical suppression.

Propofol

1. Insoluble in water, presented in a lipid emulsion
2. Dose: 2 to 2.5 mg/kg iv
3. Rapid smooth induction within 30 sec
4. Recovery within 4 to 8 min
5. No hangover effect
6. Can be used in infusion 0.1 to 0.2 mg/kg/min
7. Heart rate and blood pressure—decreased
8. Uses: iv sedation
   iv inducing agent
   iv maintenance of anaesthesia.
9. Disadvantages:
   Pain at the site of injection
   Cardiorespiratory depression
   Allergic reaction
   May cause convulsion.
10. Contraindications:
    Epilepsy
    Hypersensitive patients.
11. Safe in porphyria.

Benzodiazepines

- Produce sedation and hypnosis by affecting polysynaptic pathways in brain (midbrain reticular formation) and spinal cord
- Causes emotional modification by depressing excitability of the limbic system
- Act at specific receptors in CNS. This receptor stimulates the activity of inhibiting neurotransmitter GABA.

Main actions:

Anxiolysis
Amnesia
Sedation/hypnosis
Anticonvulsive effect
Muscle relaxation

No analgesic effect
Minimum depression of ventilation and CVS. CNS effects antagonised by flumazenil

Uses in anaesthesia

Night sedation
Premedication
iv sedation
Induction of anaesthesia.

- Most of the benzodiazepines are metabolised to active compounds with long elimination half lives as for desmethyl diazepam.

Diazepam

1. Insoluble in water, formulating in emulsifying agent
2. Usual inducing dose: 0.3 to 0.5 mg/kg
3. Onset of sleep–Slow, recovery prolonged
4. Little effect on cardiovascular system
5. Mild muscular relaxation
6. No analgesic effect
7. Adverse effects:
   Persistent drowsiness, occasionally muscle weakness, headache, vertigo, pain on injection, nausea/vomiting.

Midazolam

1. Water-soluble benzodiazepine
2. Dose: 0.15 to 0.3 mg/kg iv
3. Rapid smooth induction within 80 sec
4. Recovery is rapid within 6 to 8 min
5. Maintains cardiovascular stability
6. No hangover effect
7. No pain during iv injection
8. Other effects:
   Hypnosis, anxiolysis, muscle relaxation, anticonvulsant activity.

- Benzodiazepine antagonist
  Flumazenil: Specific antagonist
  Dose: 0.2 mg/kg every 60 sec upto 1 mg. Duration of actions is about 20 min, so resedation may occur.

Opioids

1. Exogenous substances that bind specifically to opioid receptors and produce some agonist responses

2. Analgesia mediated through a complex interaction of mu, delta and kappa receptors which are normally activated by endogenous endorphins
3. Affinity of most opioid agonists for receptors parallels analgesic potency
4. Binding of opioids to specific receptors results of all neurotransmissions concerned with analgesia within CNS
5. Fentanyl, sufentanil and alfentanil may be used for induction and/or maintenance of anaesthesia
6. Clinical uses:
   Provision of analgesia in pre and postoperative period
   Induction and/or maintenance of anaesthesia
   Inhibition of sympathetic reflex activity
   Supplementation of inhaled anaesthetics.

Fentanyl

1. Neuroleptanalgesia when used in combination with droperidol
2. Analgesic potency is 100 times more than morphine
3. Onset of analgesia usually rapid within 1 to 2 min
4. Duration of effect: About 30 min
5. Use: Anaesthesia for short surgical procedures
6. Dose related respiratory depression
7. Little effect on cardiovascular system
8. Nausea/vomiting: Common
9. Wooden chest effect. It can be overcome by use of muscle relaxants
10. Histamine release may occur
11. Dose: 5 to 15 μg/kg (Ventilation should be controlled with muscle relaxants).

Alfentanil

1. Derivative of fentanyl
2. Onset of action fast, within 1 arm-brain circulation time
3. Short duration of action
4. Low potential for postoperative respiratory depression
5. Can be used as continuous infusion
6. Little effect on cardiovascular system
7. Can produce muscular rigidity like fentanyl
8. No significant cumulative effect
9. Prompt postoperative awakening with minimal depression of ventilation.

Sufentanil

1. Most potent of the newer opioids
2. High lipoid solubility
3. Prompt onset of action

4. Brief duration of action due to subsequent redistribution to inactive tissue sites
5. Cumulative effect
6. May be used for analgesic component of balanced anaesthesia
7. Excellent haemodynamic stability
8. High doses 5 to 20 μg/kg is used in cardiac surgery.

Remifentanil

1. A recent synthetic opioid with strong affinity to mu opioid receptors
2. Metabolised by esterases in blood and other tissues
3. Antagonised by naloxone
4. It has rapid onset of action, a small volume of distribution and clearance and terminal half life 8 to 20 min
5. It is 10 to 20 times more potent than alfentanil
6. Little change of blood pressure
7. It can cause muscle rigidity.

- **Opioid antagonist**

1. Naloxone is specific opioid antagonist reversing both desirable (analgesia) and nondesirable (respiratory depression) effects
2. High doses can cause abrupt awakening with intense pain and activation of sympathetic stimulation causing hypertension, tachycardia, dysrhythmia
3. Duration of effect is about 30 min. So continuous infusion may be helpful.

Hypersensitivity Reactions of iv Anaesthetics

1. Features: Erythema, oedema, vasodilation, hypotension, bronchospasm
2. May occur following thiopentone, methohexitone, thiamylal, propanidid, althesin, etc.
3. Common in cremophor EL containing drugs
4. Common in patients with asthma, hay fever, eczema, with history of food or drug allergy, previous same anaesthetics
5. Avoid use of drugs likely to cause reactions particularly in those considered to be at risk.

Continuous Infusion of iv Anaesthetics

Criteria:

1. Onset of sleep should be within one circulation time
2. Predictable and short duration of action
3. Rapid inactivation by plasma or hepatic metabolism
4. Noncumulative
5. Inactive
6. Nontoxic metabolites
7. Absence of toxicity/allergenicity to solvents
8. Minimum cardiovascular effects.

Note:

- Thiopentone : Cumulative, prolonged recovery
- Etomidate : Adrenocortical suppression
- Methohexitone : Ketamine, propofol and midazolam seem to be more satisfactory for continuous infusion
- The technique of iv infusion should be guided by individual sensitivity, type of surgery and presence of adjunctive drugs
- It should be adopted when proper monitoring devices and reliable delivery systems are available
- A clear understanding regarding drug kinetics and drug effect is essential.

Total Intravenous Anaesthesia

1. It implies the avoidance of inhalational anaesthetics and its replacement with only iv anaesthetics
2. Methohexitone and thiopentone were used to provide total iv anaesthesia, but these agents usually prolong recovery
3. Propanidid is no longer used due to its adverse reactions to stabilising agent cremophor EL.
4. Etomidate is not used as it causes adrenocortical suppression
5. Ketamine has gained some popularity, but may lead to dysphoria in recovery phase. But it is satisfactory when combined with midazolam
6. Benzodiazepines appear to act in synergism with opioids. Midazolam can be used with fentanyl or alfentanil. Delayed recovery from midazolam can be antagonised with flumazenil
7. Propofol seems to have satisfactory pharmacokinetic profile in this respect and is most satisfactory to provide iv anaesthesia
8. The essential points to note that there should be improved methods of control of concentration of drugs and the drug administration must be titrated to achieve the desired effect for the individual patient and the degree of surgical stimulation.

CHAPTER

6 Local Anaesthetic Drugs

- The local anaesthetic drugs are usually in solution as the hydrochloride salts
- These are weak bases and exist in equilibrium between lipid-soluble anionic uncharged form and water-soluble cationic form.
- The local anaesthetic drug penetrates the nerve fibre following injection close to the nerve and the cationic form blocks the sodium channels to prevent sodium influx. This causes blocking of membrane depolarisation. The block is mostly dependent on concentration of the local anaesthetic. Thus when the concentration falls below a critical minimum level, the block gradually terminates. This the local anaesthetics are able to cause temporary block of nerve conduction when applied locally close to the nerve
- All local anaesthetic drugs have three essential functional components, an aromatic group joined to an amine group by an ester or amide linkage. Thus the local anaesthetics are divided into two groups:
  1. Amides: Lignocaine, mepivacaine, bupivacaine, etiodocaine, prilocaine, ropivacaine, etc.
  2. Esters: Procaine, chloroprocaine, tetracaine.
- Local anaesthetics can also be classified on their potency and duration of action.
  1. Weak potency and short duration of action: Procaine, chloroprocaine
  2. Intermediate potency and medium duration of action: Lignocaine, mepivacaine, prilocaine.
  3. High potency and long duration of action: Tetracaine, bupivacaine, etidocaine, ropivacaine.

  Criteria for a good local anaesthetic :
  1. Rapid onset of action
  2. Adequate duration of action
  3. Complete recovery
  4. Safe
  5. Devoid of toxic and allergic reactions.
- Potency depends on
  1. Lipoid solubility
  2. Protein binding
  3. State of ionisation

- Addition of adrenaline 1 : 200000, 5µg/ml to the local anaesthetic solution prolongs the analgesic effect by delaying the absorption of the drug and increases the quality of block
- Contraindications for use adrenaline containing anaesthetic solution:
  1. Unstable angina pectoris
  2. Cardiac dysrhythmias
  3. iv regional anaesthesia
  4. Uteroplacental insufficiency
  5. Site that lacks collateral blood flow (digits, penis.
- Safe maximum single dose of some local anaesthetics in adults in shown in Table 6.1.
- Physiochemical properties of some local anaesthetics are shown in Table 6.2

SYSTEMIC TOXIC REACTIONS OF LOCAL ANAESTHETICS

Factors Responsible

1. Type of local anaesthetic
2. Concentration of the drug
3. Total quantity of the drug
4. Inadvertent intravascular injection
5. Rate of absorption
6. Injection in inflamed site
7. Vascularity of the site
8. Physical status of the patient, nutrition, age, body weight
9. Hypersensitivity of the drug
10. Presence of adrenaline
11. Liver diseases
12. Concomitant use of anticholinesterase drugs may increase the toxicity of ester local anaesthetic.

Manifestations

i. Central nervous system stimulation: Circumoral numbness, excitement, restlessness, tinnitus, vertigo, headache, tremor, muscle twitching, convulsion

ii. Followed by CNS depression: Unconsciousness, cardiorespiratory collapse

iii. Cardiovascular system
Bradycardia, extreme pallor, sweating, hypotension.
Cocaine causes tachycardia.

iv. Allergic reactions
Urticaria, angioneurotic oedema, bronchospasm

v. Other effects:
Palpitations, tachycardia, tachypnoea, hypertension. These are mostly due to adrenaline containing anaesthesit solution.

Management

Prevention

1. Dose should be accurate.
2. Adequate skill of the anaesthetist needed
3. Proper premedication and assessment
4. Resuscitative drugs and equipment should be available
5. Avoid hyperventilation as it can elevate seizure threshold by lowering $PaCO_2$.

Treatment

1. Head down tilt
2. Patent airway, endotracheal intubation
3. IPPV with 100% oxygen
4. iv fluids
5. Vasopressors
6. Convulsion should be treated with diazepam, curare, or thiopentone sodium.

- The minimum *concentration* of the local anaesthetic that will reliably produce 'effective block', should be used to reduce the risk of toxicity. The smallest *volume* to produce effective anaesthesia should also be used. The extent of block depends on the volume of the anaesthetic solution.
- Nerve fibres vary in diameter and the large nerves need higher concentration to be anaesthetised than the smaller fibres.
- Type and function of different nerve fibres:
  - Aα motor function, proprioception
  - β touch, pressure sensation
  - γ motor to spindles, muscle tone
  - δ pain, touch, temperature sensation
  - B preganglionic autonomic axons
  - C postganglionic autonomic, pain sensation.
- A fibres vary in diameter 2 to 20 μm. Aδ is thinnest. B fibres are myelinated with diameter less than 3μm. C fibres are nonmyelinated with diameter 0.5 to 1 μm

Cocaine

1. Extracted from the leaves of coca tree
2. Stimulates CNS: Restlessness, excitement, euphoria, tachycardia, tachypnoea, hypertension
3. Sudden cardiac arrest or profound cardiovascular collapse can occur
4. Causes vasoconstriction
5. Mucosal surface anaesthesia in eye: Mydriasis, blanching of conjunctiva
6. Intranasal cocaine: Vasoconstriction.
7. 4 to 25% solution is used. Not more than 200 mg should be administered.
8. Acute intoxication can occur
9. Toxicity: Convulsion, dysrhythmia, myocardial ischaemia, coma, shock, cardiac arrest.
10. Not much used now a days.

Procaine

1. Widely used local anaesthetic agent.
2. Rapid onset and medium duration of action
3. Action may last for 60 to 90 min when used with adrenaline
4. Dose: Infiltration 0.25 to 1%
   Nerve block 1 to 2 %
5. Maximum dose: 500 to 1000 mg
6. Toxic reaction: Convulsion, cardiovascular collapse
7. Not much used now a days.

Lignocaine

1. Amide local anaesthetic, highly lipid-soluble
2. Commonly used local anaesthetic
3. Available in a wide range of concentration from 0.5 to 4%
4. Total dose: 500 to 750 mg
5. Dose: For infiltration 0.5 to 1%
   For nerve block 1 to 1.5%
   For spinal block 4% (heavy)
   For epidural block 1.5 to 2%
   For corneal analgesia 4%
6. Lignocaine has little effect on blood vessels
7. Adrenaline (in 250000) may be added to prolong the effect
8. Other uses: Antiarrhythmic drug, in management of neonatal convulsion, parenteral analgesic
9. Does not cross the placental barrier.

Prilocaine

1. More potent and less toxic and more widespread than lignocaine. Wider margin of safety
2. Duration of analgesia 2.5 to 3 hours
3. Uses: For infiltration 0.5%
   For extremity blocks 2 to 3%
   For caudal/epidural block 3 to 4%.
4. Safe maximum dose 400 mg; 600 mg with adrenaline
5. Can cause methaemoglobinaemia which can be reversed by methylene blue
6. Eutectic mixture of local anaesthetic (**EMLA**) is a combination of equal amounts of crystalline 2.5% prilocaine and 2.5% lignocaine. It becomes an oil and it is then emulsified with water to form EMLA cream. It is in the ionised and readily diffusible form.

Mepivacaine

1. Potent local anaesthetic
2. Onset of action is rapid, duration ranges from 2 to 3 hours
3. Concentration may vary 0.5 to 2%

4. Uses: For infiltration 0.5 to 1%
   For nerve blocks 1 to 1.5%
   For spinal block 4% heavy
   For epidural block 1.5 to 2%
5. Side effects:
   Mild tachycardia, hypotension.
6. Can pass through placental barrier.

Bupivacaine

1. Potent local anaesthetic agent of the amide group; 4 times more potent than lignocaine.
2. Slower onset of action than that of lignocaine
3. Increased lipid solubility and protein binding compared to lignocaine leading to increased duration of action (3 to 12 hours)
4. Low placental transfer
5. Produces more sensory than motor block
6. Adrenaline may be added to prolong the action and improve the block
7. Not more than 2 mg/kg should be used
8. Concentration is usually 0.5%, but 0.25 and 0.75% solution are also available
9. Used in nerve blocks, spinal/epidural block.

Ropivacaine

1. Potency and duration are mostly similar, but the onset time is shorter than bupivacaine
2. Cardiovascular toxicity is less, causes vasoconstriction
3. Used in infiltration analgesia, peripheral nerve block and epidural analgesia
4. Available in solutions of 0.5 to 2
5. Maximum safe dose 150 to 200 mg.

Table 6.1: Recommended safe maximum single dose of some local anaesthetics in adults

Anaesthetic	*mg/kg plain*	*mg/kg with adrenaline*
Lignocaine	4	7
Mepivacaine	4	7
Bupivacaine	2.5	3.2
Prilocaine	7	8.5

Table 6.2: Physiochemical properties of some local anaesthetic agents. (After Yao and Artusio: Anaesthesiology)

Anaesthetic	*pKa*	*Protein binding %*
Procaine	8.9	5.8
Lignocaine	7.9	64.3
Mepivacaine	7.6	77.5
Bupivacaine	8.1	95.6

Minimum Blocking Concentration (Cm)

It is the minimum concentration of local anaesthetic that will block impulse conduction within a specified time. It is important clinically for only drug concentration greater than Cm anaesthetise the nerve. As the potency of the drug varies greatly, each anaesthetic agent has a unique Cm.

A thick axon has a greater Cm than a thin one. The Cm of alpha motor fibre is roughly twice that of delta sensory fibres.

If motor block is intended in addition to sensory block, a more concentrated local anaesthetic solution must be needed.

CHAPTER

7 Muscle Relaxants

Muscle relaxants or neuromuscular blocking agents act by blocking the specific nicotinic receptor sites in the neuromuscular junction or motor end plate of striated muscle. Normally acetylcholine released by nerve impulses diffuses across the junctional gap and stimulates muscle fibres by acting on specific nicotinic receptor sites on the postjunctional membrane of the motor end plate.

These receptors are related to an ion channel through which sodium and calcium ions flow and depolarise the membrane. The action of acetylcholine is short as it is rapidly hydrolysed by acetylcholinesterase. There are also prejunctional nicotinic receptors, stimulation of these receptors hasten the mobilisation of stored acetylcholine and thus increases the transmitter output during high frequencies of stimulation.

Neuromuscular blocking agents act by blocking choline receptors at both sites. These agents may also act as ion-channel blockers.

Muscle relaxants are traditionally distinguished into two groups:

1. Depolarising (noncompetitive) agents—Suxamethonium
2. Nondepolarising (competitive) acetylcholine antagonists—Tubocurarine, gallamine, pancuronium, atracurium, vecuronium, etc. These may be further subdivided according to their duration of action.
    a. Long-acting: Tubocurarine, gallamine, metocurine, pancuronium, doxacurium, pipecuronium
    b. Intermediate-acting: Atracurium, vecuronium, rocuronium
    c. Short-acting: Mivacurium.

- Depolarising muscle relaxants act by holding the ion channels open and preventing repolarisations. These are acetylcholine agonists.

Characteristics of Depolarising Block

1. Muscle paralysis is always preceded by strong stimulation of the motor end plates. This causes initial *fasciculations* of the muscles all over the body
2. Anticholinesterase drugs may make the block profound
3. Absence of tetanic fade during partial block

4. Effects are decreased by nondepolarising relaxants
5. An absence of posttetanic facilitation
6. Following repeated administration of depolarising muscle relaxant over a prolonged period, the characteristics of depolarisation block change from a depolarising to a non-depolarising nature and it leads to development of *dual block* (desensitising block or phase II block).

- Nondepolarising neuromuscular blocking drugs compete with acetylcholine for the receptors at the motor end plate, but do not have any initial stimulating action on the motor end plate. This is often called competitive neuromuscular blocking agent.

Characteristics of Nondepolarising Block

1. Noninitial muscular fasciculation
2. Block is antagonised by anticholinesterases
3. Presence of fade of successive stimuli on both tetanic (fast) and twitch (slow) nerve stimulation
4. Following a train of tetanic stimuli, single shock leads to a temporary increase in the strength of muscle twitch (*posttetanic facilitation*)
5. Paralysis increased by nondepolarising agents.

Uses of muscle relaxants in clinical anaesthesia:

1. For smooth endotracheal intubation
2. For adequate muscle relaxation in surgical field
3. For smooth artificial ventilation
4. To reduce the amount of inhalational anaesthetics
5. To overcome laryngospasm, convulsion, spasticity, rigidity, etc.

Types of neuromuscular block:

1. Prevention of acetylcholine synthesis: Hemicholinium
2. Prevention of acetylcholine release: Botulinum toxin, high magnesium concentration
3. Depletion of acetylcholine stores:
   tetanus toxin, β-bungarotoxins.
4. Block of acetylcholine receptors:
   a. Nondepolarising muscle relaxants : Tubocurarine, gallamine, pancuronium, etc.
   b. Depolarising muscle relaxants : Suxamethonium.
5. Block of cholinesterase:
   a. Anticholinesterases: Neostigmine
   b. Organophosphorus poisoning.

Sequence of effects following motor nerve stimulation

Nerve action potential
↓
Depolarisation of nerve terminal
↓
Release of acetylcholine
↓

Diffusion of acetylcholine through synaptic cleft
↓
Acetylcholine activation receptors in postjunctional membrane
↓
Changes in permeability leading to sodium flux into and potassium flux out of cell
↓
Depolarisation of postjunctional membrane
↓
Muscle action potential
↓
Muscle fibre contraction

Factors altering the response to muscle relaxants

1. Age
   Newborns are generally resistant to depolarising blocking agent and more sensitive to nondepolarisers. Use of depolarising drug may cause dual or phase II block in infants
2. General anaesthetic agents can potentiate the action of nondepolarisers
3. Neuromuscular diseases
   i. Patients suffering from myasthenia gravis are much sensitive to nondepolarisers and may show resistance to depolarisers. Rapid phase II block can also occur
   ii. In some myopathies (myotonia dystrophica, myotonia congenita) generalised muscle spasm may occur following use of depolarisers
   iii. Muscular dystrophy, congenital myopathies, familial periodic paralysis: Response to muscle relaxants unpredictable. It is better to avoid them
   iv. Amyotrophic lateral sclerosis, poliomyelitis, syringomyelia: Exaggerated response to nondepolarisers
   v. Thyrotoxic myopathy: Decrease response to succinylcholine due to increased level of pseudocholinesterase in hyperthyroidism
   vi. Diseases producing hypokalaemia potentiate the action of nondepolarisers
   vii. Malignant hyperthermia is a dangerous condition following use of succinylcholine.
4. Electrolyte imbalance
   i. Hyponatraemia, hypokalaemia : Increased sensitivity to muscle relaxants
   ii. Hyperkalaemia: Decreased sensitivity to nondepolarising agent
   iii. Hypocalcaemia, hypomagnesaemia prolong the action of muscle relaxants.
5. Temperature:
   Hypothermia potentiates the action of neuromuscular blocking agents.
   Intensity of block is decreased in cases of hyperthermia.
6. Hypo/hyperventilation can also alter the response of muscle relaxants.

Curare (d-tubocurarine)

1. Produces profound muscle relaxation due to nondepolarising myoneural block
2. Airway reflexes depressed
3. Bronchospasm may occur due to histamine release.

4. Mild hypotension, bradycardia
5. Passes through placental barrier
6. Little effect on liver and kidney
7. General anaesthetics potentiate the curare effect
8. Actions are antagonised by use of anticholinesterase drugs like neostigmine
9. Dose: 15 to 30 mg iv for endotracheal intubation. It takes 2 to 3 min for full effect, duration of effect is usually about 30 min
10. Uses:
    i. For smooth endotracheal intubation
    ii. To produce muscle relaxation
    iii. For better controlled ventilation
    iv. To make bronchoscopy, oesophagoscopy and other endoscopies easier
    v. As an aid, in treatment of tetanus, myositis, strychnine poisoning, spasticity, rigidity, etc.

Gallamine Triethiodide

1. Synthetic nondepolarising agent, produces profound muscular relaxation
2. Dose 2 mg/kg iv, action is rapid within 2 to 3 min, lasts for about 20 min
3. Action antagonised by anticholinesterases
4. Atropine like effect (vagal blocking) on cardiac postganglionic nerve endings causing tachycardia
5. Minimum histamine release, no ganglion blocking effect
6. Passes through placental barrier
7. General anaesthetics potentiate its action
8. No direct effect on liver and kidney.

Alcuronium

1. Nondepolarising potent muscle relaxant
2. Muscle paralysis occurs in 3 to 4 min and lasts or about 20 min
3. Minimum histamine release
4. Mild ganglion blocking effect, mild hypotension
5. No sympathetic stimulation, no vagolytic effects
6. It is 40% protein bound and undergoes negligible metabolism.

Pancuronium

1. Bisquarternary aminosteroid with no hormonal effects
2. Nondepolarising potent muscle relaxantes
3. Acts within 2 to 3 min and lasts for about 30 min
4. Usual dose: 0.1 mg/kg
5. Mild sympathomimetic and vagolytic effect, mild increase in heart rate and blood pressure
6. Less histamine release, no ganglion blocking effect

7. No cumulative effect
8. It is 34% bound to albumin, 53% to globulin and only 13% unbound
9. Broken down in liver, effect prolonged in cases with liver failure.

Vecuronium

1. Potent nondepolarising muscle relaxant
2. Dose: 0.1 mg/kg
3. Muscle paralysis within 1.5 to 2 min. and lasts for about 15 min
4. General anaesthetics potentiate its action
5. Does not cause histamine release, neither ganglion blocking nor vagal bloking effect, no sympathomimetic effect
6. Pulse rate and blood pressure remain unaltered
7. Metabolism is mostly dependent on liver. It should be avoided in severe liver disease
8. Cumulation may occur with repeated doses
9. May show spontaneous recovery, but antagonism of the block with anticholinesterase can be achieved.

Atracurium

1. Bisquarternary ammonium compound, potent nondepolarising muscle relaxant
2. Dose: 0.6 mg/kg
3. Good intubating condition within 90 sec
4. Action lasts for 20 to 30 min
5. May release histamine
6. Devoid of sympathetic stimulation, vagolytic and ganglion blocking effects
7. It is self-destroyed by Hofmann reaction at a pH of about 7.4 and at 37°C, but ester hydrolysis in liver and plasma is the main metabolic pathway
8. Atracurium shows excellent recovery spontaneously, no need of specific antidote
9. Relaxant of choice in patients with severe liver and kidney disease.

Mivacurium

1. Synthetic nondepolarising muscle relaxant with short duration of action
2. Dose: 0.15 to 0.25 mg/kg
3. Profound muscle relaxation within 3 min and lasts for about 15 to 20 min
4. Also used in continuous infusion in a dose of 5 to 6 μg/kg/min
5. Hydrolysed by plasma cholinesterase
6. Cardiovascular side effects minimum
7. Histamine release insignificant.

Pipecuronium

1. Long-acting nondepolarising muscle relaxant
2. Intubation dose: 0.07 to 0.085 mg/kg iv

3. Satisfactory intubating condition within 2.5 to 3 min
4. Duration of action ranges from 45 to 120 min
5. No ganglion blocking and vagolytic effects
6. No histamine release
7. Cardiovascular side effects minimal
8. Effect is antagonised by neostigmine.

Succinylcholine

1. Potent depolarising muscle relaxant, ultrashort acting
2. Dose: 1 mg/kg iv ; 50 to 75 mg on average
3. Satisfactory intubating condition with 60 sec and the effect lasts fo 3 to 4 min
4. Causes initial generalised muscular fasciculations
5. Does not pass through placental barrier
6. Chief use is for quick and reliable intubating condition including *crash induction*
7. Destroyed by hydrolysis by plasma pseudocholinesterase
8. Not antagonised by neostigmine, indeed the action is potentiated by it
9. Newborns are resistant to the drug. Dual block may occur in infants
10. May cause bradycardia, hypertension and even arrhythmia
11. Disadvantages:
    i. Muscle pain: More common in ambulatory patients, mostly seen in neck, shoulder girdle, abdomen, can be lessened by pretreatment with nondepolarising muscle relaxants. Diazepam, lignocaine or dantrolene may also help; self-taming is possible
    ii. Hyperkalaemia: After injection of suxamethonium, potassium leaks into extracellular fluid. Patients suffering from tissue injury from trauma, burns, neurological injuries may exhibit servere hyperkalaemia and on occasion has resulted in cardial arrest
    iii. Raised intraocular pressure, raised intracranial pressure
    iv. Raised intragastric pressure
    v. Bradycardia, sinus arrest
    vi. Malignant hyperpyrexia may be triggered in susceptible subjects
    vii. Prolonged apnoea in patients with deficiency or abnormality of the enzyme pseudocholinesterase
    viii. Anaphylactoid reactions
    ix. Trismus
    x. Myoglobinuria.
12. Contraindications:
    i. Burns
    ii. Muscle trauma
    iii. Upper and lower motor neurone disease
    iv. Patients with arrhythmias
    v. Patients with deficiency or abnormality of pseudocholinesterase
    vi. Patients with penetrating eye injury, glaucoma
    vii. Patients susceptible to malignant hyperthermia.

Pseudocholinesterase

It determines the duration of action of succinylcholine. Normal level in plasma is 80 to 120 units. A level less than 25 units is regarded as low.

- High levels are found in childhood, obesity, goitre, nephrosis, depressed states, psoriasis, alcoholism
- Low levels may be seen in patients with liver disease, pregnancy, cancer, severe anaemia, uraemia, cardiac failure, hyperpyrexia, cytotoxic drugs, acetylcholinesterase inhibitors, drugs like phenelzine, hexaflurenium, etc.

Dibucaine number

It indicates the percentage of enzyme inhibited by 10^{-5} molar concentrate of dibucaine (cinchocaine). It does not reflect the quantity but the quality that is, its ability to hydrolyse succinylcholine.

Dibucaine inhibits the normal enzyme by about 80% and an abnormal enzyme by about 20% under standardised test conditions.

Drugs metabolised by pseudocholinesterase

1. Suxamethonium
2. Mivacurium
3. Atracurium
4. Propanidid
5. Procaine
6. Chloroprocaine
7. Amethocaine.

Side effects of nondepolarising drugs

1. Histamine release: Tubocurarine, alcuronium, atracurium
2. Ganglion blockade: Tubocurarine
3. Vagal blockade: Gallamine, fazadinum, pancuronium
4. Sympathomimetic action: Pancuronium.

ANTICHOLINESTERASE DRUGS

Neostigmine

1. Widely used to antagonise nondepolarising muscle relaxants
2. Dose may range from 0.5 to 2.5 mg (0.04 to 0.07 mg/kg) depending on the dose of relaxant and time of its administration. Dose should not exceed 5 mg
3. Neostigmine may cause bradycardia, miosis, excessive salivary and bronchial secretions, bronchospasm, contraction of gut, etc. To counteract these side-effects atropine should always be given at 5 minutes before injecting neostigmine. Dose of atropine 0.015 mg/kg, adult dose 1 to 1.5 mg or glycopyrrolate (0.008 mg/kg) adult dose 0.5 to 0.6 mg may also be helpful.

Edrophonium

1. Short-acting synthetic anticholinesterase
2. Duration of action is about 5 min. So recurarisation may occur and repeat dose may be necessary
3. Muscarinic actions are not so prominent, but atropine should always be given before injecting neostigmine
4. Usual dose: 10 to 20 mg iv

Criteria for adequate reversal of curarisation:

1. Adequate normal tidal exchange and ability to produce vital capacity of at least 10 mg/kg
2. Able to open his eyes and to keep them open
3. Able to raise head and sustain for at least 5 sec
4. No jerky respiratory movements
5. Effectively cough on endotracheal tube
6. Muscle power normal with electrical nerve stimulation
7. Adequate grip strength
8. Ability to produce negative inspiratory effort of at least—20 cm H_2O against obstructed airway
9. A TOF ratio greater than 0.7 or its equivalent
10. Intraocular tension normal.

Inadequate decurarisation :

1. Unability to open the eyes, ptosis
2. Jerky respiration
3. Ineffective cough on endotracheal tube
4. Incomplete respiratory movement
5. Tracheal tug
6. Cyanosis.

Factors increasing the duration of neuromuscular block :

1. Overdose of muscle relaxants
2. Incomplete decurarisation
3. Liver dysfunction
4. Kidney dysfunction
5. Use of general anaesthetics
6. Preexisting disease: Myasthenia gravis
7. Deficiency or abnormal pseudocholinesterase
8. Hypothermia
9. Alkalosis
10. Electrolyte changes: Hypokalaemia, hypernatraemia, hypermagnesaemia hypocalcaemia
11. Drug interactions:
    i. Antibiotics, aminoglycosides like neomycin, gentamicin, kanamycin, streptomycin
    ii. Local anaesthetics
    iii. Antiarrhythmic drugs: Quinidine, procainamide
    iv. Hypotensive agents: Trimethaphan, nitroprusside, nitroglycerine in high doses
    v. Ketamine
    vi. Diuretics: Furosemide
    vii. Ca channel blockers.

Monitoring of neuromuscular block

1. Essential for close supervision of the degree and duration of muscle paralysis and the recovery from it.
2. Can be performed by
    i. Continuous mechanical measurement of the actual muscle strength (force of contraction) throughout the operation
    ii. Electromyography and accelography to measure the electrical activity of muscle (compound electromyogram) or the acceleration of the thumb respectively
    iii. Use of peripheral nerve stimulator. It is the most practical way of monitoring muscle relaxation.

Peripheral Nerve Stimulator

The simple instrument is used to deliver an electrical stimulus to a particular nerve and the response of the muscle innervated by the same nerve is evaluated. The stimulation pattern may be single twitch, train-of-four and tetanus. Tactile or visual evaluation is done. It can also be measured by pressure transducer.

These should be used routinely in all cases where muscle relaxants are given. The ulnar, facial, posterior tibial and the common peroneal nerves are often used. The ulnar nerve at the wrist is popularly selected. Two electrodes are placed over the nerve with negative electrode distally and the positive electrode about 2 cm proximally. Supramaximal stimulus is used to stimulate the nerve.

A current of 15 to 40 mA is used. Duration of stimulation is less than 0.2 ms. Observation or measurement of muscle movement (thumb, adductor pollicis muscle) can be easily performed.

Effects of nerve stimulation:

1. **Twitch-tetanus-twitch:** Here a train single shocks are given at a rate not more than 1 every 3s followed by a tetanic train at 50 Hz or more for 3s and then a train of single shocks are repeated.
    i. Normally twitch response is followed by tetanic strong sustained contraction. No potentiation of posttetanic twitches
    ii. Total block: No response is obvious
    iii. Partial depolarising block: Twitch responses are weak and this is followed by a weak but sustained tetanic contraction. No posttetanic potentiation is observed
    iv. Partial nondepolarising block: Here the initial twitch response is weak, the tetanic train shows contraction within fades quickly and there is potentiation of posttetanic twitches.
2. **Train of four**

    This method uses four stimuli at 2 Hz given at 0.5s intervals. It may be repeated every 10s. TOF ratio is calculated.

    In train of four stimulation a twitch and train of four are alway, combined. The first twitch of TOF is always equal to the single twitch.

    The train of four ratio is calculated as the ratio of the force generated by the fourth force of contraction to the first when force transducers are used. TOF ratio is the ratio of height of the fourth to the first twitch. A ratio greater than 70% indicates adequate neuromuscular transmission following competitive blockers.

Normally it is 1 (100%)
Absence of T_4 response implies 75% block.
Absence of T_3 response implies 80% block.
Absence of T_2 response implies 90% block.
Fading occurs in nondepolarising block.
No fading, but all four responses diminish simultaneously in amplitude in depolarising block.
Phase II block: Patient is on succinylcholine, but shows fading.

3. **Posttetanic twitch count.**
   - **Features of depolarising block**
     1. Reduction of twitch height
     2. No fade of TOF or tenany
     3. No posttetanic facilitation.
   - **Features of nondepolarising block**
     1. Reduction of twitch height
     2. Fade of TOF and tetany
     3. Posttetanic facilitation.
   - **Common uses of nerve stimulation**
     1. Prolonged anaesthesia. Facilitates titration of muscle relaxants. Avoids excess dose
     2. Patients with renal and/or liver dysfunction
     3. Hypersensitive patients, Myasthenia gravis
     4. Infusion of muscle relaxants
     5. Patients with myasthenia gravis or myasthenic syndrome
     6. New muscle relaxant investigation
     7. To assess the residual block. Monitors adequate reversal.

- **Initial dose of muscle relaxants for tracheal intubation.**

d tubocurarine 0.6 mg/kg
Pancuronium 0.1 mg/kg
Atracurium 0.5 mg/kg
Doxacurium 0.05 mg/kg
Mivacurium 0.2 mg/kg
Vecuronium 0.1 mg/kg
Rocuronium 0.6 mg/kg
Pipecuranium 0.1 mg/kg
Suxamethonium 1 mg/kg
Gallamine 2 mg/kg.

- **Continuous infusion of muscle relaxants**

Criteria:

1. Small volume of distribution
2. Rapid clearance
3. Rapid equilibration between plasma and neuromuscular junction.

Muscle relaxants for continuous infusion :

1. Mivacurium is the relaxant of choice
2. Atracurium
3. Vecuronium.

- **Priming**

Intubation time can be shortened by giving a priming dose of the muscle relaxant (10 to 20% of the intubation dose) which blocks upto 60 to 70% of the motor end plate receptors but does not give any significant muscle relaxation. Sometimes after the priming dose, a large bolus of the paralysing dose can take action within a much shorter time. Muscle relaxant produces paralysis markedly faster than if the two doses were given together.

The ideal time between the priming dose and the intubation dose is about 4 min.

Some patients may become profoundly weak following the initial dose. Moreover, the benefits of priming may vary from patient-to-patient.

- Some drugs can reduce the neuromuscular block
  1. Phenytoin
  2. Carbamazepine
  3. Calcium.
- Drugs used to reverse the nondepolarising block
  1. Neostigmine
  2. Pyridostigmine.

CHAPTER

8 Monitoring during Anaesthesia

- To measure a physiological variable and to indicate prompt recognition of any change, thus enabling appropriate therapeutic action to be taken.

CLINICAL MONITORING

1. Skin : Colour, capillary refill, rash, oedema
2. Nail beds : Colour, cyanosis
3. Mucous membrane
4. Movement, position
5. Eyes, pupil, tearing
6. Surgical site, blood loss
7. Pulse
8. Respiration
9. Skeletal muscle tone
10. Body temperature
11. Blood pressure: Continuous or intermittent
12. Ventilation, breath sounds
13. Heart sounds—Amplitude, rhythm.

SPECIAL BASIC MONITORS USED IN ANAESTHESIA

1. Precordial/oesophageal stethoscope
2. Noninvasive blood pressure
3. Pulse oximeter: Heart rate, peripheral O_2 saturation
4. Electrocardiogram : Heart rate, rhythm, ischaemic changes
5. Capnometry : End tidal CO_2, rate of respiration
6. Expired tidal/minute volume
7. Body temperature
8. Arterial blood gases/pH
9. Central venous pressure

10. Peripheral nerve stimulator
11. Disconnect alarm: Automatic alarms provided with anaesthetic machine and ventilator
12. Urine output.

- **Some other monitors may be needed in special situations :**
  1. Oxygen analyser
  2. Pulmonary artery catheter
  3. Mass spectrometry
  4. Raman spectroscopy
  5. Spirometer
  6. Echocardiography
  7. Electroencephalography
  8. Evoked potentials to allow assessment of the functional integrity of neural pathways during anaesthesia
  9. Estimated blood loss.
- Invasive monitoring methods should be used when specially indicated.
- Echocardiography helps to detect/assess :
  1. Myocardial ischaemia
  2. Cardiac mitral or aortic valve function
  3. Intracardiac air
  4. Cardiac function
  5. Ejection fraction.
- **Note :**
  1. Check, calibrate all the monitors before use
  2. Set alarm limits of all monitors
  3. Monitors should not be regarded a substitute for sound clinical judgement. One should constantly integrate and interpret the data available in the light of clinical condition.
- Meticulous record keeping is essential for all patients undergoing anaesthesia. It is also important for medicolegal purposes.

MONITORING THE ANAESTHETIC APPARATUS

Oxygen Supply

1. Cylinder of oxygen on the anaesthetic machine should be checked and immediately replaced when it is exhausted
2. Pipeline system should also be checked and should automatically comes in line when it is exhausted. These are usually supplied either from a liquid oxygen tank or from a bank of O_2 cylinders. There should be audible alarm and a warning lamp on display panel
3. Anaesthetic machine should be fitted with a low pressure alarming device when O_2 supply fails.

Breathing System (circuit)

1. Components of the circuit should be checked
2. O_2 failure, kinked and obstructed airway, blocked gas exit can occur
3. Leak, disconnection, overpressure or hyperventilation can also occur
4. High airway pressure may cause pulmonary barotrauma. There should be high pressure alarm system
5. During mechanical ventilation, it is essential to monitor the airway pressure. Alarms should be fitted with adjustable low-and high pressure limits
6. Breathing circuit should be complete, undamaged and unobstructed
7. Leak check of the breathing circuit should be done
8. Monitor the vaporisers, valves, flowmeters, etc.
9. Monitor the ventilator parameters during use.

CHAPTER

9 Anaesthetic Equipment

The anaesthetic machine enables to deliver gas and vapour mixtures to the patient accurately and continuously. The Boyle anaesthetic machine is designed by HEG. Boyle in 1915. Modern machine differs greatly in detail and modified time-to-time, but the basic principles remain the same. It consists of:

1. Oxygen and anaesthetic gas supply
2. Pressure gauges
3. Reducing valves
4. Flowmeters
5. Vaporisers
6. Common gas outlet
7. Certain other features:

Highflow oxygen flush, pressure relief valve, oxygen supply failure alarm, suction apparatus, monitoring devices.

MEDICAL GAS SUPPLY

Cylinders

1. Made of molybdenum steel to withstand high pressures
2. Made of different sizes (A to J). Size E cylinders are used in the anaesthetic machine
3. Oxygen is stored as gas at about 2000 lb/inch^2 and nitrous oxide is stored in a liquid phase with vapour on the top at a pressure of 760 lb/inch^2. It is 75% filled with liquid nitrous oxide.
   Note: Filling ratio is the weight of fluid in the cylinder divided by the weight of water needed to fill the cylinder.
4. Cylinders are colour coded.
   Oxygen: Black with white shoulders
   Nitrous oxide: Blue
   Carbon dioxide: Grey
   Entonox: Blue with white/bluequarters shoulder
   Air: Grey with white/black quarters shoulder.

5. Some markings engraved on the cylinders:
   Test pressure, chemical formula, Tare weight,
   dates of test performed, etc.
6. Checking and testing by manufacturers at regular intervals:
   i. Flatening test
   ii. Bending test
   iii. Impact test
   iv. Pressure test
   v. Tensile test.
7. Gases and vapours must be free from water vapour as it may freeze and block the exit port at a decreased temperature particularly when opening
8. Cylinder valve provides *pin index system* as a safety feature to make it almost impossible to connect a cylinder to a wrong yoke
9. Should be stored in a dry, well-ventilated and fire proof room. Avoid dampness, corrosives and fumes near by. No oil or greese or any other flammable materials or any source of heat should be allowed
10. Full cylinders should be kept separately and should not be mixed with empty ones
11. Avoid overpressurised full cylinders.

Pin Index System (Fig. 9.1)

A specific pin configuration for each medical gas on the yoke of the anaesthetic machine. The pin will match the holes on the valve block. It permits only the correct gas cylinder to be fitted in the yoke.

Oxygen: 2 and 5
Nitrous oxide: 3 and 5
Cyclopropane: 3 and 6
Entonox: 7
Air: 1 and 5
Carbon dioxide: 1 and 6

- Pressure in the cylinders
  Oxygen: About 2000 lb/inch^2
  Nitrous oxide: About 750 lb/inch^2
  Cyclopropane: 75lb/inch^2 [stored in light alloy cylinders as a liquid]
  Carbon dioxide: 720 lb/inch^2.

Cylinder valve (Fig. 9.2)

1. Mounted on the neck of the cylinder, screwed with threaded connection
2. The valve can be opened or closed by an off/on spindle for gas pathway
3. Noninterchangeable safety device (pin index system) prevents wrong cylinder assembly
4. Bodok seal is placed between the valve outlet and yoke of the machine to make the gas tight joint.

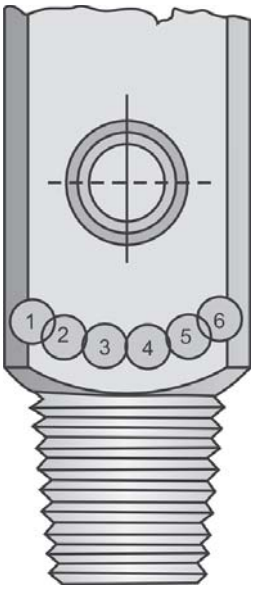

Fig. 9.1: Disposition of holes in flush—type outlet valve

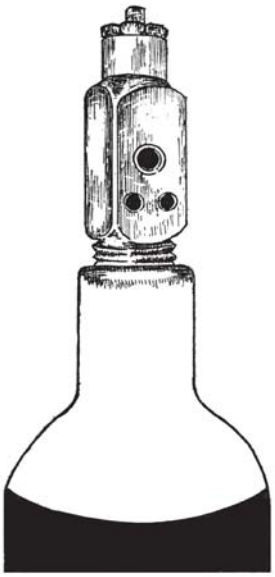

Fig. 9.2: Cylinder valve—Flush type

5. The cylinder valve should be fully open during use. Check the Bodok seal before use to detect any damage.

Piped gas supply

1. Gas delivered from a central supply to different locations at a pressure of about 400 kPa
2. Oxygen, nitrous oxide, entonox, compressed air and medical vacuum can be used through the pipe line system
3. Components:
    i. Central supply (cylinder bank/liquid oxygen storage bank or oxygen concentrator)
    ii. Pipe work (made of copper), flexible and colour coded
    iii. Outlets (identified by gas colour coding, gas name and by shape) accept matching quick connect or disconnect probes with an indexing colour specific for each gas
    iv. The cylinders of each group are connected through nonreturn valve to a common pipe. Then in turn is connected to the pipe line through pressure regulators
    v. The cylinders should be well-housed in a well-ventilated room (fire proof) in a suitable place in hospital.

Liquid oxygen

1. Oxygen can be stored and supplied in a vacum thermally insulated evaporator at a temperature of – 150° to – 170°C and at a pressure of 5 to 10 atmospheres.
2. A pressure regulator permits gas to enter the pipelines and maintains it at about 400 kPa

3. It also provides a safety valve to release the build up high pressure, if occurs
4. A control valve is also there to meet the extra demands on the system
5. Cold oxygen gas is warmed outside the vessel in copper tubing coil. The increase in temperature increases the pressure.

Oxygen Concentrator

1. Extracts oxygen from air when exposed a zeolite molecular sieve column at certain pressure
2. The zeolite sieve selectively retains nitrogen and other unwanted constituents of air and releases them to atmosphere
3. Maximum oxygen concentration can be achieved is nearly 95% by volume. Argon may be main of the other constituents.

Compressed Air

1. Can be used either clinically at a pressure of 400 kPa or to drive power tools at a pressure of about 700 kPa
2. Can be supplied from cylinders or from a compressor
3. For clinical use air should be cleaned by filters and separators and then dried.

Pressure Gauge (Fig. 9.3)

1. Measures the pressure in the cylinder mounted in the front facing panel on the anaesthetic machine
2. High pressure gas acts to straighten a coiled tube (Bourdon gauge). Movement of the tube causes the needle pointer to move on a calibrated dial to indicate the pressure

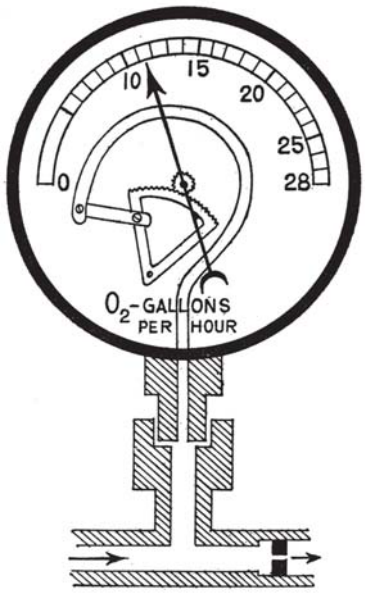

Fig. 9.3: Pressure gauge

3. Colour coded and calibrated for a particular gas or vapour
4. Indicates the contents of gas available in the cylinder
5. Nitrous oxide cylinder does not provide pressure gauge as it is stored as a *liquid* and vapour
6. Pressure gauge meant for pipeline is not for cylinder and *vice versa*. May lead to inaccuracies and/or damage
7. Misassembly is possible.

Pressure regulator (Reducing valve)

1. Reduces the variable gas pressure from cylinders to about 400 kpa
2. Positioned between the cylinders and the rest of anaesthesia machine
3. Provides fine control of gas flow and protects the parts of machine against high pressure
4. Prevents the pressure from increasing above a predetermined limit
5. Contents of the cylinder should be free from water, otherwise ice can form inside the valve
6. Earlier models are with 'fins' to augment acquisition of heat from the environment
7. Mechanism of action: The gas from the cylinder enters into the chamber of reducing valve where it distorts a diaphragm to which a toggle mechanism is connected and a balance between two opposing forces maintains a constant predetermined operating pressure (60 psi)
8. Diaphragm can rupture
9. Relief valve is fitted downstream of the regulator. It helps to escape the gas, if regulator fails.

Flow restrictor

1. Pipeline pressure increase can be controlled by using a pressure regulator on a flow restrictor
2. Flow restrictor provides a constriction between the pipeline supply and the remaining part of the anaesthetic machine. The constriction causes a significant pressure drop in presence of a high gas flow rate.

Flowmeters (Fig. 9.4)

1. Measures flow rate of a gas per minute
2. Each gas is individually calibrated
3. Oxygen should be the last to be added in mixture
4. Calibration done at room temperature and atmospheric pressure, accuracy with an error margin ± 2%
5. It contains: A flow control valve, a tapered (wider at the top) transparent glass or plastic tube, a light weight rotating bobbin. Bobbin stops at either end of the tube
6. Flow control (needle) valves:
    i. Controls the flow through the flowmeters by manual adjustment
    ii. Positioned at the base of flowmeter
    iii. Control knobs are labelled and colour coded, blue for nitrous oxides, white for oxygen and grey for carbon dioxide.

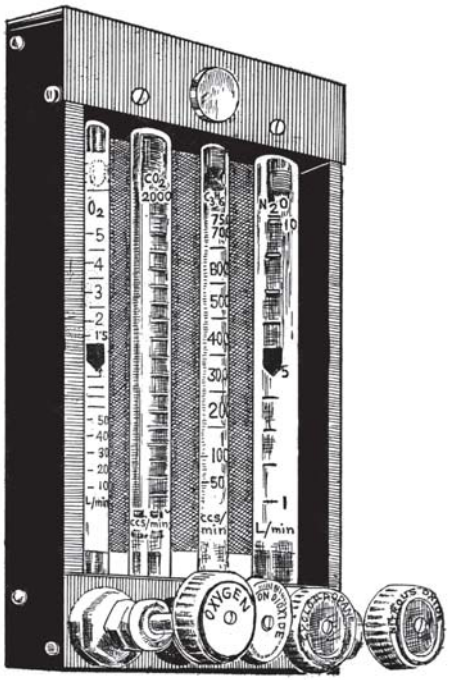

Fig. 9.4: Rotameter unit

7. When the gas flows, with the help of flutes the bobbin spins clears of the walls of the tube and thus avoids the errors of friction. Bobbins should be made antistatic
8. The viscosity and density of the gases can influence the gas flow in the flowmeter. Each flowmeter is calibrated for each gas
9. Flowmeter should be set in vertical position, otherwise may give incorrect reading
10. Malfunction: Broken, cracked, bobbin stuck, wrong gas, inproper alignment, back pressure, etc.
11. Other types:
    i. Heidbrink flowmeter: Metal tapered tube with inverted black float
    ii. Connell flowmeter: Provides round float, reading from its centre.

Vaporisers

To administer a controlled amount of an inhalational agent after changing a liquid to vapour to the fresh gas flow.

Ideal vaporiser characteristics

1. Performance not affected by changes in fresh gas flow, liquid volume, ambient temperature, and pressure, decrease in temperature due to vaporisation and pressure fluctuation due to mode of respiration
2. Low resistance to flow

3. Light weight with small liquid requirement
4. Economy, safety, minimum servicing
5. Corrosion and solvent resistant
6. Quality control by authorised institution.

Boyle anaesthetic machine provides two vaporising bottles one for diethyl ether and the other for trichlorethylene. These vaporisers are of variable bypass, flow over or bubble through type. These are neither properly calibrated nor temperature compensated.

The concentration of vapour depends on the rate of gas flow, liquid surface area, the way the gas impinges on the liquid and the temperature of liquid.

Boyle's bottle/glass-ether vaporiser (Fig. 9.5)

1. Contains diethyl ether which vaporises to an extent governed by its saturated vapour pressure at room temperature
2. The amount of gas entering the vaporiser can be altered by moving the lever
3. Gas enters the vaporiser above the anaesthetic liquid to vaporise and its concentration can be altered by depressing the plunger
4. Vaporisation needs latent heat of vaporisation. Larger amount of heat is needed to vaporise ether. The concentration from the vaporiser usually falls significantly as the temperature and vapour pressure of ether fall. So the total gas flow may need to pass through the vaporiser and even bubbled through it
5. Sealing washer of the Boyle's bottle should be of good order
6. Dark brown-coloured bottles are used as ether can be decomposed by light

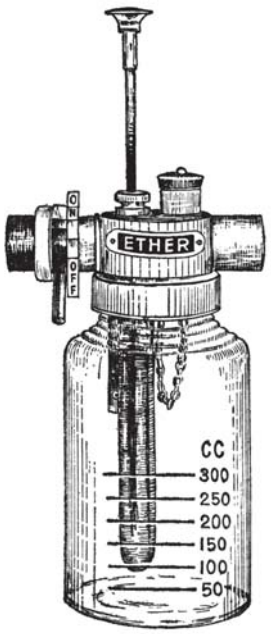

Fig. 9.5: Boyel ether vaporiser

7. Metal parts of U tube and hood of plunger should be made of copper as it is anticatalyst and can prevent decomposition of ether.

Trichlorethylene vaporiser bottle

It is similar to ether bottle but it is smaller in size and the inlet U tube and the hood of plunger are entirely chrome plated.

Goldman halothane vaporiser (Fig. 9.6)

1. Simple vaporiser, flow-over type, no wicks
2. Neither temperature compensated, not accurately calibrated
3. Can be used inside or outside the breathing circuit
4. Control device on the top which can be rotated to alter the vaporizer output
5. Low resistance to gas flow
6. Maximum concentration never exceeds 3%
7. Vapour concentration can be increased by
   i. Splashing (ii) incorporating wicks (iii) employing 2 vaporisers in series.

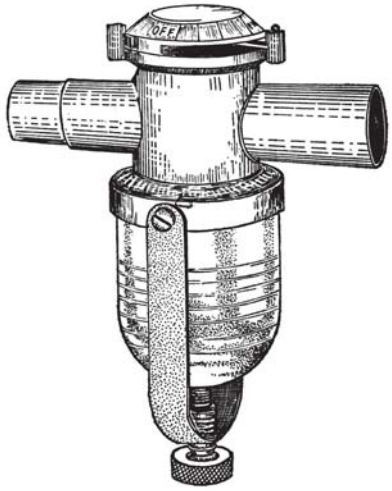

Fig. 9.6: Goldman vaporiser

Back bar

1. Part of the Boyle machine on which rotameter (containing flowmeters), vaporisers (ether and trichlorethylene) and other accessories are fitted
2. '*Trilene safety interlock*' is placed at the end of back bar (Fig. 9.7)
3. Provides an angled outlet with a nonreturn valve to prevent a back pressure during positive pressure ventilation
4. At extreme right there is an *emergency bypass* which can deliver high flow of O_2 directly, bypassing the rotameter

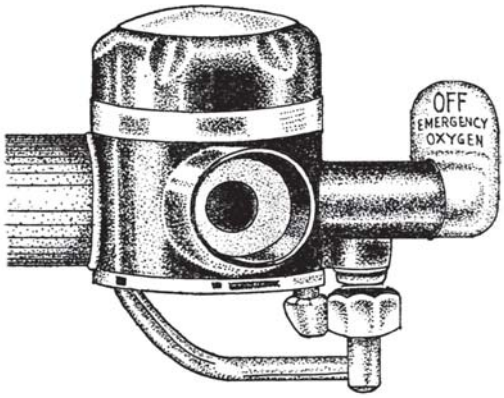

Fig. 9.7: Terilene interlock unit

5. Some machines may have an emergency press button unit to suppy plentiful oxygen (oxygen flush). Risk of accidental activation includes barotrauma, dilution of anaesthetic gas, awareness.

Oxygen supply failure alarm

1. Various designs are available
2. Activates on the pressure of oxygen
3. No need of battery or mains power
4. Gives audible signal sufficient to draw attention
5. Should have pressure linked control which interrupt the flow of other gases when they come into operation.

Plenum vaporisers

1. Designed to maintain a constant output of volatile anaesthetic agent
2. The case is made of copper which is a good heat sink
3. Provides a bypass channel and vaporising chamber which contains wicks to increase the surface area available for vaporisation
4. Has a temperature-compensation device. Bimetallic strip inside to compensate for the cooling of the liquid anaesthetic. When cooling takes place due to latent heat of vaporisation, the strip made of two different metals with different coefficients of expansion bend to permit a greater fraction of the total flow to enter the vaporising chamber
5. The gas coming out of the vaporising chamber is fully saturated
6. The effect of back pressure is compensated
7. The calibration of each vaporiser is agent specific
8. Vaporiser filling devices are agent specific. These are geometrically coded to fit the safety filling port of the correct vaporiser and anaesthetic bottle. The fillers are also colour coded, *red* for halothane, *orange* for enflurane and *purple* for isoflurane.

9. Caution:
    i. The liquid anaesthetic should not enter the bypsss channel
    ii. The effect of back pressure must be compensated
    iii. Preservative like thymol (in halothane) can deposit on wicks and interfere the efficacy of vaporiser. Enflurane and isoflurane do not contain preservative
    iv. A pressure relief valve can prevent the damage of flowmeter/vaporiser
    v. Corrosion of bimetallic strip can occur.

Common gas outlet

1. Receives all gases and vapours from the machine
2. Attached to the delivery hose
3. Leak/disconnection can occur. Adequate care is needed
4. A check valve can be provided just proximal to outlet to prevent retrograde gas flow from flush valve or breathing system.

Bag mount (Fig. 9.8)

1. Made of metal tube. One end connected with machine outflow and the other end to the angle piece adaptor to connect corrugated rubber hose. Rebreathing bag is attached from the under surface
2. May have a valve. By turning a lever to one side, the rebreathing bag is cut out of the circuit
3. In intermittent flow machine the bag and bag mount should be removed from the machine.

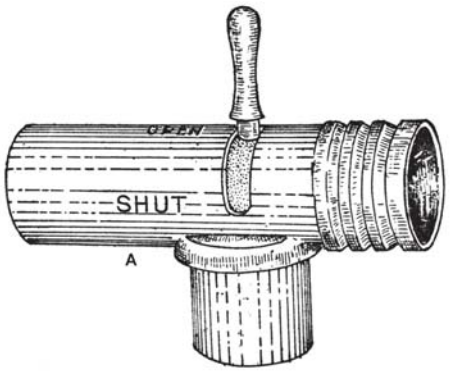

Fig. 9.8: A = Bag mount

Rebreathing bag (Fig. 9.9)

1. Made of antistatic rubber, ellipsoidal in shape
2. Capacity may vary from 2L to 0.5L, capacity of bag must exceed patient's tidal volume. Accommodates fresh gas flow
3. Bag movement is important in assessing or controlling the ventilation
4. Limits pressure build up in the system
5. Must be comfortable for use.

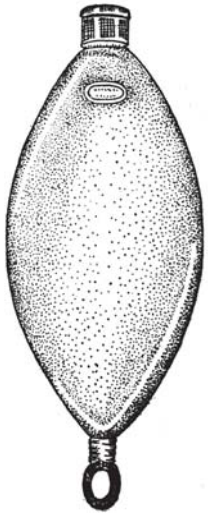

Fig. 9.9: Rebreathing or reservoir bag

Corrugated rubber tube (Fig. 9.10)

1. Flexible, light weight breathing tube. Made of antistatic rubber. Usual length about 1 metre
2. Corrugation helps acute angulation without kinking
3. Can act as reservoir in certain systems
4. Can be used to connect the ventilator to the breathing circuit
5. Tube diameter should be such to present low resistance to gas flow and to promote a laminar flow
6. Irregular walls of the tube may cause some turbulence and allow some dirt or infective material into it.

Fig. 9.10: Corrugated rubber tube

Adjustable pressure limiting valve (Expiratory valve) (Fig. 9.11)

1. Allows the exhaled gas and excess fresh gas flow out of the breathing system
2. Oneway spring loaded valves with three ports: Inlet, patient and exhaust ports. The exhaust port can be open to atomosphere

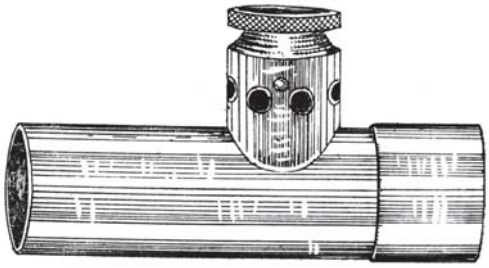

Fig. 9.11: Expiratory valve (Heidbrink type)

3. The spring adjusts the pressure required to open the valve
4. During spontaneous ventilation, a positive pressure in the system during expiration can cause the valve to open
5. During positive pressure ventilation an intentional leak is produced by adjusting the valve dial during inspiration
6. Malfunction:
    i. May remain open/closed.
    ii. If closed, a pressure relief safety mechanism should be there which is activated at a pressure of about 60 cm H_2O
    iii. Condensation of water vapour can damage the valve.

Face mask and angle piece (Figs 9.12 and 9.13)

1. Made of antistatic rubber or transparent plastic designed to fit the contour of face anatomically
2. Airfilled cuff ensures the snug fit over the face
3. Proximal end connects to the angle piece
4. May have some clamps for the harness to be attached
5. It should have a minimum dead space. Dead space may increase by upto 200 ml in adults
6. Problems:
    i. Difficult to achieve airtight seal over the face particularly in edentulous patients
    ii. Excessive pressure by mask can damage branches of trigeminal or facial nerve.

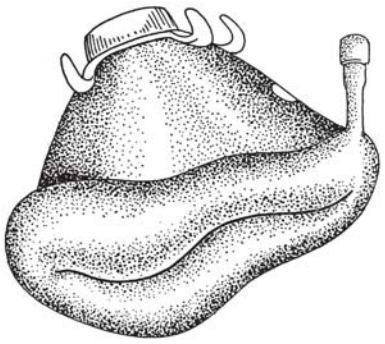

Fig. 9.12: Face mask

Fig. 9.13: Face mask angle piece adaptor

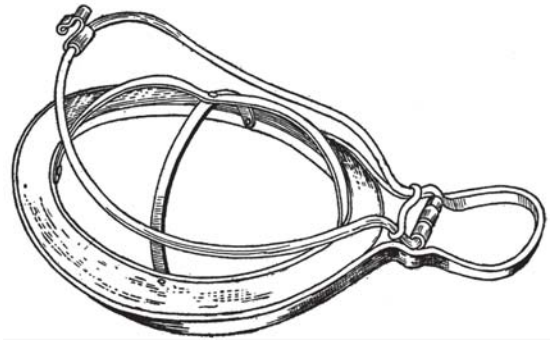

Fig. 9.14: Schimmelbusch mask

Anaesthetic Breathing System

Formerly classified as open, semiopen, semiclosed and closed systems.

1. Open system (open drop inhalation method):
   - Volatile anaesthetic is administered to the patient with atmospheric air. Respiratory tract has access to atmosphere all the time during both inspiration and expiration
   - No reservoir/rebreathing bag
   - Schimmelbusch mask (Fig. 9.14) is used for open drop anaesthesia. It consists of a simple wire frame over which 8 to 12 layers of gauge are stretched and kept in position. Mask provides one effective surface for volatile anaesthetics and some space for confining the anaesthetic vapour.
2. Semiopen system: Here also the anaesthetic is administered with air and respiratory tract is open to atmosphere during inspiration and expiration. But some reservoir is made over the mask (by a folded towel over the mask), but it is mostly open to the atmosphere
3. Semiclosed system:
   - Patient inhales from the continuous flow of gases/vapours from anaesthetic machine and it includes one reservoir/rebreathing bag
   - When all the expired gases escape to the atmosphere through nonrebreathing valve, then it is nonrebreathing type of semiclosed system
   - If part of exhaled gases escape through expiratory valve and part passes through rebreathing bag then it is partial rebreathing type of semiclosed system.
4. Closed system:
   - Anaesthetic gases and vapours are not voided in atmosphere. The same gases are continuously recycled after absorption of carbon dioxide by soda lime.
   - Oxygen utilised in metabolism and gases/vapours utilised in the body or lost are to be supplemented
   - Some intentional leak is always kept in expiratory valve.

Advantages:

i. Economy
ii. Retention of body heat and moisture

iii. Less pollution
iv. Less chance of explosion.

Disadvantages:

i. Circuit should be leak proof
ii. Cumbarsome and heavy equipment
iii. CO_2 absorption may not be adequate
iv. Resistance to breathing and dead space may be high
v. Heat from soda lime may affect the body
vi. Alkaline dust from soda lime may also affect
vii. Cross infection
viii. Dilution of fresh gas mixture possible.

Soda lime

Composition: Sodium hydroxide 4%
Potassium hydroxide 1%
Water 14 to 19%
Silica (to prevent powdering calcium hydroxide) 95%

Size: 4 to 8 mesh

Chemical neutralisation of CO_2

$$CO_2 + H_2O \rightarrow H_2CO_3$$
$$H_2CO_3 + 2NaOH \rightarrow Na_2CO_3 + 2H_2O + \text{heat}$$
$$H_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + 2H_2O + \text{heat}$$

- Soda lime is pink coloured and it turns white when it becomes ineffective. There is gain in weight, when it is exhausted. Some regeneration can occur, when it is rested for 2 to 3 hours
- Trichlorethylene should never be used in a closed circuit with soda lime, otherwise toxic products like dichloroacetylene may be formed. It can produce paralysis of cranial nerves particularly 5th and 7th cranial nerve.

Baralyme

Composition: Barium hydroxide 20%
Calcium hydroxide 80%
Water bound crystalisation
No silica is needed.

Chemical neutralisation of CO_2

$$CO_2 + H_2O \rightarrow H_2CO_3$$
$$H_2CO_3 + Ba(OH)_2 \rightarrow BaCO_3 + 2H_2O + \text{heat}$$
$$H_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + 2H_2O$$

- Produces less heat than soda lime
- Less caustic than soda lime.

Absorbers

1. Absorber of to-and-fro system is made of metal, but that of circle system is usually glass or transparent plastic. Metals conduct and dissipate heat better and more resistant to corrosive effects of alkali. Plastic is light and enables to observe colour changes
2. Shape cylindrical. Wide and short canister preferred
3. Granular space: Space occupied by the absorbent. Measured by the bulk density. It is 0.9 gm/cc for soda lime and 1 gm/cc for baralyme
4. Air space: Usually 45 to 75% of the volume of canister. It includes intergranular (void) space and intragranular (pore) space
    i. Intergranular space : Usually about 45%, depends of size of granules and type of packaging
    ii. Intragranular space: Space within the pores of granules. Varies directly with the weight of absorbent but inversely with its moisture conent. Usually about 25 ml/100 gm of absorbent.
5. Exhaustion time depends on exhaled CO_2, type of ventilation, tidal volume, absorbent capacity, degree of channelling, fresh gas flow, position and accuracy of the canister.

Water's 'to-and-fro' system (Fig. 9.15)

1. Introduced by Ralph Waters in 1923
2. A soda lime canister is place between the face mask and rebreathing bag. Both inspiration and expiration take place through the canister. Fresh gas should be very near to face mask.

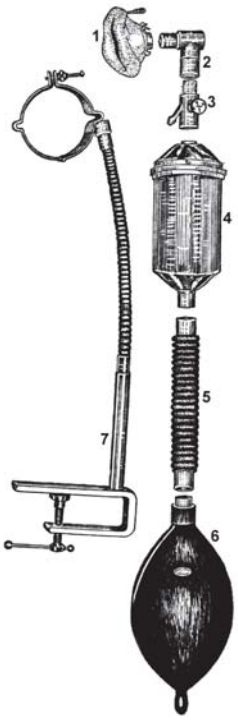

Fig. 9.15: Water's canister and its attachments Key : 1=Face mask; 2=Angle piece; 3=Expiratory valve with gas feed, inlet; 4=Water's canister; 5=Corrugated rubber tube connector; 6=Rebreathing bag; 7=Fixing device of canister

3. Canister: 8×13 cm, capacity 1 lb soda lime. Air space about 400 ml, intergranular space should be nearly the tidal volume of the patient
4. Resistance of this circuit may be more than 2 to 3 cm H_2O during spontaneous ventilation
5. Mechanical dead space: About 200 ml (from wire gauge of canister to face)
6. Channelling can occur. Canister needs adequate proper filling
7. Disadvantages: Heat production, alkaline dust, channelling, reduced efficiency
8. Advantages: Cheap, simple, easy to operate and sterilise, low resistance, conservation of moisture and heat.

Circle breathing system

1. Soda lime is used to absorb the patient's exhaled CO_2. Fresh gas flow requirement is low
2. Soda lime canister is positioned vertically. It provides an inlet delivering fresh gas flow from machine and 2 ports — one to deliver fresh gas flow to patients and the other to receive exhaled gases from the patient. These 2 ports incorporate unidirectional valve. An expiratory valve connected to a rebreathing bag (Fig. 9.16)
3. Inspiratory and expiratory tubings are connected to the canister
4. A vaporiser can be incorporated in the back bar of the anaesthetic machine (outside circle) or on the expiratory limb within the circle (VIC)
5. Exhaled gases are circled back to the soda lime canister. After CO_2 absorption the gas joins the fresh gas flow to be delivered to patient
6. The system can be used for both spontaneous or controlled ventilation
7. Mechanical dead space includes the space between the face piece and the beginning of double corrugated tubing. Resistance to gases is within 2 to 3 cm H_2O pressure
8. Canister usually large, capacity 4lb soda lime, divided in two halves and this is reversible
9. Advantages: Efficient

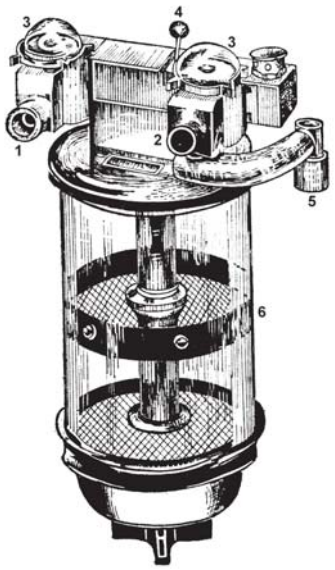

Fig. 9.16: Circle carbon dioxide absorber Key : 1=Gas inlet port; 2=Gas outlet port; 3=Non-return valves; 4=ON/OFF control lever; 5=Reservoir bag mount; 6=Soda lime canister

10. Disadvantages: Bulkiness, more resistance, more difficulty in recharging, chance of cross infection
11. Malfunction: Expiratory valve stuck closed, inspiratory valve stuck closed, circle system valve stuck open, misassembled valve components, foreign body in valve assembly
12. Adequate monitoring of inspired oxygen, end tidal CO_2 and inhalation anaesthetic needed.

Vaporiser outside the circle breathing system

1. Positioned on the back bar
2. Can deliver high output concentration at low flow rates
3. Have high resistance to gas flow
4. Vaporisers should be efficient enough to deliver proper concentration of vapour with both high and low fresh gas flows.

Vaporiser inside the circle breathing system

1. Minimal resistance to gas flow
2. Positioned in the expiratory limb
3. Here vapour-free fresh gas flow dilutes the inspired vapour concentration
4. During spontaneous ventilation, deep anaesthesia depresses respiration and thus anaesthetic uptake is reduced and overdose of anaesthetic is prevented. This mechanism is absent in controlled ventilation.

MAPLESON'S CLASSIFICATION

Mapleson classified the breathing system as Mapleson A, B, C, D, E and F. Now a days only A, D, E and F and some of their modifications are in common use.

Criteria for an ideal breathing system

1. Simple and easy to use
2. Safe and efficient
3. Can be used in all age groups
4. Can be used in either spontaneous or controlled ventilation
5. Satisfactory with low fresh gas flow
6. No complications like barotrauma
7. Compact, light weight, cheap, minimum running cost, easy to maintain
8. Can be easily sterilised
9. Easy removal of exhaled gas possible.

Mapleson A System (Fig. 9.17)

1. Mostly popular and widely used
2. Contains a fresh gas inlet connected to a reservoir bag, then attached to a corrugated tube and then connected with face mask or endotracheal tube

Fig. 9.17: Mapleson A circuit

3. Not ideal for controlled/assisted ventilation. Can be used for spontaneous ventilation. Fresh gas flow should be equal to alveolar minute volume (about 10 ml/kg/min)
4. Rebreathing occurs and not suitable for IPPV unless large fresh gas flow is used
5. Most commonly used version of Mapleson A is Magill system
6. Not ideal for paediatric anaesthesia.

Mapleson B System (Fig. 9.18)

1. Fresh gas inlet is towards patient end in between the expiratory valve and corrugated tube. Contains a reservoir bag at one end of tubing and face mask/endotracheal tube as usual
2. Less efficient during spontaneous ventilation, but more efficient in conrolled ventilation
3. Not used commonly

Fig. 9.18: Mapleson B circuit

Mapleson C System (Fig. 9.19)

1. Mostly similar to Mapleson B system
2. Here corrugated tube is absent. Reservoir bag is attached to fresh gas inlet. Expiratory valve is in between face mask/endotracheal tube and fresh gas inlet
3. Not much used.

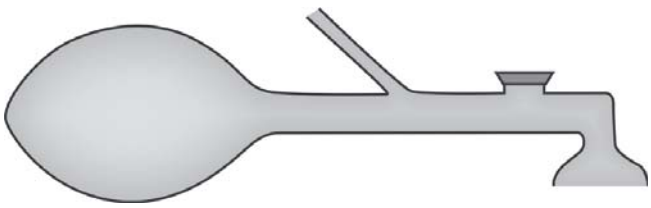

Fig. 9.19: Mapleson C circuit

Fig. 9.20: Mapleson D circuit

Mapleson D System (Fig. 9.20)

1. Consists of face mask/endotracheal tube, fresh gas inlet nearer face mask, corrugated tube and connected with expiratory valve and reservoir bag
2. Efficient for controlled/assisted ventilation. Can be used in spontaneous ventilation
3. Bain coaxial system is the modification of Mapleson D system.

Mapleson E System (Fig. 9.21)

1. Identical with Ayre's T piece system
2. Fresh gas flow is nearer to face mask/endotracheal tube, then connected to corrugated tube
3. No reservoir bag is used. No expiratory valve is there
4. It is a T-piece with 3 ports, Fresh gas flow in one port, second port to face mask, third port is meant for a tubing
5. Widely used in paediatric anaesthesia (upto 25 kg body weight)
6. Needs high fresh gas flow to prevent rebreathing
7. As there is no expiratory valve in this system, scavenging is a problem.

Fig. 9.21: Mapleson E circuit

Mapleson F System

1. Modified version of Mapleson E system
2. Here in T-piece system a double ended bag is attached to the end of the tubing
3. Suitable for spontaneous/controlled ventilation
4. Widely used in paediatric anaesthesia (upto 25 kg)
5. Needs high fresh gas flow (2.5 to 3 times minute ventilation) to prevent rebreathing
6. Volume of reservoir bag should approximate tidal volume.

Bain Circuit (Fig. 9.22)

1. Coaxial version of Mapleson D system
2. Fresh gas flow through inner tube, exhaled gas through outer tube. The reservoir bag and expiratory valve mounted at the machine end

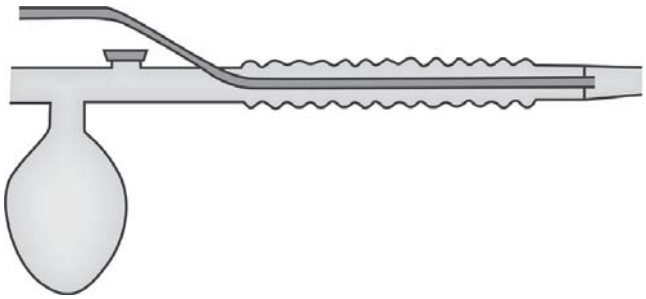

Fig. 9.22: Bain circuit

3. Internal tube should have swivel mount at patient end to avoid kinking
4. Tubes are transparent to detect inside, and kinking, or disconnection
5. Efficient in controlled ventilation. Fresh gas flow rate should be 70 to 100 ml/kg/min
6. Not much efficient for spontaneous ventilation. Fresh gas flow should be 200 to 300 ml/kg to prevent rebreathing
7. Use of ventilator is possible in this system
8. Usual length 180 cm
9. Advantages: Simple, light weight and easy to handle, safe and reliable. Can be easily sterilised, disposable tubing available
10. Disadvantages: Unrecognised disconnection, kinking, etc.

ENDOTRACHEAL TUBES AND AIRWAYS

Endotracheal tubes (Fig. 9.23)

- Tubes through which the anaesthetic gas/vapours along with respiratory gases are conveyed to and from the trachea. It is the artificial extension of larynx and a means of securing the airway
- Two ends: Patient end is bevelled, machine end is not
- Made of plastic (disposable) or red rubber or latex
- Criteria for an ideal endotracheal tube: Nontoxic, nonallergic, smooth, properly curved, low kinkability, easily sterilised, smooth, cheap
- Orotracheal tube: Short, curved and bevel angle should not be less than 45° in relation to long axis

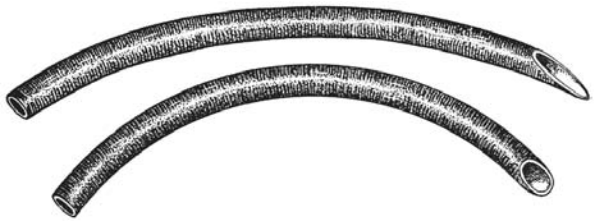

Fig. 9.23: Plain endotracheal tubes
Upper : Nasal tube
Lower : Oral tube

- Nasotracheal tube: Long curve, bevel angle should not be less than 30° to long axis
- Size of the tube: **Magill system** arbitrary number from 00 to widest 10. French scale denotes the external diameter in mm multiplied by 3. It is more or less the external circumference of the tube. Internal diameter of the tube ranges from 4 to 12 mm. Usually 8.5 mm tube is meant for females and 9.5 mm for males.
- **Length of the tube:**
  i. About twice the length from the ear to his nostrils
  ii. Usually about 24 to 30 cm in adults
  iii. Formula for children: Age (years)/2 + 12 cm for oral tube.
  Age (years)/2 + 15 cm for nasal tube.
- Diameter of the tube in children; 4.5 mm + Age (years)/4 in mm
- Cuff of the endotracheal tube: To provide an airtight endotracheal seal. Consists of an inflating tube and a pilot balloon. Cuff is vulcanised on the outer side of the tube about 12 mm from its end. Usually inflated with 4 to 8 ml air.

  An ideal cuff should expand symmetrically and the distance between the end of cuff and the nearest part of the cuff should be 1 to 1.25 cm. Overinflated cuff may cause ulceration and necrosis and even tracheal stenosis.
- **Type of cuff:**
  i. Low volume cuff: Needs inflation to a high pressure to produce seal. High pressure cuff causes little pressure on tracheal wall
  ii. High volume/low pressure cuff: Usually floppy. May fit an irregularly shaped tracheal wall. Insertion is usually difficult and traumatic
  iii. Sometimes double cuffs are used for alternate inflation and deflation at regular intervals to minimise pressure effect
- Culf volume should be monitored and readjusted, whenever needed
- N_2O may diffuse into the cuft filled with air and thus may increase the pressure
- Avoid cuffed tubes in children.

Oxford endotracheal tube (Fig. 9.24)

1. L-shaped nonkinking endotracheal tube mostly used for head and neck surgery
2. Made of rubber/plastic, cuffed or uncuffed, wall is thick
3. Bevel is oval-shaped, faces posteriorly

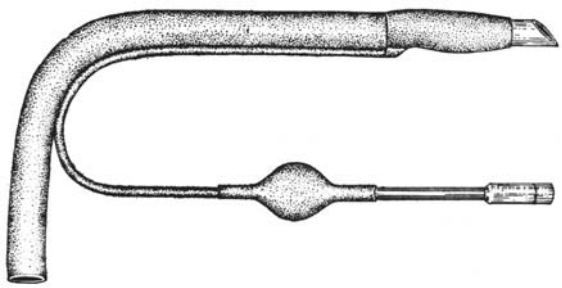

Fig. 9.24: Oxford nonkinking endotracheal tube

4. Stylet is needed for its insertion
5. Distance from the bevel to the curve of the tube is fixed.

Armoured endotracheal tube (Fig. 9.25)

1. Made of plastic or silicone
2. Thick walls contain a spiral of metal wire or tough nylon
3. Spiral helps to prevent kinking
4. Introducer is needed for its insertion
5. Tube length is fixed; risk of bronchial intubation
6. Used in anaesthesia for head/neck surgery.

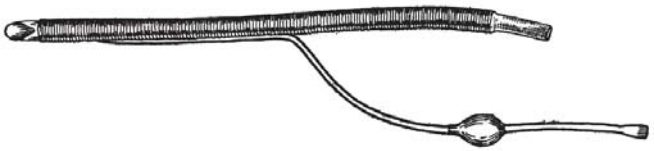

Fig. 9.25: Latex armoured endotracheal tube

RAE (Ring, Adair and Elwyn) endotracheal tube

1. Preformed shape to fit the mouth and nose without kinking
2. Provides a bend located just as the tube emerges at the level of chin/forehead
3. Cuffed/noncuffed variety
4. Uncuffed tubes mainly used in paediatric cases
5. Cuffed tube may include one Murphy eye
6. Uncuffed tube may contain two Murphy eyes
7. Risk of bronchial intubation.

Laser resistant endotracheal tube

1. Used for anaesthesia in laser surgery on larynx/trachea
2. Designed to withstand the effects of laser beams and thus helps the risk of fire or damages of the tube
3. Has a flexible stainless steel body
4. Reflected beams from the tube defocussed to reduce the unwanted laser strike to healthy tissues
5. Cuff should be filled with saline instead of air to reduce the risks of ignition
6. Some designs may have two cuffs.

Microlaryngeal endotracheal tube

1. Tube is of small diameter but with an adult sized cuff
2. It can be used nasally
3. Helps better exposure and surgical access to the larynx.

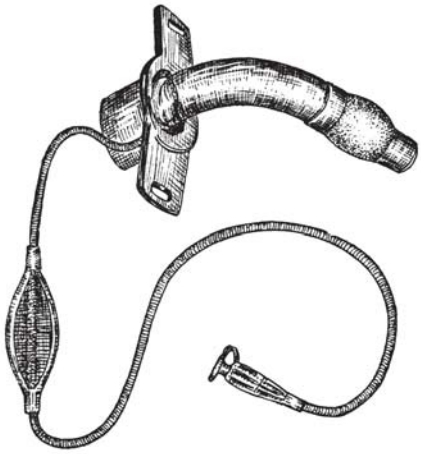

Fig. 9.26: Tracheostomy tube with inflatable cuff

Tracheostomy tubes (Fig. 9.26)

1. Curved plastic tubes
2. Usually inserted through 2nd, 3rd, and 4th tracheal ring
3. Introducer needed for insertion
4. Provides wings on the proximal part of the tube to fix
5. May be cuffed/uncuffed
6. Proximal end ends in a standard 15 mm connector. Tip is cut horizontally
7. Different sizes are available
8. Uses:
    i. Long-term IPPV
    ii. Upper airway obstruction
    iii. Maintenance of airway to protect the lungs.
9. Side effects:
    i. Loss of voice
    ii. Loss of expulsive cough
    iii. Loss of nasal humidifying effect.
10. Complications:
    i. Displacement
    ii. Accidental bronchial intubation
    iii. Erosion of vessels
    iv. Obstruction
    v. Tracheal ulceration
    vi. Tracheal stenosis.

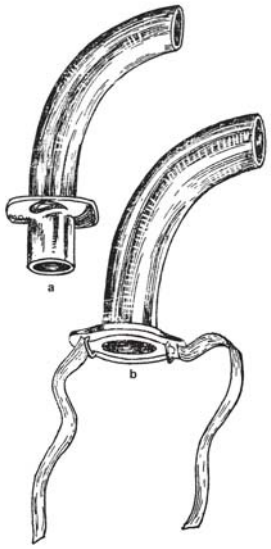

Fig. 9.27: Metal tracheostomy tubes
a= Inner tube, b=Outer tube with flange for tapes

Metal tracheostomy tubes (Fig. 9.27)

1. Made of stainless steel/silver
2. Provides inner and outer tube
3. Uncuffed
4. Inner tube usually removed for clearing at regular intervals
5. Used in cases needing long-term IPPV
6. After long term use, a track is formed and them the tracheostomy tube is removed
7. Speaking version is available.

Double lumen endobronchial tubes

1. Allows the anaesthetist to deflate one particular lung while maintaining standard ventilation of the other
2. Includes two separate lumens each with its own cuff and pilot tube and balloon
3. Contains two curves, anterior and lateral. Anterior curve is usual to fit the upper airway and the lateral curve (right or left) to fit into the right or left bronchus
4. The machine end of the tube is connected to a Y-shaped catheter mount to connect the breathing system
5. Right sided variety provides an eye in the bronchial cuff to ventilate the right upper lobe. No eyes in left sided varity
6. Carlen's tube is commonly used and it has a carinal hook. Other varieties: Robsrtshaw, Whie etc.
7. Tubes are available in various sizes
8. Position of the tube must be checked just after intubation and immediately after positioning for surgery
9. Problems
   i. Hook can cause trauma
   ii. Relatively small lumens cause increase in resistance and difficulty in suctioning
   iii. Needs technical skill and experience
   iv. Risk of malpositioning.

Oropharyngeal Airway

1. Curved tubes, anatomically shaped, made of metal or rubber or plastic
2. Inserted through the mouth into oropharynx above the tongue to maintain the upper airway patency
3. Prevents the fall back of the tongue in an unconscious patient
4. Curved body contains air channel. Usually flattened anteroposteriorly and curved laterally
5. Flange at the oral end
6. Bite part is straight and hard, fits in between the teeth
7. Available in various sizes and in different varieties.
   i. Philips airway: Rounded rubber tube with a metal mount, flattened on cross section i.e. (Fig. 9.28)
   ii. Water's airway: Made of metal and has two holes in the sides near the pharyngeal end and right or left nipple for attachment of oxygen catheter (Fig. 9.29)
   iii. Guedel airway: Made of rubber, standard pharyngeal airway (Fig. 9.30).

Fig. 9.28: Philips airway

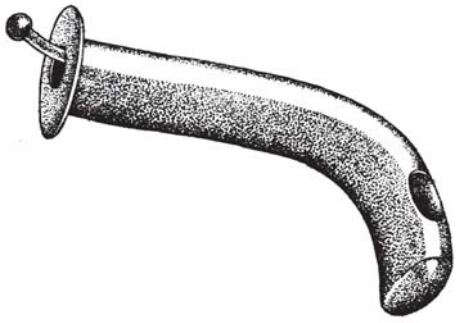

Fig. 9.29: Water's airway

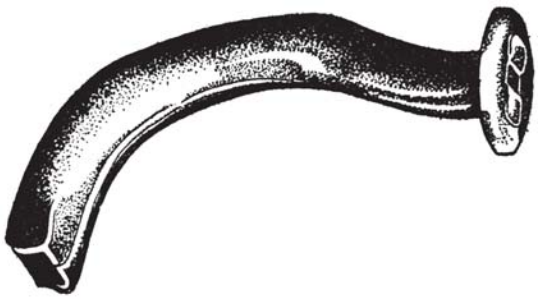

Fig. 9.30: Guedel airway

8. Complications:
    i. Trauma
    ii. Risk of gag reflex stimulation and vomiting.
9. **Note**:
    i. Air channel should be as large as possible
    ii. Cleaning at regular intervals is essential
    iii. Proper size should be selected
    iv. Patient himself clears it away when he regains consciousness.

Nasopharyngeal airway (Fig. 9.31)

1. Here the airway tube is inserted through the nose into nasopharynx. The distal end should be kept just above the epiglottis and below the base of tongue
2. Round curved tube, bevel usually left facing, flange at the proximal end

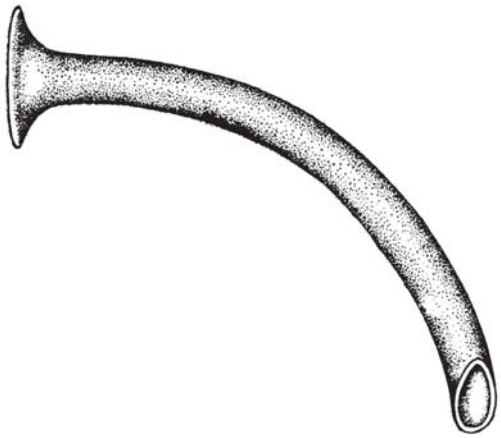

Fig. 9.31: Nasopharyngeal airway

3. Used as an alternative to oropharyngeal airway particularly when mouth cannot be opened
4. Nasotracheal suction can be done
5. Better tolerated
6. Complications:
    i. Injury
    ii. Bleeding
    iii. False passage.
7. Contraindications:
    i. Coagulopathy
    ii. Nasal sepsis
    iii. Nasal deformity.

Laryngeal mask airway (Fig. 9.32)

1. Popularly used as alternative either to face mask or endotracheal tube for anaesthesia
2. Transparent tube with an elliptical cuff resembling small face mask. It can be inflated by a pilot balloon with a self-sealing valve. The proximal or machine end provides a standard 15 mm connection. Slits at the junction between the tube and cuff prevent the epiglottis from obstructing the laryngeal mask
3. Before application, the cuff is deflated and lubricated. It is gently introduced blindly into the mouth and the cuff should lie over the laryngeal inlet. It is then inflated
4. Different sizes are available. Wide internal diameter helps reduction of flow resistance.
5. Uses:
    i. As an aid in difficult intubation
    ii. Reinforced version can be used for head/neck surgery.
6. Advantages:
    i. Easy to apply
    ii. No laryngoscopy needed.

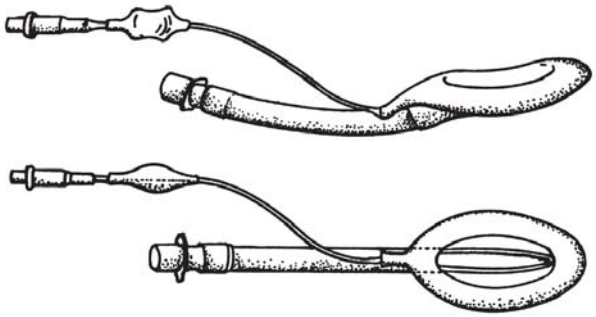

Fig. 9.32: Laryngeal mask airway

7. Disadvantages:
    i. Does not protect against aspiration of gastric contents
    ii. Airway obstruction can occur
    iii. Less reliable and predictable than using cuffed endotracheal intubation
    iv. Not a substitute for tracheal intubation.
8. Contraindications:
    i. Vomiting prone patients
    ii. Oropharyngeal mass/abscess.

Laryngoscopes

1. Device used to perform direct laryngoscopy and to aid endotracheal intubation
2. Consists of a handle and a blade. Handle provides power source/batteries. Blade is either straight or curved and is fitted in the handle. A bulb is screwed on the blade. Electrical connection occurs when the blade is opened for use
3. Various designs and shapes are available
4. Straight bladed **Magill laryngoscope** (Fig. 9.33)
    i. It picks up the epiglottis. Tip of the laryngoscope is advanced over the posterior border of the epiglottis and is then lifted directly to see the laryngeal inlet
    ii. Usually needed for intubating the neonates, infants and children. Larger blades can be used for adults.
5. Curved blade **Macintosh laryngoscope** (Fig. 9.34)
    i. Designed to fit in the oral/oropharyngeal cavity. Usually introduced through the right angle of the oral cavity and advanced to reach the vallecula. It is then lifted upwards to elevate the larynx and see the vocal cords
    ii. Left sided Macintosh blade is also available. It is meant for left handed anaesthetists and also in patients with right sided deformity, where the use of right sided blade insertion is difficult.
6. Mecoy laryngoscope

    Modified Macintosh laryngoscope with a hinged tip which is operated by lever mechanism present in handle. Helpful in difficult intubation.

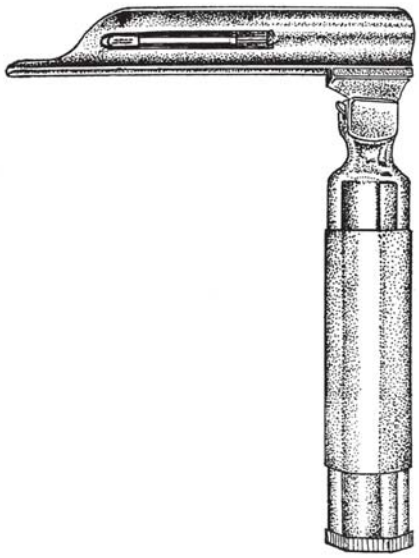

Fig. 9.33: Magill laryngoscope

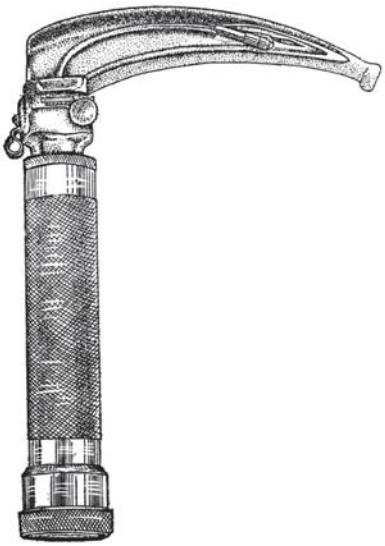

Fig. 9.34: Macintosh laryngoscope

7. Complications:
    i. Trauma
    ii. Cardiovascular reflex disturbances
    iii. Malfunction.

- Two functional laryngoscopes should always be available during endotracheal intubation.

Endotracheal tube connections

1. 15 mm disposable connections provided with plastic disposable endotracheal tubes
2. Variety of endotracheal connections available
    i. Magill connection: Curved, one end is serrated and the other end tapered to fit catheter mount. Nasal type has a sharper curve than the oral connections. Causes less resistance to gas flows. (Figs 9.35 and 9.36)

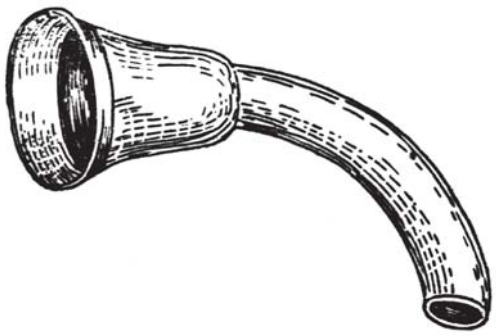

Fig. 9.35: Magill connection—Nasal

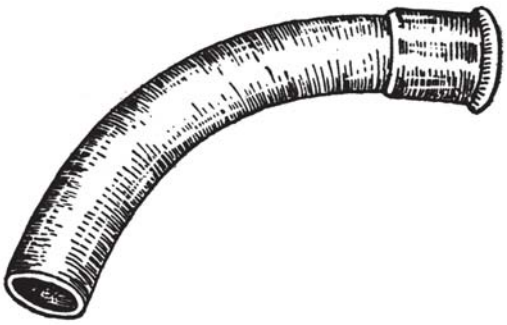

Fig. 9.36: Magill connection—Oral

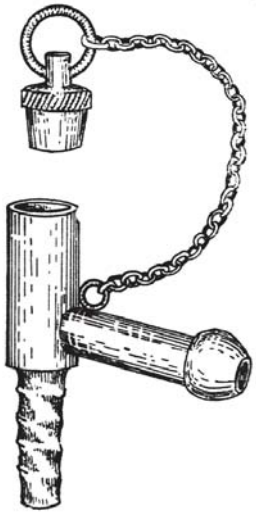

Fig. 9.37: Cobb's suction union

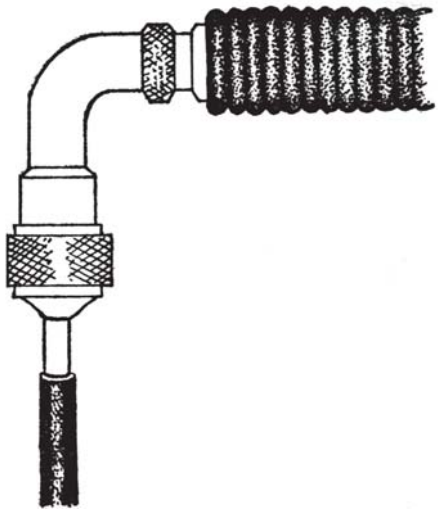

Fig. 9.38: Nosworthy endotracheal connection

ii. Rowbotham: Right angled. The end where the tracheal tube is attached is serrated and tapered
iii. Cobb's: Cobb's suction union is a modification of a Rowbotham connector. Designed to allow a suction catheter down the tube (Fig. 9.37)
iv. Nosworthy (Fig. 9.38)
v. Worcestor.

Catheter mount (Fig. 9.39)

1. Made of metal tube and its one end provides a small rubber tube
2. Machine end is metallic to be attached to the expiratory valve. Patient end attached to endotracheal tube
3. Standard size
4. Internal diameter wide, gas flow resistance is low
5. Acts as an adaptor between endotracheal tube and breathing system
6. Acts to stabilise the endotracheal tube
7. Length contributes dead space
8. In some designs there is a built-in condenser humidifier.

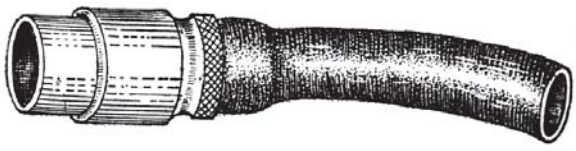

Fig. 9.39: Catheter mount

Intubating forceps (Magill) (Fig. 9.40)

1. Used to manipulate a nasotracheal or nasogastric tube through the oropharynx and into the correct position
2. Designed to be held at right hand
3. Dinner fork curvature, tip is blunt, No 'catch'
4. Other uses: To introduce throat pack, to remove foreign bodies, etc.
5. Caution : Not to injure tube cuff and soft tissues.

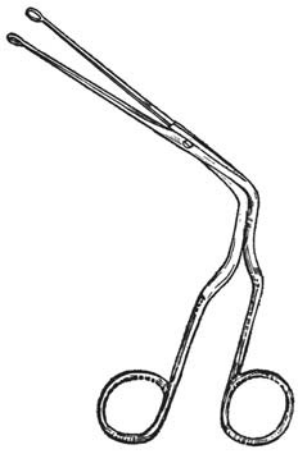

Fig. 9.40: Magill forceps

Laryngeal spray

1. Used to deposite a fine mist of local anaesthetic (lignocaine 4%) on the mucosa of the larynx and upper trachea
2. Aids to minimise the autonomic reflexes and circulatory changes related with laryngoscopy and endotracheal intubation.

Gum elastic bougie

1. It is used when the larynx cannot be visualised
2. The bougie is inserted in the trachea through the vocal cords, then the endotracheal tube is rail roaded over it
3. Bougie and the endotracheal tube should be lubricated during use.

Stilet

1. The curvature of the endotracheal tube can be altered with a malleable wire or stilet.
2. It should be lubricated before use.

Ventilators

Ideal characteristics:

1. Simple, portable, robust, economical
2. Versatility: Tidal volume upto 1500 ml with respiration rate 60/min, variable I/E ratio. Can be used in different anaesthetic systems. Can deliver any gas/vapour
3. Monitors airway pressure, inspired and exhaled minute and tidal volume, respiratory rate, inspired O_2 concentration
4. Provision of humidification
5. Alarms: Disconnection, high/low airway pressure, power failure
6. Provision of other modes of ventilation: PEEP, CPAP, IMV, etc.
7. Easy to clean and sterilise
8. Easy to use and safe
9. Facilities of manual operation and emergency back-up.

Options:

1. Whether to use sophisticated machine with ancillary apparatus built-in or relatively simple machine with separate apparatus
2. Ventilators suitable for ICU are almost universally constant flow generators and they need to be more versatile than those in OT
3. Most important single feature of a satisfactory ventilator for ICU is that it can cope with changing, sometimes rapidly changing pulmonary mechanics.

SPINAL NEEDLE (FIG. 9.41)

1. A long needle (usually 10 cm) with a stilet and a transparent hub to detect the flow of CSF
2. Different gauges : From 18 G to 25 G. 25G and smaller needles usually need introducer
3. Bevel may be cutting, traumatic or pencil like, or atraumatic with a side hole just proximal to tip
4. Atraumatic needles separate rather than cut the longitudinal fibres of dura
5. Uses:
   i. to inject local anaesthetics/opioids in subarachnoid space
   ii. to sample CSF
   iii. for intrathecal injection of drugs.
6. Disadvantages:
   i. Bloody tap
   ii. Postspinal headache.

Fig. 9.41: Spinal needle

EPIDURAL NEEDLE (FIG. 9.42)

1. Used to identify and cannulate the epidural space, to inject the local anaesthetics/opioids in epidural space
2. Usual length 10 cm marked at 1 cm intervals, has a Huber point which allows a catheter to be directed along the long axis of the epidural space. Bevel designed to be slightly oblique at 20° to the shaft
3. Stilet introducer is provided
4. Various gauges available. 16G or 18G commonly used
5. Common variety — Tuohy needle
6. Some designs may have wings
7. Shorter needles are available for paediatric use
8. Needle wall is usually thin to allow a catheter to be introduced through it.

Fig. 9.42: Tuohy needle

EPIDURAL CATHETER

1. 90 cm transparent, malleable, made of nylon or teflon
2. Distal end has two or more ports with closed and rounded tip
3. Distal part of the catheter is marked at 5 cm intervals with additional 1 cm markings between 5 to 15 cm
4. Proximal end of the catheter is connected to a Luer-lock and a filter
5. Filter (0.22 micron mesh) is bacterial, viral and foreign bodies filter. Filter should be changed every 24 hours
6. Syringe should have a special low resistance plunger to detect the epidural space
7. Disadvantages :
    i. Catheter obstruction
    ii. Kinking
    iii. Injury to epidural vessels
    iv. Malposition
    v. Infection
    vi. Transection of catheter.

NERVE BLOCK NEEDLES

1. Made of steel with Luer-lock attachment, short with blunt bevel
2. Transparent hub for early detection of intravascular prick
3. Some designs may have a side port
4. Can be connected with nerve stimulator
5. Various sizes and gauges are available
6. Insulated needles:
    i. Teflon coated with exposed tips
    ii. Current passes through the tip only
    iii. Usually have a greater diameter
    iv. Higher risk of nerve injury.

NERVE STIMULATOR FOR NERVE BLOCKS

1. Designed to produce visible muscle contractions, when the needle tip reaches the peripheral nerve or nerve plexus
2. Provides 2 leads, one to the skin and the other to the needle
3. Usually a current 0.25 to 0.5 mA is used with a frequency of 1 to 2 H_z. Stimulus is given for a short time 1 to 2 ms
4. Usually battery powered.

PULSE OXIMETRY

1. Meant for noninvasive measurement of the arterial blood oxygen saturation at the level of arterioles

2. Includes a probe with two light emitting diodes (LED) and a photodetector. Also provides a microprocessor to display oxygen saturation, pulse rate and a plethysmographic waveform of the pulse
3. Alarm limits are set for low saturation value and for high and low pulse rate
4. Mostly accurate, simple and rapid method
5. Sources of inaccurate readings:
   i. Smoking
   ii. Carbon monoxide poisoning
   iii. Nail polish
   iv. iv use of certain dyes: Methylene blue
   v. Methaemoglobinaemia.
6. Hypoperfusion and vasoconstriction can affect pulse oximetry reading
7. Excessive movement, malposition of the probe, external fluorescent light can be a source of error
8. Site of the probe placement should be checked at regular intervals.

ESTIMATION OF END-TIDAL CARBON DIOXIDE

1. Carbon dioxide concentration can be estimated directly and continuously throughout the respiratory cycle. End-tidal carbon dioxide reflects accurately arterial CO_2 tension
2. Works with the principle of infrared absorption by carbon dioxide
3. Sampling can be done both on side stream and mainstream
4. Uses:
   i. to monitor the level of ventilation
   ii. to confirm endotracheal intubation
   iii. to diagnose pulmonary embolism
   iv. Aids to diagnose malignant hyperpyrexia.
5. Loose connections and system leaks can dilute end-tidal CO_2
6. Nitrous oxide can distort the readings.

WRIGHT RESPIROMETER (FIG. 9.43)

1. Measures the tidal volume and minute volume
2. A vane manometer. A rotating vane surrounded by slits. Attached to a pointer
3. Is mounted in the expiratory limbs of the circuit. It should be as near to the endotracheal tube as possible
4. Flow is unidirectional
5. Rotation of the vane drives the pointer around the dial and the gas volume is recorded
6. Usually over read at high tidal volumes and under read at low volumes
7. Function is affected in presence of moisture
8. Mostly accurate ± 5 to 10%.

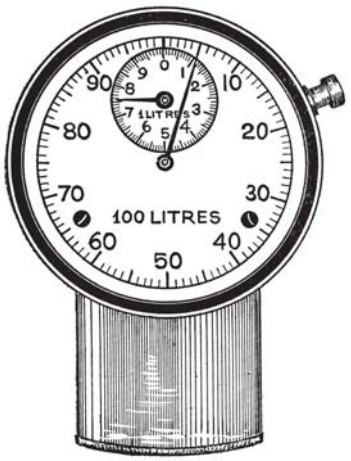

Fig. 9.43: Wright respirometer

PERIPHERAL NERVE STIMULATOR

1. Designed to monitor neuromuscular transmission. The type of neuromuscular block, the depth of block and adequate reversal of block can be judged
2. Two surface electrodes are positioned over the nerve and connected through the leads to the nerve stimulator. Supramaximal stimulus (current of 15 to 40 mA) is used to stimulate the nerve
3. Muscle contraction can be visually observed and palpated. It can be measured with the help of a pressure transducer. Electromyography can also be done.
4. **Common Nerves Used:**
    i. Ulnar nerve
    ii. Facial nerve
    iii. Posterior tibial nerver
    iv. Common peroneal nerve.

ARTERIAL BLOOD PRESSURE MONITORING

1. Clinically blood pressure measurement is done with the help of sphygmomanometer. Systolic and diastolic pressures are determined with Korotkoff sounds.
2. Oscillometry is the popular noninvasive method to measure arterial blood pressure during anaesthesia. The systolic pressure, diastolic pressure, mean arterial pressure and pulse rate can be measured, calculated aid displayed
3. A cuff with a tube is used for inflation and deflation. It is attached to a transducer and microprocessor. It provides the display and timing mechanism. Alarm limits can also be set.
4. The measurement is mostly accurate and reliable
5. Size of the cuff, arrhythmia, external pressure, etc. can affect the reading
6. Control of inflation/deflation is needed.

INVASIVE ARTERIAL BLOOD PRESSURE MONITORING

1. Provides beat-to-beat information with much reliability
2. Contains indwelling arterial cannula, a heparinised saline column, a flushing device, a transducer, an amplifier and an oscilloscope
3. Besides blood pressure monitoring, myocardial contractility, vascular tone, stroke volume can be measured
4. The arterial pressure waveform should be displayed
5. Caution:
    i. Damping or resonance can occur due to air bubble, clot, etc.
    ii. Transducer should be kept at proper position at the level of right atrium
    iii. Arterial thrombosis can occur
    iv. Risk of bleeding
    v. Risk of infection.

CENTRAL VENOUS PRESSURE (FIG. 9.44)

1. Filling pressure of right ventricle is CVP
2. Measured directly using a central venous catheter inserted percutaneously via internal jugular vein/subclavian vein/ basilic vein/external jugular vein/antecubital vein
3. CVP can be read using either a pressure transducer or water manometer
4. CVP monitoring in useful aid to blood and fluid replacement
5. Normal range of values: 0 to 6 cm H_2O
6. Complications:
    i. Air embolism
    ii. Arterial puncture
    iii. Sepsis
    iv. Pneumothorax
    v. Nerve damage.
7. CVP catheters differ in size, length, material and number of lumens.

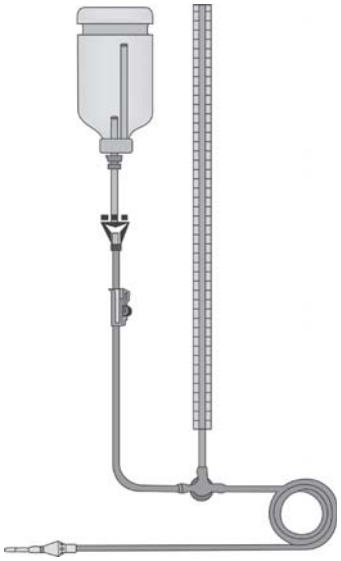

Fig. 9.44: Central venous pressure set

PULMONARY ARTERY PRESSURE MONITORING

Uses:

i. To assess the volume status of the patient when CVP is unreadable.
ii. Sampling of pure mixed venous blood
iii. Measurement of cardiac output using thermodilution method.

Indications :

1. Poor left ventricular function
2. Valvular heart disease
3. Myocardial infarction
4. ARDS
5. Major vascular surgery
6. Severe shock, haemorrhage
7. Evaluation of response of fluid therapy or administration of drugs like vasopressors, vasodilators, inotropes
8. Assessment of intravascular fluid volume
9. Pulmonary artery catheters differ in sizes and are usually 110 cm in length. These are marked at 10 cm intervals
10. These include 4 lumens :
    i. Proximal lumen: About 25 cm from tip, should lie in the right atrium. CVP can be measured
    ii. Distal lumen: Situated at the tip of the catheter, lies in a major branch of pulmonary artery. Can measure the pulmonary artery and PCW pressure

iii. Another lumen contains 2 insulated wires leading to a thermistor. Measures the temperature of blood at this site. Used for measurement of cardiac output
iv. Balloon lumen permits the introduction of about 1 ml of air into the balloon which surrounds the distal tip.

11. Catheter is inserted through a large central vein into the right atrium, right ventricle, pulmonary artery for continuous pressure monitoring.
12. Left ventricular filling pressure can also be measured.
13. Complications :
    i. Air embolism
    ii. Vascular injury, perforation
    iii. Arrhythmias, heart block
    iv. Knotting and kinking of the catheter
    v. Valvular damage
    vi. Thrombosis.

OESOPHAGEAL STETHOSCOPE

1. Helps to monitor heart and breath sounds continuously when fitted with a moulded earpiece
2. Change in heart sounds, air entry to lungs, development of abnormal breath sounds, crepitations or rhonchi can be detected readily
3. Simple, cheap, safe, noninvasive and free from electrical interference, and reliable.

BODY TEMPERATURE MONITORING

1. Monitoring of body temperature is essential and should be a routine procedure during surgery
2. Temperature probes can be thermistors, thermocouples and infrared thermometers
3. Skin temperature can be taken from axilla and core temperature can be measured from oesophagus, rectum, tympanic membrane, nasopharynx and urinary bladder
4. i. temperature in nasopharynx approximates brain temp
   ii. in oesophagus approximates cardiac temp
   iii. on tympanic membrane—Most reliable core temp
   iv. in rectum usually reads higher core temp.

OXYGEN ANALYSER

1. Inspired oxygen concentration in the anaesthetic delivery system can be measured by oxygen analyser
2. It should have a low oxygen concentration limit alarm. It should be set to sound when the inspired oxygen concentration decreases below 30%.

CHAPTER

10 Spinal Anaesthesia

Anaesthesia is produced by injection of local anaesthetic solution into the subarachnoid space when it is mixed with cerebrospinal fluid. Patients remain awake or sedated by intravenous drugs like midazolam, propofol or opioids. Skeletal muscle relaxation is profound without the need of muscle relaxants.

ANATOMICAL CONSIDERATIONS

Spine

Spinal column consists 7 cervical, 12 thoracic, 5 lumbar and 5 fused sacral vertebrae.

Vertebra consists of its body, an arch with 2 pedicles anteriorly and 2 laminae posteriorly. Transverse process is at the junction of lamina and pedicle. The spinous process arises from the junction of laminae in posterior midline. Lamina and spinous processes are joined by ligaments, but the pedicles form a gap through which the spinal nerves emerge.

Spinal Cord

It lies within the vertebral canal from foramen magnum to sacral hiatus. It is bounded anteriorly by vertebral bodies, posteriorly by laminae and laterally by pedicles.

Extension: From brainstem to termination at L_1 L_2 vertebral level, then continue as cauda equina in spinal canal.

Covering: Pia mater, arachnoid mater and dura mater.

Subarachnoid space: In between pia mater and arachnoid mater, extends from cranium to the level of S_2. Contains nerve roots and cerebrospinal fluid (Fig. 10.1).

Epidural space: In between dura mater and connective tissues covering the vertebrae and ligamentum flavum, a potential space where local anaesthetic solution is injected for epidural block. It is bounded by dura anteriorly and ligamentum flavum posteriorly, extends from the base of skull to sacral hiatus, contains nerves, fat, lymphatic vessels and the veins of epidural plexus.

The specific gravity of cerebrospinal fluid is 1.004. Most local anaesthetic solutions are of specific gravity 1.024 or more and addition of 5% dextrose make them hyperbaric solution. Some hypobaric and isobaric solutions are also described.

Movement of hyperbaric solution within the subarachnoid space depends on:

1. Gravity
2. Position of the patient
3. Curvature of the spinal cord.

- Lumbar puncture is usually made at L_3 L_4 or L_4 L_5 space and the hyperbaric solution should spread in a caudad and cephalad direction when the position is kept horizontal.
- Density of a local anaesthetic solution is the function of its concentration and the fluid in which it is dissolved. The density of CSF may range 1.001 to 1.005g/ml. Baricity is the density of the local anaesthetic solution divided by the density of CSF.
  a. Hyperbaric: Local anaesthetic solution with densities greater than 1.008 g/ml
  b. Isobaric: With densities between 0.998 and 1.007 g/ml
  c. Hypobaric: With densities less than 0.997 g/ml.

  The dose, baricity of the local anaesthetic solution and position of the patient during and after injection are most important to determine the distribution of local anaesthetic and level of anaesthesia.
- Factors influencing the spread of local anaesthetics:
  1. Position of the patient during and after injection
  2. Curvature of spine
  3. Speed of injection
  4. Barbotage
  5. Interspace chosen
  6. Drug dosage
  7. Volume of the local anaesthetic
  8. Specific gravity of the drug.

- **Physiological effects**
  1. Differential nerve block: Fibre size is an important factor that governs susceptibility of a nerve to be blocked by local anaesthetics. Sympathetic fibres are blocked to a level about two segments higher the upper segmental level of sensory block. Motor block is usually extended to within two segments below of the upper level of sensory block.
  2. Cardiovascular system
     i. Proportional to the height of block and extent of sympathetic block
     ii. Hypotension due to dialation of resistance and capacitance vessels
     iii. Bradycardia
     iv. Reduction of hepatic and renal blood flow.
  3. Respiratory system
     i. No effect on respiration in low spinal block
     ii. High block may affect phrenic nerve and cause total apnoea
     iii. Intercostal paralysis occurs in block reaching the thoracic level

iv. Thoracic block may decrease vital capacity, decrease in expiratory reserve volume and causes reduction in cardiac output and pulmonary artery pressure. Increased ventilation/perfusion imbalance.

4. Alimentory system
   i. Constricted gut with increased peristaltic activity
   ii. Nausea/vomiting.

Indications of subarachnoid block

1. Most suitable for surgery below the umbilicus
2. To get comparatively bloodless operative field
3. Obstetrical procedures: Forceps delivery, removal of retained placenta etc.
4. For vaginal or operative obstetric delivery where general anaesthesia is risky
5. For patients with medical problems like diabetes, thyrotoxicosis, respiratory or cardiovascular disorders.

Contraindications

1. Patients with anticoagulant therapy
2. Hypovolaemia
3. Infection at the injection site
4. Patients with coagulation disorders
5. Active bacterial or viral infections of peripheral or central nervous system
6. Chronic neurological disease, disseminated sclerosis, peripheral neuropathy, poliomyelitis
7. Where the sterility is not guaranted
8. Where resuscitative drugs and equipment are not available
9. Unwilling patient, patient refusal.

Technique of subarachnoid block

1. Preoperative assessment
   i. To select the patient, to examine the patient carefully, to note the cardiovascular, respiratory and haematological status
   ii. Patient should be explained regarding the procedure
   iii. Obtain the written consent properly
2. Intravenous infusion should be started before the procedure
3. Correct positioning of the patient is essential. This helps rapid performance of lumbar puncture
4. Full sterile technique should be adopted
5. Spinal anaesthesia kit with all drugs and equipment should be kept ready
6. Selection of spinal needle: 22 G and 25 G should be kept ready
7. Selection of drug is also important
8. Patient should be in lateral position. An assistant should help for proper positioning the patient, the lumbar spine is flexed to spread spinous process and enlarge the interlaminar space.
   i. Midline approach is mostly adopted
   ii. Skin of the chosen interspace (commonly L_4 and L_5) is infiltrated

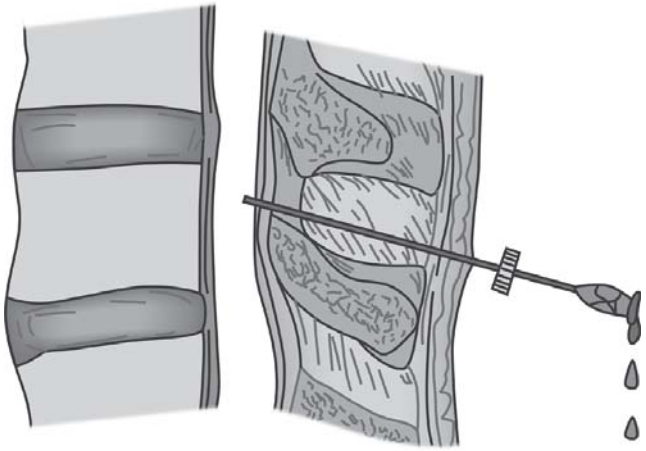

Fig. 10.1: Spinal needle in subarachnoid space

iii. Spinal needle is advanced in midline sagittal plane directed slightly cephalad (10°) toward the interlaminar space
iv. Needle will pass through skin, subcutaneous tissue, supraspinous ligament, interspinous ligament and ligamentum flavum and dura mater. A little resistance followed by a popping sensation will be felt
v. Then the stilet a removed, CSF flows freely from the needle (Fig. 10.1)
vi. Then a very slow injection of local anaesthetic solution should be given in the subarachnoid space
vii. After injection the needle with stilet should be taken out slowly
viii. Site should be dressed and the patient should be positioned supine.

9. Vasopressors should be available
10. Monitoring of pulse rate, blood pressure, respiration and ECG is essential.

Common drugs used

a. Lignocaine: Onset time 1 to 3 min; duration 45 to 75 min
b. Bupivacaine: Onset time 2 to 4 min; duration 120 to 180 min 0.75% hyperbaric.

Different types of block

1. Saddle block: Upper level of analgesia S_1
   Use: Cystoscopy, perineal, anal surgery
2. Low spinal: Upper level of analgesic L_1 T_{12}
   Use: Perineal/anal surgery, lower extremities.
3. Medium spinal: Upper level of analgesia $T_{10} - T_8$
   Use: Lower abdomen surgery, appendix, prostate, hip surgery, lower extremities

4. High spinal: Upper level of analgesia T_4
   Use: All abdominal surgery.
5. Unilateral spinal analgesia

Complications

1. Hypotension
2. Severe itching
3. Confused state
4. Nausea/vomiting
5. Headache, postdural puncture headache
6. Urinary retention
7. Backache
8. Labyrinthine disturbances
9. Cranial nerve palsy: VI nerve pasly
10. Meningitis, meningism, paraesthesia
11. Transverse myelitis
12. Cauda equina syndrome from adhesive arachnoiditis
13. High spinal anaesthesia may cause respiratory insufficiency
14. Unexpected cardiac arrest.

Postdural puncture (Postspinal) Headache

1. Normally occurs 2 to 7 days after lumbar puncture
2. May persist for upto 6 weeks
3. Causes:
   i. Leaking of CSF out of the subarachnoid space through dural puncture
   ii. Brain and its supporting structures sag
   iii. traction on pain sensitive vascular structures
4. Pain worsened by standing, sitting and relieved by supine position
5. May be frontal, occipital or both accompanied by tinnitus, vertigo, diplopia
6. Common in young patients, women
7. Depends on the size of hole in dura, the rate of CSF losses
8. Small needles 24G or lesser should be used. Use of conical tip needle
9. Blunt or rounded point tips part the dural fibres rather than transecting the dura
10. Bevel of the spinal needle should be parallel to the longitudinal dural fibres
11. Treatment:
    i. Bed rest, no ambulation
    ii. Large fluid intake
    iii. Analgesics, oral or, i.v. caffeine
    iv. Extradural infusion of saline
    v. Abdominal binders
    vi. Extradural blood patch.

- **Advantages of spinal anaesthesia**
  1. Simple and quick to perform
  2. Rapid onset
  3. Profound analgesia and muscular relaxation
  4. Low dose needed. Systemic toxicity—low risk
  5. Low risk of pulmonary aspiration
  6. Less surgical haemorrhage
  7. Physiological response to injury—less.

Note

1. Spinal cord is about 45 cm in length. It extends from medulla oblongata to its termination at conus medullaris at L_1L_2 level from which pia continues as filum terminale
2. Spinal dura ends at the level of S_2
3. Spinal cord terminates at the lower border of L_3 in the newborn and at the lower border of L_1 or upper border of L_2 in the adult
4. There are 31 pairs of spinal nerves. Their ventral and dorsal roots pass through the dura and epidural space independently and unite at the intervertebral foramina to form spinal nerve trunks. Then they divide into anterior and posterior primary rami.

CHAPTER

11 Epidural Anaesthesia

Epidural anaesthesia follows from the injection of local anaesthetic solution into the epidural space. It blocks the spinal nerve roots as they emerge from the spinal cord and traverse the epidural space.

A part of local anaesthetic may enter the CSF through dura and contribute to anaesthetic effect.

The block can be performed in the sacral (caudal block), lumbar, thoracic or even cervical regions. Lumbar approach is most popular.

Local anaesthetics for epidural anaesthesia

Choice depends on duration of operation and required intensity of motor block. Lignocaine is most widely used and it is intermediate-acting. Bupivacaine and etidocaine are long acting.

Lignocaine 1 to 2% onset 5 to 15 min, duration 60 to 90 min.
Mepivacaine 1.5% onset 5 to 15 min, duration 90 to 120 min.
Bupivacaine 0.5 to 0.75% onset 10 to 20 min, duration > 180 min.
Etidocaine 1% onset 10 to 20 min duration > 150 min.

- Addition of adrenaline 5 mg/ml to local anaesthetics prolongs their effect, decreases vascular absorption and reduces blood concentration of the drug and lessens the risk of systemic toxicity.
- Management of epidural anaesthesia is mostly similar to that of spinal anaesthesia. But the identification of epidural space during the procedure is most important.

Epidural Space

1. More or less a circular space surrounding the dural sac and its extensions
2. Extends from foramen magnum to coccyx (sacrococcygeal membrane)
3. Contents: Areolar tissue, fat, spinal nerve roots with dural sleeves, spinal arteries and venous plexus
4. Structures pierced to get the epidural space in midline plane: Skin, subcutaneous tissue, supraspinous ligament, interspinous ligament and ligamentum flavum
5. Negative pressure in epidural space
6. Following points are helpful to detect the needle in epidural space:
    i. Sudden disappearance of resistance to the advancing needle due to piercing the ligamentum flavum.

ii. Sudden ease of injection of air from the needle attached to a syringe.
iii. Hanging-drop sign: Withdrawal of hanging drop of saline placed on the hub of the needle
iv. Capillary tube method of Odom: Movement of the bubble of air in the capillary tube attached to the hub of the needle
v. spring loaded syringe attached to needle may be unloaded due to loss of resistance
vi. Inflated balloon attached to the hub of needle will collapse at the epidural space.

- **Continuous epidural analgesia**
  1. Provides better control of duration and extent of analgesia
  2. A plastic cannula is placed through the needle exactly in the epidural space
  3. The needle is then withdrawn keeping the catheter *in situ*. Local anaesthetic solution can then be repeatedly injected in the space through the catheter.
- In cases of inadvertent dural puncture following measures can be adopted:
  1. Spinal analgesia
  2. Needle withdrawn to epidural space and local anaesthetic solution can be injected
  3. Another interspace may be chosen for epidural block.

- **Extent of epidural analgesia and duration depends on**
  1. Volume and concentration (dose) of local anaesthetic
  2. Site of interspace where injection is made
  3. Position of patient after injection
  4. Speed of injection
  5. Specific gravity of the drug
  6. Presence or absence of adrenaline in local anaesthetic solution
  7. Weight, height and age of the patient and rate of injection usually seem to influence distribution of local anaesthetic in epidural space. But spread may be increased in old age as the solution cannot readily pass through the intervertebral foramen. Taller patients may need larger dose
  8. In pregnancy, spread is greater
  9. In dehydration, shock, cachexia spread is extended.

Indications of epidural anaesthesia

1. Upper and/or lower abdominal surgery, operation of lower limb, perineum, obstetric cases
2. For postoperative pain relief
3. For relief of intractable pain
4. For painless labour
5. To reduce blood loss during pelvic surgery
6. In combination with iv drugs
7. In combination with general anaesthesia.

Advantages of epidural anaesthesia

A. Against spinal anaesthesia

1. Meningitis and/or neurological complications less

2. Postspinal headache absent
3. Postoperative urinary retention not so common
4. Prolonged analgesia can be obtained
5. Haemodynamic alterations are less.

B. Against general anaesthesia

1. Causes profound analgesia and muscular relaxation
2. Can be employed in patients with respiratory, metabolic disorders
3. Physiological derangement, metabolic response to injury less
4. Spontaneous respiration, consciousness maintained
5. Nausea/vomiting less
6. Duration of anaesthesia can be prolonged by catheter technique.

• Comparison between subarachnoid and epidural block is shown in Table 11.1.

Disadvantages

1. Extra technical skill is needed
2. Time consuming procedure
3. Onset of action is slow
4. Large quantity of drug is required, so there is risk of systemic toxicity
5. Inadvertent dural puncture can occur
6. Total spinal block can occur
7. Muscle relaxation may not be complete
8. Incomplete segmental block can occur
9. Catheter technique may induce injury to venous plexus
10. Backache may be frequent
11. Haematoma, extradural abscess
12. Trauma to spinal cord and nerve roots.

Complications of epidural anaesthesia

1. Inadvertent dural tap may lead to:
   - Total spinal block
   - Postspinal headache
2. Toxicity of local anaesthetics
3. Hypotension: It may be due to systemic absorption, high sympathetic block, bradycardia with a sympathetic block to $T_{1–4}$
4. Respiratory inadequacy
5. Inadvertent injection of chemical irritants
6. Postepidural sequelae: Paraplegia, anterior spinal artery syndrome, backache
7. Failure of block
8. Nerve block may be inadequate
9. Haematoma in spinal canal
10. Extradural infection, abscess

11. Trauma to spinal cord and nerve roots
12. Prolonged analgesia or paraesthesia
13. Nausea/vomiting, shivering
14. Horner's syndrome
15. Introduction of a foreign body—very rare
16. Implantation dermoid—very rare
17. In catheter technique: Knotting of catheter, tear of catheter, misplaced catheter, etc.

Table 11.1: Comparison between subarachnoid and epidural block

	Subarachnoid block	*Epidural block*
Technique	Easy	Relatively difficult
Drug dosage	Small	Large
Onset of action	Rapid (2-8 min)	Slow (20-30 min)
Site of action	Spinal cord and spinal nerve roots	Diffusion into CSF Paravertebral nerve block
Extent of block	Extensive	Dependent of dose and volume
Intensity of block	Usually complete	May be incomplete
Segmental block	No	Yes
Success rate	100%	Missed segments, failure may occur
Quality of block	Satisfactory	Patchy block
Headache	Common	Less common
Backache	Frequent	Less frequent
Urinary retention	Frequent	Less frequent

Note

- Epidural space is widest in the midline posteriorly, in the lumbar region it is about 5 mm. A midline septum and midline tenting of the dura may present in some patients.
- Ligamentum flavum is composed of elastic fibre disposed in vertical direction, thinnest in cervical region and gradually thickened as it descends caudally.
- Epidural veins :
  No valves
  Drain the spinal cord, vertebral canal and CSF from subarachnoid space
  Connect all segments of the body from pelvis to cranium by anastomotic channels involving caval and azygos systems.

Total spinal anaesthesia

1. Mostly due to inadvertent injection into the subarachnoid space and pooling of the large quantity of drug cephalad in upper thoracic level
2. Respiratory failure due to phrenic nerve paralysis and medullary depression
3. Severe hypotension, dilated pupils
4. Convulsion

5. Management
    i. Early detection is vital
    ii. Endotracheal intubation, IPPV with 100% oxygen
    iii. iv fluids
    iv. Vasopressors.
6. Precautions
    i. Response to initial injection or subsequent top up injection should be seriously considered
    ii. Detection of epidural space should be accurate before giving injection
    iii. Resuscitation equipment and drugs should be available and kept ready
    iv. iv infusion must be established before initiating the block.

Contraindications of epidural block

1. Infection at local site
2. Severe hypovolaemia, dehydration
3. Raised intracranial pressure
4. Coagulation defects, patients with anticoagulants
5. Patient refusal
6. Presence of neurologic diseases
7. History of back surgery
8. History of back pain
9. Systemic infection.

CHAPTER

12 Caudal Anaesthesia

It is one particular type of epidural anaesthesia where the local anaesthetic solution is injected in extradural space in the sacral canal.

It can be achieved either by a single injection or by continuous infusion through a catheter into the sacral canal.

Lignocaine 2% can produce analgesia for about one and half hours.

Physiological changes

1. Cardiovascular changes—Not significant
2. Pulse rate may be slowed, BP is usually unaltered
3. Respiration not much affected
4. Gastrointestinal tone may be increased little
5. Type of block
   i. Low block: Block extends upto L_2
      Uses: Surgery on perineum, rectum, anal canal, urethra, vagina.
   ii. Mid block: Block extends upto T_{10}
      Use: Operation on pelvic organs, hernia, lower limb
   iii. High block: Block may extend upto T_4
      Operations on upper abdomen can be done.

Uses of Caudal Anaesthesia

1. Surgery of perineum
2. For painless labour
3. For relief of intractable pain in the pelvis and lower limb.
4. Therapeutic use for sciatica, low backache, etc.

Advantages

1. No postoperative headache
2. Not much physiological alterations

3. Less chance of neurological complications
4. Technically easy in children
5. Location of sacral hiatus and the technicque are easy.

Disadvantages

1. Anomalies of sacrum and caudal canal may cause technical problems
2. Much time is needed to produce the block
3. Subarachnoid injection may occur
4. Intravascular injection is possible
5. Control of height of analgesia is often difficult
6. High block may cause hypotension
7. Large volume of local anaesthetic solution may increase the risk of systemic toxicity
8. Muscular relaxation may not be adequate
9. Infection may occur in coccyx, sacrum and epidural space.

Contraindications

1. Patient refusal
2. Active diseases in CNS
3. Presence of pilonidal cyst
4. Presence of anomalies on sacrum
5. Caesarean section
6. Coagulation disorders

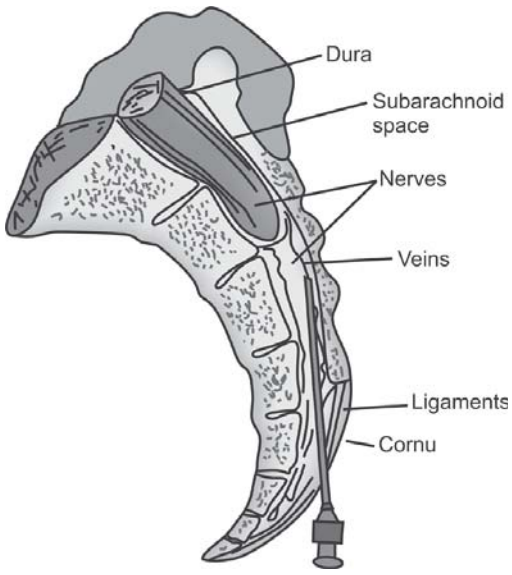

Fig. 12.1: Caudal block (needle advanced upto the level of S_2 vertebra)

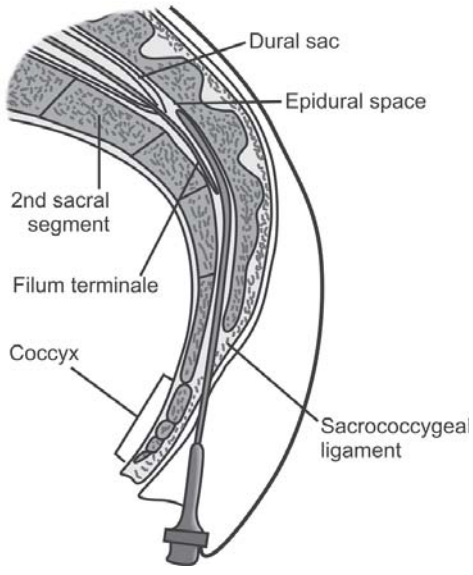

Fig. 12.2: Caudal analgesia. Catheter in caudal space

7. Uncooperative patients
8. Obese patients—technical problem
9. Sterility of equipment is not guaranteed.

Technique of Caudal Block (Figs 12.1 and 12.2)

1. Patient is in prone position
2. Sacral hiatus is identified. It is located about 3 cm from the tip of coccyx between the sacral cornua
3. A needle is inserted perpendicular to skin through the sacrococcygeal ligament until it touches sacrum
4. The needle is slightly withdrawn and the angle reduced and then advanced about 2 cm into the caudal canal
5. Aspiration test should be done to avoid subarachnoid or intravascular injection
6. Subcutaneous injection should be avoided 5 ml air may be injected and the skin should be palpated for crepitations
7. The needle should never be advanced beyond the second sacral vertebra as dural sac usually ends between S_1 and S_2
8. Local anaesthetic solution 1.5% lignocaine is injected slowly
9. Continuous caudal block can be achieved by introducing a catheter inside the caudal canal and injecting the drug carefully.

CHAPTER

13 Peripheral Nerve Blocks

FORM OF REGIONAL ANAESTHESIA

Uses

1. Anaesthesia
2. Postoperative analgesia
3. Diagnosis and treatment of chronic pain syndromes.

Advantages

1. Less physiological response to injury
2. Patient awareness
3. Intact airway reflexes
4. Profound muscle relaxation
5. Early ambulation, oral feeding possible.

Disadvantages

1. More difficult and time consuming
2. Failure/inadequate block
3. Risk of nerve damage.

Contraindications

1. Noncooperation of the patient. Unwilling patients
2. Infants and children
3. Local skin infection
4. Coagulation defect
5. Preexisting neuropathy
6. Sensitivity of local anaesthetics
7. Obscured landmarks.

COMMON NERVE BLOCKS

Cervical Plexus Block

1. Formed by the first four cervical nerves
2. **Indications** :
   i. Operations of the neck
   ii. Chronic pain syndromes
   iii. Neuralgia
   iv. Tracheostomy.
3. **Technique** : Supine position, head turned to opposite side. A line connecting the tip of mastoid process and the anterior tubercle of transverse process of C_6 vertebra indicates the plane in which transverse process lie. The transverse process of C_2, C_3 and C_4 palpated and 3 to 5 ml of local anaesthetic solution is injected after aspiration test.
4. **Complications** :
   i. Phrenic nerve block, vagus nerve block
   ii. Subarachnoid/epidural/intravascular injection
   iii. Horner's syndrome
   iv. Recurrent laryngeal nerve block.

BRACHIAL PLEXUS BLOCK (FIG. 13.1)

1. Arises from anterior rami of C_5 to C_8 and T_1. These rami unite to form three trunks, then pass over the first rib and under midpoint of clavicle to reach the apex of axilla.
2. Technique :
   A. Interscalene approach : 30 to 40 ml of local anaesthetic solution is injected into the interscalene groove opposite the transverse process of C_6. A line extended laterally from the cricoid intersects the interscalene groove at C_6. Patient lies supine with head turned to opposite side.

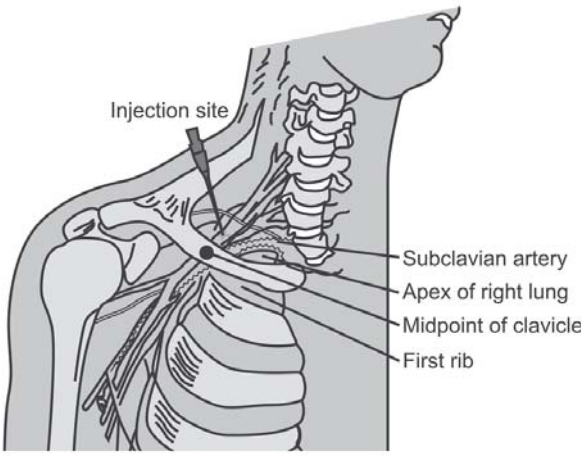

Fig. 13.1: Brachial plexus block (supraclavicular approach)

Advantages :

i. Easy
ii. No risk of pneumothorax
iii. Suitable for shoulder manipulations.

Disadvantages :

i. Absence of ulnar block
ii. Subarachnoid/epidural/intravascular injection
iii. Horner's syndrome
iv. Phrenic nerve/laryngeal nerve block.

B. Supraclavicular approach : Supine position, head turned to opposite side. A point located 1 cm above and just lateral to midclavicular point. Needle inserted immediately posterior to subclavian artery inclined at 80° to skin and directed backwards, inwards and downwards to contact first rib. About 20 ml of local anaesthetic solution is deposited just withdrawing the needle a little.

Complications :

i. Pneumothorax
ii. Block of phrenic nerve, recurrent laryngeal nerve
iii. Block of vagus nerve
iv. Risk of subarachnoid/epidural/intravascular injection.

C. Axillary approach : Arm abducted to 90° and externally rotated. Axillary artery palpated and traced towards axilla. While palpating the artery, needle is inserted just anterior to artery into the axillary sheath. Popping sensation can be felt and the needle will pulsate with arterial pulsations. 25 to 30 ml local anaesthetic solution is deposited.

Advantages :

i. No risk of phrenic nerve/vagus nerve/recurrent laryngeal nerve/stellate ganglion block
ii. No risk of subarachnoid/epidural block
iii. Least risk of pneumothorax.

Disadvantages :

i. Risk of intravascular injection, systemic toxicity
ii. Difficult in obese people
iii. Surgery of the shoulder and upper arm not possible
iv. Cannot be done when arm cannot be abducted.

MEDIAN NERVE BLOCK

A. At elbow : Injection of about 5 ml of local anaesthetic solution is given 1 cm medial to brachial artery in the flexion crease.
B. At wrist : About 5 ml of local anaesthetic solution is injected just lateral or radial side to the flexor palmaris longus tendon.

ULNAR NERVE BLOCK

A. At elbow : Injection of about 3 ml of local anaesthetic solution is given in the groove formed by the medial condyle of the humerus and the olecranon of the ulna at the elbow.
B. At wrist : The ulnar nerve can be blocked at the wrist by injection of local anaesthetic solution just medial to the ulnar artery.

RADIAL NERVE BLOCK

About 3 ml of local anaesthetic solution is injected at the wrist just lateral to the radial artery. A subcutaneous cuff of anaesthesia is also produced on the lateral and dorsal aspects of the radial side of the wrist to block the branches of radial nerve that have left the main nerve in the lower part of the forearm.

SCIATIC NERVE BLOCK (FIG. 13.2)

Sciatic nerve arises from sacral plexus which is formed by $L_{4–5}$, $S_{1–3}$. It is about 3 cm thick as it leaves pelvis.

Technique

Patient should lie on the side opposite one to be blocked. A line is drawn from the greater trochanter of the femur to the posterior superior iliac spine. Its midpoint is located. A needle is inserted about 5 cm caudal from that point. About 25 ml of local anaesthetic solution is deposited after eliciting paraesthesia. Avoid intraneural injection by withdrawing the needle a little before injecting the drug.

The block can provide adequate analgesia of the foot and lower leg.

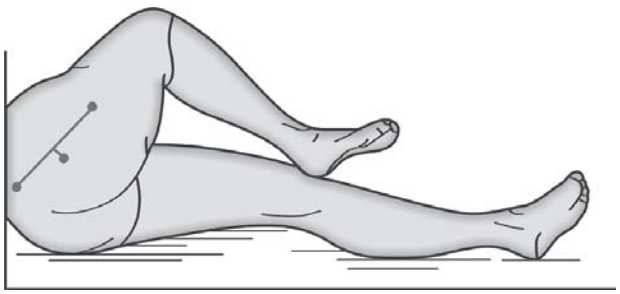

Fig. 13.2: Sciatic nerve block (posterior approach). 1. Posterior superior iliac spine; 2. Greater trochanter; 3. Site for injection

FEMORAL NERVE BLOCK

The patient is placed supine. Midpoint of the inguinal ligament is located. A line is drawn from the anterior superior iliac spine to symphysis pubis indicates inguinal ligament. Injection of 10 to 15 ml of local anaesthetic solution is given immediately lateral to the femoral nerve. Aspiration test for blood should be done before injection. Paraesthesia may be obtained.

THREE IN ONE BLOCK

1. Femoral, obturator and lateral cutaneous nerve of thigh are blocked with a single injection
2. Lumbar plexus is blocked as a fascial envelope surrounds the femoral nerve. It serves as conduit for carrying the local anaesthetic solution below the inguinal ligament cephalad to the level where the lumbar plexus forms
3. Patient is in supine position, hip slightly abducted and externally rotated. Femoral artery is palpated and the needle is inserted 2 cm lateral to femoral artery in slightly cephalad direction. About 25 ml of local anaesthetic solution is injected to block three major branches of lumbar plexus
4. Indicated in surgery in the medial, anterior and lateral aspects of the lower limb.

INTERCOSTAL NERVE BLOCK (FIG. 13.3)

1. It can be blocked at any point along the rib, posteriorly, laterally or anteriorly. Usual site is at the angle of rib
2. In upper thoracic region it is about 5 cm from midspinous point and in lower region it is about 10 cm
3. Technique : A needle inserted over the lower border of rib at the angle perpendicular to skin till the bone is touched. It is then redirected to reach the lower border until there is a sensation of *give* as it pierces external intercostal fascia. About 5 ml of local anaesthetic solution is deposited there.
4. Indications :
   i. Some operations on chest or abdomen
   ii. Intercostal drainage of empyema
   iii. Rib fracture to produce analgesia, rib resection
   iv. Pain relief for chest wounds.
5. Disadvantages :
   i. Time consuming
   ii. Large volume of anaesthetic solution needed, risk of systemic toxicity.

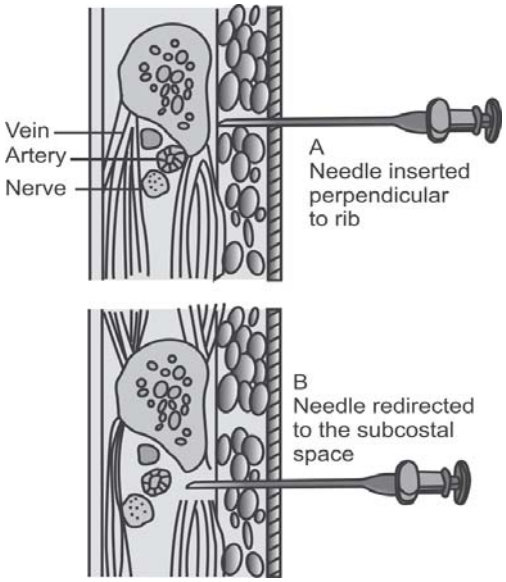

Fig. 13.3: Intercostal nerve block

FIELD BLOCK FOR REPAIR OF INGUINAL HERNIA (Figs 13.4 and 13.5)

1. Nerve supply form 11th and 12th thoracic and 1st and 2nd lumbar nerves via iliohypogastric, ilioinguinal and genitofemoral nerves.
2. Technique :
   i. A needle is inserted 2.5 cm medial to anterior superior iliac spine perpendicular to skin to pierce the external oblique aponeurosis with a sense of *click* and about 20 ml of local anaesthetic deposited to block the ilioinguinal and iliohypogastric nerves

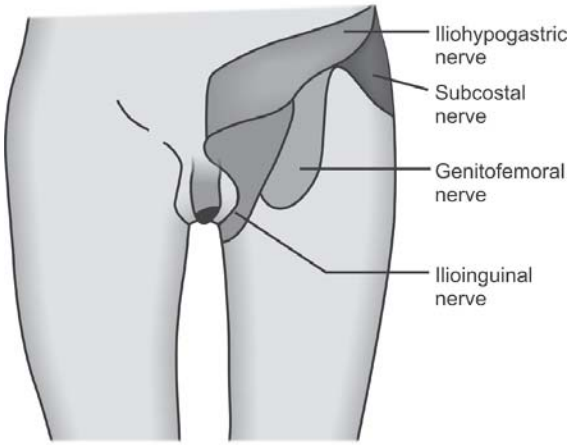

Fig. 13.4: Cutaneous nerve supply of groin

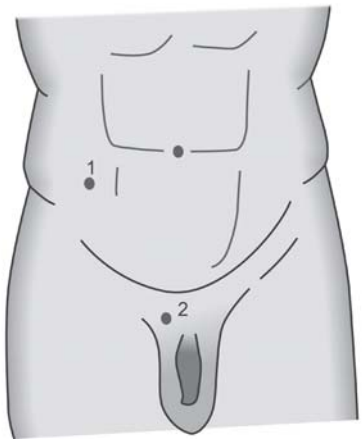

Fig. 13.5: Landmarks for field block for inguinal hernia, 1. Anterior superior iliac spine; 2. Pubic tubercle

ii. A long needle in inserted subcutaneously over the pubic spine and local anaesthetic solution injected upto the umbilicus to block the nerves coming from opposite side
iii. A needle is passed half inch above the midinguinal point to pierce the external oblique aponeurosis to block the genital branch of genitofemoral nerve
iv. Further infiltration along the course of incision.

PENILE BLOCK

1. Nerve supply of penis: From S_2, S_3 and S_4 through the dorsal nerve of penis (terminal branch of pudendal nerve). It runs along the dorsum of penis with the arteries and veins.
2. Technique :
   i. Injection of local anaesthetic to the skin on the dorsum of penis at a point 2 cm from the base, gradually passed subcutaneously around both sides of penis
   ii. Further drug is injected to make a complete ring
   iii. About 2 ml of the drug may be injected at the frenulum.

Indications of Penile Block

1. Circumcision
2. Surgery on the glans.
   - No adrenaline in local anaesthetic solution while using this block.

PUDENDAL NERVE BLOCK (FIG. 13.6)

1. Derived from anterior divisions of S_2, S_3 and S_4 nerves. It is usually blocked by infiltration just medial and posterior to ischial tuberosity.

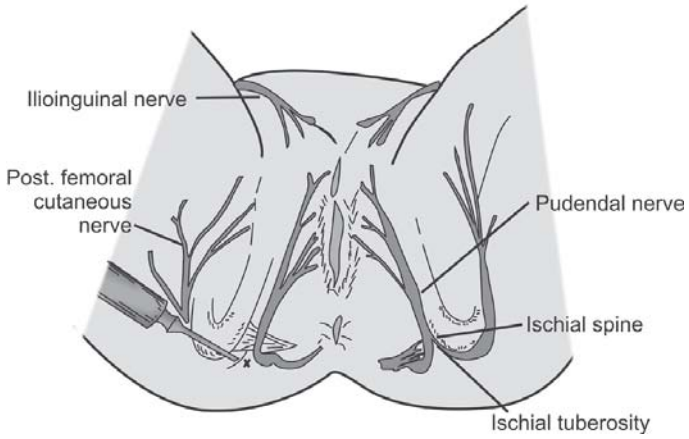

Fig. 13.6: Innervation of female perineum and transperineal pudendal nerve block

2. Indications :
   i. Episiotomy
   ii. Forceps delivery
   iii. Repair of tears of perineum
   iv. Operation on piles.
3. Technique :
   A. Transperineal approach: Lithotomy position. Skin wheal at the posteromedial margin of ischial tuberosity. A needle is passed through the wheal for about 1 inch and about 5 ml of local anaesthetic solution is injected.
   Needle is further introduced into the ischiorectal fossa for further injection of the solution.
   B. Transvaginal approach: Ischial spine is located by placing the index finger in vagina. A long needle guided lateral to the finger is directed into the region of ischial spine and about 10 ml of local anaesthetic solution is deposited there. The injection is repeated on the other side.

STELLATE GANGLION BLOCK

1. Formed by the fusion of the inferior cervical ganglion and first thoracic ganglion
2. Situated between the transverse process of C_7 vertebra and neck of 1st rib usually on the anterolateral surface of the body of C_7 vertebra.
3. Indications :
   To release vascular tone as in thrombosis, embolism and spasm of the vessels of head, neck and upper extremity.
4. Technique : Supine position, head extended on a pillow. Retracted sternomastoid muscle laterally and located the transverse of process of C_6 vertebra. This is at the level of cricoid cartilage.

The needle is inserted through the skin over the transverse process and advanced 1 to 1½ inch until it makes the contact the bone, C_7. The needle is withdrawn a little and local anaesthetic solution is deposited.

5. Signs of successful block :
   Horner's syndrome:
   Ptosis
   Miosis, enophthalmos
   Nasal congestion
   Vasodilation
   Anhydrosis
   Increased skin temperature.
6. Complications :
   i. Pneumothorax
   ii. Intravascular injection usually in vertebral artery
   iii. Block of cardioaccelerator fibres
   iv. Hoarseness
   v. Spinal/epidural block
   vi. Perforation of oesophagus
   vii. Brachial plexus block
   viii. Phrenic nerve block.

COELIAC PLEXUS BLOCK

1. Largest plexus of sympathetic nervous system.
2. Innervates the abdominal organs such as pancreas, liver and stomach, etc.
3. Technique: A long needle is introduced about 8 cm from midline at the lower edge of 12th rib and advanced to reach the body of L_1 vertebra at a depth of about 10 cm. It is slightly withdrawn and redirected to slide of the vertebral body. Needle position may be confirmed by radiography or computed tomographic scan. About 30 ml of anaesthetic solution is deposited.
   Indications :
   i. To relieve visceral pain/cancer pain
   ii. Management of acute pancreatitis
   iii. To treat pancreatic cancer pain, alcohol or phenol is used.

Complications

1. Hypotension
2. Haematoma, visceral puncture.
3. Intraarterial injection/systemic toxicity
4. Spinal/epidural anaesthesia

INTRAVENOUS REGIONAL ANAESTHESIA (BIER'S BLOCK)

1. A simple and easy method of providing anaesthesia of the arm or leg by intravenous injection of a large volume of anaesthetic solution when the circulation of the limb is occluded by a suitable tourniquet.
2. Method : An intravenous catheter is inserted on the distal part of the limb and the limb is exsanguinated by applying an Esmarch bandage.

   The tourniquet is inflated to about 50 mm Hg above the systolic pressure.

   The local anaesthetic solution (25 to 50 ml for arm and 100 to 200 ml for leg) is injected slowly. Usually 0.5% lignocaine is employed. Double tourniquet may be used to eliminate tourniquet pain.
3. Onset of anaesthesia is rapid, muscle relaxation is good. Duration of anaesthesia depends on the time of inflation of tourniquet. Recovery is good.
4. At the end of operation tourniquet is released, sensation and muscle tone return within a few minutes.
5. Complications :
   i. Systemic toxicity
   ii. Methaemoglobinaemia, if prilocaine is used.
6. Contraindications :
   i. History of drug sensitivity
   ii. Patients with liver disease, cardiac disease
   iii. In myasthenia gravis
   iv. Prolonged surgery.

CHAPTER

14 Complications of Anaesthesia

Anaesthesia cannot be practised without any accident and complications. But most of them can be pevented by taking adequate measures. If the complications arise, these must be diagnosed and treated accordingly in proper time.

NAUSEA AND VOMITING

1. Nausea common in females, and children, after prolonged anaesthesia, vomiting prone patients
2. Pre-and postoperative medications: Morphine, pethidine
3. Some anaesthetic agents like ether, cyclopropane
4. Site of operation: Abdominal surgery, laparoscopy, strabismus surgery, orchidopexy, etc.
5. Hypoxia from any cause
6. Other factors: Pregnancy, gastric dilation, toxaemia.

Dangers of Vomiting

1. Pulmonary aspiration
2. Dehydration, fluid and electrolyte imbalance, acid base imbalance
3. Hypoxia due to airway obstruction
4. Raises intraocular, intrathoracic, intraabdominal and intracranial tensions
5. Increases the incidence of postoperative lung complications.

Prevention

1. Adequate preparation, preoperative fasting for at least 4 to 6 hours
2. Avoid morphine, pethidine, etc.
3. Avoid hypoxia, hypotension and drugs like ether, chloroform
4. Administer antiemetic drugs like prochlorperazine, metoclopramide, phenothiazines, etc.

Management

1. Proper tracheobronchial suction, toilet, nursing care.
2. Tonsillar position
3. Oxygenation
4. Gastric suction
5. Ondansetron 4 to 6 mg.

POSTANAESTHETIC RESTLESSNESS (AGITATION)

Factors Responsible

1. Postoperative pain
2. Hypoxaemia
3. Drug effect:
    i. Ketamine
    ii. Barbiturates, hyoscine, promethazine
    iii. Addiction of alcohol, opium or other drugs.
4. Psychological make-up of the patient
5. Elderly patients
6. Toxic confusional state.

Manifestations

1. Tachycardia
2. Tachypnoea
3. Hypotension
4. Cyanosis, pallor, sweating
5. Hypoxaemia.

Management

1. Diagnosis of specific cause and treatment accordingly.
2. Patient's psychology needs consideration.
3. Analgesics in presence of pain. Hypoxaemia must be ruled out before prescribing analgesics
4. Oxygenation in cases with hypoxia.

HEADACHE

Factors Responsible

1. Personality of the patient should be considered
2. Duration of surgery: The incidence is inversely related
3. Drug effect: Halothane
4. Postspinal headache (see chapter on Spinal Anaesthesia)

Management

1. Diagnosis of causative factors and treatment accordingly
2. Sedative/hypnotic/analgesic may be helpful.

RESPIRATORY OBSTRUCTION

A. Upper airway obstruction

1. Oedentulous patient
2. Overweight, short necked patient
3. Fall back of tongue
4. Swelling, oedema, tumours in supraglottic region
5. Congenital subglottic stenosis, vascular ring
6. Foreign bodies, mucus, saliva, blood, etc.
7. Epiglottitis, oedema glottis
8. Laryngotracheobronchitis
9. Laryngeal spasm
10. Large goitre, malignant thyroid tumour
11. Collapsing trachea
12. Damage of recurrent laryngeal nerve
13. Big haematoma in the neck
14. Mechanical obstruction: Obstruction of intubated trachea: Bite, kinking, pack pressure, overinflation of cuff, foreign bodies, tube bevel against tracheal wall, badly placed Boyle Davis gag or palatal gag, etc.

B. Lower airway obstruction

1. Bronchial asthma
2. Bronchopneumonia
3. Aspiration pneumonitis
4. Unintentional endobronchial intubation leading to hypoxaemia, bronchospasm, pulmonary collapse, etc.

Clinical Features

1. Noisy breathing, hurried respiration
2. Rocky movement of the chest
3. Vigorous abdominal excursion
4. Alae nasi moving, flaring of nostrils, tracheal tug
5. Suction of sternal notch and intercostal space
6. Auditory signs only in partial obstruction, no phonation in complete obstruction
7. Hypoxaemia, cyanosis
8. Inspiratory stridor in upper airway obstruction. Expiratory stridor in lower airway obstruction.

Management of upper airway obstruction

1. Establish and/or improve the airway
2. Ventilate the patient
3. Endotracheal intubation, IPPV

4. Oxygenation transtracheally
5. Tracheostomy in extreme cases
6. Treat the cardiovascular instability
7. Further treatment according to aetiology.

LARYNGOSPASM

Causes

1. Following induction with thiopentone
2. Irritation caused by blood, saliva, foreign bodies
3. Instrumentation: Laryngoscopy, intubation
4. Certain operations: Anal stretch, breast surgery, dilatation of cervix
5. Following extubation under light plane of anaesthesia
6. Trauma to recurrent laryngeal nerve during thyroid surgery.

Management

1. 100% oxygenation with respiratory assistance
2. Transtracheal oxygenation
3. Intubation following use of suxamethonium on rare occasions.

EPIGLOTTITIS

1. Common in children between 2 to 6 years
2. Mostly bacterial infection
3. Total upper airway obstruction can occur at anytime
4. Clinical features:
    i. inspiratory stridor
    ii. pharyngitis
    iii. fever
    iv. restlessness
    v. tachycardia
    vi. cyanosis
    vii. swollen epiglottis
    viii. Blood exam: Neutrophilia.

Management

1. Bed rest, oxygenation
2. Urgent endotracheal intubation
3. Tracheostomy in extreme cases
4. iv fluids, antibiotics, corticosteroids
5. Adequate nursing care.

LARYNGOTRACHEOBRONCHITIS (CROUP)

1. Viral infection of upper airway, common in infants
2. Clinical features: Inspiratory stridor, croupy cough, rhinorrhoea, fever, blood exam: Lymphocytosis, lateral chest radiography reveals narrowing of subglottic area
3. Management:
    i. Oxygenation
    ii. Humidification of inspired gases
    iii. Aerosolised racemic adrenaline
    iv. Steroids
    v. Fluids
    vi. Endotracheal intubation in extreme cases
    vii. Adequate nursing care.

POSTINTUBATION LARYNGEAL OEDEMA

1. Common in infants and children. Oedema of 1 mm in neonate can decrease laryngeal cross section by 65%.
2. Causes:
    i. Trauma
    ii. Infection
    iii. Sensitivity of drugs
    iv. Incautious instrumentation
    v. Mechanical injury by oversized tube, overinflation of cuff etc.
    vi. Aggravated in presence of anaemia, hypoxia and hypotension.
3. Management:
    i. Keep the patient upright in bed
    ii. Cool humidified mist inhalation
    iii. Adrenaline through nebulizer
    iv. Corticosteroid
    v. Antibiotics
    vi. Tracheostomy in extreme cases.

BRONCHOSPASM

Causes

1. Preexisting bronchial asthma, chronic obstructive pulmonary diseases
2. Following inhalation of foreign bodies, irritant vapours
3. Following instrumentation in light anaesthesia
4. Certain drugs: Propranolol
5. During development of pulmonary oedema

Management

1. Oxygenation
2. Salbutamol, terbutaline
3. Hydrocortisone
4. Aminophylline
5. Antibiotics
6. Increase the depth of anaesthesia. Halothane may be helpful.

HICCUPS

1. Incoordinated diaphragmatic movement due to vagal stimulation
2. Inducing agents: Methohexitone, althesin
3. Can occur in spinal/epidural block
4. Common in upper abdominal surgery
5. Hypocapnia, unduly light anaesthesia
6. Insufficient doses of nondepolarising muscle relaxants
7. Management:
    i. Manual ventilation
    ii. Deepen anaesthesia
    iii. More muscle relaxants
    iv. Stimulation of the postnasal space with a suction catheter may help.

PNEUMOTHORAX

1. Serious problem of anaesthesia. Nitrous oxide diffusion enlarges pneumothorax, produces haemodynamic disturbances. Positive pressure ventilation intensifies the problem and may result tension pneumothorax.
2. Causes:
    A. Traumatic: Chest injury, rib fracture
    B. Iatrogenic: Cannulation of subclavian/internal jugular vein
    Brachial plexus block, inadvertent barotrauma, cervical/thoracic injury
    C. Spontaneous: Congenital bullae, emphysema, lung abscess, asthma, rapid decompression of divers.

Management

A chest drain should be given before inducing anaesthesia in presence of known pneumothorax specially when IPPV is needed.

Pneumothorax during anaesthesia

1. Diagnosis: Unexplained tachycardia, hypotension, bronchospasm, cyanosis, altered breathing, surgical emphysema
2. Management:
    i. Discontinue N_2O, administer 100% oxygen
    ii. Tension pneumothorax can be relieved by introducing a cannula through the second intercostal space in midclavicular line temporarily
    iii. Underwater seal intercostal drain should be given.

ASPIRATION PNEUMONITIS

1. Inhalation of gastric contents
2. Common in obstetric cases, children, elderly patients, patients with full stomach, vomiting prone subjects and certain drug effect
3. Gastric fluid volume of 25 ml or more and/or its pH less than 2.5 are needed to produce acid aspiration syndrome
4. Other causative factors may include aspiration of food material, hypertonic solutions, irritating and infective materials
5. Pathophysiology
    i. Usually nonspecific in character, large intrapulmonary shunt, increased lung water, loss of pulmonary compliance
    ii. Other mechanism: Reflex airway closure, alteration of surfactant, interstitial and alveolar oedema
    iii. Highly acidic material causes loss of alveolar capillary permeability, intense inflammation, oedema, noncardiogenic pulmonary oedema, haemorrhage and necrosis of airways and lung parenchyma
    iv. Aspiration of large volume may lead to acute respiratory failure
    v. Infection, lung abscess.

Manifestations

1. Respiratory insufficiency, hypoxaemia, tachypnoea
2. Bronchospasm, cyanosis
3. Tachycardia, hypotension
4. Crepitations and coarse asthmatic rhonchi
5. Chest X-ray: Areas of density
6. Pulmonary oedema.

Management

1. Head down tilt, tracheobronchial toilet
2. Careful bronchoscopic suction
3. 100% oxygenation, endotracheal intubation, IPPV
4. Bronchodilators
5. Steroids
6. Broad spectrum antibiotics
7. Judicious administration of fluids
8. Diuretics
9. Ventilatory support
10. Adequate monitoring. Proper nursing care.

Prevention

1. Adequate preparation for anaesthesia
2. Identify the patients at risk and take necessary precautions

3. Adequate preoperative fasting
4. Nasogastric suction of gastric contents before starting anaesthesia
5. Intragastric pressure should not be allowed to increase
6. Pharmacological approach:
    i. Sodium citrate solution
    ii. Use of ranitidine, cimetidine
    iii. Metoclopramide, antiemetic drugs, ondansetron.

HYPOTENSION

- Decrease of systemic blood pressure below 70 mm Hg.

Common Causes

1. Hypovolaemia : Blood loss, inadequate fluid replacement
2. Cardiovascular : Myocardial infarction, arrhythmias, pulmonary embolism
3. Respiratory : Pneumothorax, airway obstruction, prolonged IPPV with PEEP
4. Haematologic : Disseminated intravascular coagulation, mismatched blood transfusion
5. Neurogenic : Neurogenic shock, vagal over activities
6. Drug effect:
    i. Inducing agent: Overdose, relative overdose in very young/elderly/very ill patients.
    ii. Volatile agents: Halothane, enflurane, isoflurane
    iii. Muscle relaxants: Tubocurarine
    iv. Narcotics/sedatives/analgesics.
7. Spinal/epidural anaesthesia
8. Hypersensitivity reactions
9. Posture: Sudden change of posture, abnormal posture, rough handling
10. Surgical: Traction of abdominal/thoracic viscera, handling of baroreceptors, obstruction of venous flow by abdominal packs/retractors, strabismus surgery, prolonged surgery
11. Following controlled hypotension
12. Following hypothermia
13. Drug interaction.

Management

1. The underlying cause should be detected and treated accordingly
2. Fluid and volume replacement
3. Blood transfusion, iv fluid therapy
4. Vasopressors
5. Steroids
6. Reversal of metabolic acidosis
7. Alpha blocking drugs: Phenoxybenzamine to improve organ perfusion.

POSTOPERATIVE HYPERTENSION

Causes

1. Preoperative causes: Preexisting hypertension, anxiety, pain, preeclampsia, stoppage of antihypertensive medication
2. Operative causes: Hypoxia, hypercarbia, fluid overload, thyroid overactivity, less analgesia, manipulation of adrenal tumours
3. Drug effect: Use of vasopressors, ketamine, adrenaline, ergometrine
4. Postoperative causes: hypoxia, hypercarbia, after coronary artery bypass surgery, renal transplantation, enhanced sympathetic nervous system overactivity
5. Drug interaction : MAO inhibitors
6. Hypertensive response to laryngoscopy, coughing, straining on endotracheal tube.

Management

1. Prevention and treatment of the underlying cause
2. Monitoring of blood pressure is essential
3. Avoid hypoxia and hypercarbia
4. iv infusion should always be cautious
5. Adequate ventilation
6. Antihypertensive drug therapy.

CARDIAC ARRHYTHMIAS

Causes

1. Hypoxia
2. Hypercarbia, spontaneous ventilation
3. Anaesthetic agents: Halothane, cyclopropane, trichloroethylene
4. Catecholamines: Local anaesthetics with adrenaline. Adrenaline induced arrhythmia is common with halothane
5. Hypokalaemia
6. Hyperkalaemia
7. Reflex arrhythmia during light anaesthesia
8. Drug effect: Digoxin, tricyclic antidepressants, aminophylline.

Management

1. Correction of hypercapnia, hypoxia, or hypokalaemia
2. Reduction of inspired halothane concentration
3. Avoid adrenaline or adrenaline containing drugs
4. Monitoring of pulse, blood pressure, ECG
5. Supraventricular tachycardia: iv verapamil or beta blockers. Cardioversion in extreme cases.
6. Atrial flutter/fibrillation: Diagoxin, lignocaine, cardioversion
7. Ventricular tachycardia: iv lignocaine, mexiletene, procainamide, phenytoin, beta blockers.

POSTOPERATIVE BRADYCARDIA

Pulse rate is usually below 60/min.

Causes

1. Raised intracranial pressure, head injury
2. Traction of abdominal/thoracic viscera, carotid artery
3. Drugs: Halothane, suxamethonium, digitalis, β blockers
4. Hyperkalaemia
5. Jaundice
6. Aggravated by muscle diseases, burns, recent hemiplegia.

Management

1. Atropine sulphate
2. Isoprenaline
3. Cardiac pacing.

POSTOPERATIVE TACHYCARDIA

Causes

1. Hypovolaemia, dehydration 2. Hypoxaemia 3. Stress, anxiety 4. Fever 5. Anaemia 6. Congestive cardiac failure 7. Pain 8. Drugs: ether, cyclopropane, gallamine, atropine 9. Hyperthyroidism.

Management

1. May not need treatment unless associated with congestive failure
2. Treatment of the underlying cause:
    i. If there is no congestive failure, propranolol iv or oral
    ii. In presence of congestive failure, digitalis is indicated
    iii. Specific drug therapy to tackle haemodynamically significant cardiac tachydysrhythmias: Verapamil, lignocaine. Electrical cardioversion in extreme cases.

POSTOPERATIVE PYREXIA

- Mild rise of body temperature is common in postoperative period due to metabolic response to injury
- Causes of fever:
  1. Infection
  2. Respiratory infection
  3. Urinary tract infection
  4. Thrombophlebitis
  5. Any rigor or convulsion

6. Drugs: Atropine, hyoscine
7. Associated diseases: Malaria, kalaazar, influenza, bacteraemia, septicaemia, etc.

Management

1. Bed rest
2. Antipyretics
3. Cooling
4. Fluids, oxygenation
5. Antibiotics
6. Treatment of causative factors.

POSTOPERATIVE SHIVERING

Causes

1. Following anaesthesia with halothane/cyclopropane/ether/thiopentone
2. Cold ambient temperature
3. Following blood transfusion
4. In cold stage of malarial fever.

Manifestations

1. Metabolic rate, and oxygen consumption increase
2. Increased carbon dioxide production
3. Ventilation increases
4. Hypoxaemia.

Management

1. Oxygenation
2. Methylphenidate, pethidine
3. General supportive measures, nursing care
4. Skin surface warming, if associated with decreased body temperature.

POSTANAESTHETIC CONVULSION

Causes

1. Known epileptic, convulsion-prone type of patient
2. Head injury, cerebral thrombosis/embolism
3. Hypoglycaemia, hypernatraemia
4. Brain surgery, cerebral hypoxia
5. Drug effect: Ether, enflurane, halothane, local anaesthetic toxicity
6. Eclampsia
7. Hyperpyrexia

8. Hysteria
9. Incidental tetanus convulsion.

Management

1. Prevention: Hypoxia, electrolyte imbalance and hypoglycaemia should be prevented
2. Epileptic patients should be covered by anticonvulsant drugs before and after surgery
3. Maintenance of patent clear airway
4. Oxygenation and IPPV, whenever needed
5. iv diazepam, antiepileptic drugs
6. Treatment of underlying cause.

POSTOPERATIVE BLEEDING

Causes

1. Slipped ligature
2. Haemorrhagic disorders, disseminated intravascular coagulation, hypofibrinogenaemia, vit-K deficiency
3. Following massive blood transfusion
4. Obstetric causes: Abortion, antepartum/postpartum haemorrhage, dead foetus, amniotic fluid embolism
5. Patients with anticoagulants
6. Hereditary haemorrhagic disorders: Haemophilia
7. Patients with liver disease
8. Preoperative hypotension and subsequent rise of blood pressure.

Management

1. Adequate precautionary measures
2. Preoperative specific tests: Platelet count, bleeding time, prothrombin time, partial thromboplastin time, fibrinogen content
3. iv infusion, fresh blood transfusion
4. Treatment of underlying cause
5. Reexploration in case of slipped ligature
6. Adequate correction of clotting factors
7. Overdose of heparin or oral anticoagulants should be reversed by protamine or vitamin K respectively.

POSTOPERATIVE JAUNDICE

A. Prehepatic causes:
   1. Mismatched blood transfusion, extensive haematoma
   2. Bile leak

3. Severe sepsis
4. Cholestasis.

B. Hepatocellular causes:
1. Severe hypotension
2. Viral hepatitis
3. Severe hypoxaemia
4. Drugs
   i. Haemolysis: Methyl dopa, phenacetin
   ii. Hepatotoxic: Direct dose related: Carbon tetrachloride, chloroform, paracetamol, methotrexate
   Hypersensitivity: MAO inhibitors, halothane, isoniazid
   iii. Cholestasis: Anabolic steroids, oral contraceptives, androgenic steroids
   iv. Mixed reaction: Phenothiazines, tricyclic antidepressants, chlordiazepoxide, erythromycin.

C. Posthepatic causes:
1. Ligation of bile duct
2. Incidental obstructive jaundice, gallstones
3. Pancreatitis, cholangitis.

Management

1. Proper diagnosis of type of jaundice is important
   i) Liver function tests should be done
   ii) Drug history, if any should be noted.
2. Withdraw the hepatotoxic drugs
3. Treat hypoxia, hypotension and infection
4. General supportive measures
5. No specific treatment for viral hepatitis
6. Conservative treatment, only specific treatment in extrahepatic obstructive jaundice is surgery.

POSTOPERATIVE HYPOXIA

1. Inadequate arterial oxygenation or elimination of carbon dioxide. PaO_2 below 60 mm Hg and $PaCO_2$ above 49 mm Hg denotes respiratory insufficiency.
2. Causes:
   i. Inadequate ventilation, prolonged anaesthesia, after upper abdominal and thoracic surgery
   ii. Overdose of analgesics and anaesthetics
   iii. Hypocapnia, CO_2 narcosis
   iv. Preexisting conditions: Kyphoscoliosis, poliomyelitis, myasthenia gravis, emphysema etc.
   v. Upper airway obstruction
   vi. Lower airway obstruction: Bronchospasm
   vii. Pulmonary embolism, pulmonary oedema, pneumothorax, atelectasis
   viii. Hypothermia, hyperthermia, severe shock, overhydration

ix. Use and misuse of muscle relaxants, inadequate decurarisation, incomplete hydrolysis of succinylcholine.

Manifestations

1. Hypoxia
2. Cyanosis
3. Hypercarbia
4. Respiratory depression
5. Pulse bounding and blood pressure elevated at first but later there is hypoxic cardiac depression and cardiac arrest.

Management

1. Adequate preventive measures should be taken
2. Maintain patent clear airway
3. Oxygenation, endotracheal intubation and IPPV, whenever needed
4. Treatment of the underlying cause.

DELAYED RECOVERY FROM ANAESTHESIA

A. Causes:
   1. Overdose of narcotics, analgesics and/or anaesthetics
   2. Hypoxia, hypercarbia, acid base defect, fat/air embolism, brain trauma, severe hypotension
   3. Incidental diseases: Cerebrovascular accident, myocardial infarction, myxoedema, hypopituitary states, diabetic or hypoglycaemic coma, adrenal insufficiency, uraemia, moribundity.
   4. Preexisting cerebral oedema, liver failure, renal failure, meningitis, encephalitis.

B. Diagnosis of coma is most important. Careful history, thorough examination and proper laboratory investigations may be needed.

C. Management:
   i. A clear patent airway should be maintained
   ii. 100% oxygenation and IPPV in cases of repiratory inadequacy
   iii. Care of the mouth and eyes
   iv. General supportive measures, adequate nursing care
   v. Nutritional care: Maintain fluid, electrolyte and acid base balance
   vi. Treatment according to underlying cause.

HYPERVOLAEMIA

Causes

1. Overhydration
2. Caval compression
3. Pregnancy

4. Hypoproteinaemia
5. Myocardial failure
6. Water intoxication following TURP.

Manifestations

Elevated CVP, tachycardia, low arterial pressure, distended neck veins, a third heart sound, pulmonary crepitations, pulmonary oedema.

Pulmonary artery and pulmonary capillary wedge measurement are often needed.

Management

1. Judicious administration of fluids
2. Inotropic support: Dopamine, digoxin
3. Loop diuretics
4. General supportive measures.

POSTOPERATIVE RENAL FAILURE

Causative Factors

1. Mismatched blood transfusion
2. Some diseases: Diabetes, jaundice, DIC, congestive cardiac failure, urinary tract infection
3. Drugs : Overdose of analgesics, dextran, methoxyflurane, tetracycline, rifampicin, cephalosporins
4. Miscellaneous: Shock states, extensive burns, severe infection, biliary tract surgery in presence of obstructive jaundice, major trauma with myoglobinuria, following open heart and aortic surgery.

Manifestations

1. Sudden decline in renal function
2. Urine volume scanty, oliguria
3. Rise in plasma creatinine, hyperkalaemia, hypocalcaemia, hyperphosphataemia, acidosis
4. Anaemia
5. Associated gastrointestinal haemorrhage, sepsis, respiratory failure
6. High output nonoliguric renal failure.

Management

1. Prevention: Judicious fluid replacement, proper grouping and cross matching of blood, avoidance of nephrotoxic drug
2. Prompt recognition and effected treatment of the underlying cause
3. Peritoneal dialysis
4. Haemodialysis.

MALIGNANT HYPERPYREXIA

1. Inherited neuromuscular disorder and there is a defect in calcium binding in sarcoplasmic reticulum of skeletal muscle cells. With some triggering agents like halothane, suxamethonium, etc. calcium is released into the cytoplasm producing myofibrillar contraction, increased lactic acid and CO_2 production, increased O_2 consumption and enormous production of heat. Membrane stability is lost and potassium leaks from the cells causing hyperkalaemia.
2. Susceptibility is inherited as an autosomal dominant and myopathic syndrome may sometimes be associated.

Manifestations

1. Unexplained tachycardia, cardiac dysrhythmia
2. Arterial hypoxaemia
3. Increased body temperature
4. Increased CO_2 production
5. Masseter muscle spasm following injection of suxamethonium; muscle rigidity
6. Increased plasma creatine kinase and myoglobin concentrations
7. Hyperkalaemia
8. Metabolic acidosis.

Diagnosis

1. Past history
2. Myopathic syndrome
3. Elevation of plasma creatine kinase
4. Skeletal muscle biopsy.

Management

1. All inhalation agents and suxamethonium should be discontinued
2. Hyperventilation with 100% oxygen
3. Dentrolene 2.5 mg/kg iv initially followed by repeat doses every 5-10 min until symptoms are controlled
4. Sodium bicarbonate to combat metabolic acidosis
5. Lignocaine or procainamide to treat ventricular arrhythmias
6. Active cooling
7. Adequate hydration
8. Maintain urinary output
9. Adequate monitoring is essential.

CHAPTER

15 Difficult Intubation

Anticipated difficulty in endotracheal intubation by standard techniques or when intubation failed within first 2 attempts by an expert anaesthetist.

- Structural or mechanical obstruction to visualise larynx for direct laryngoscopy/tracheal intubation.

Causes

1. Congenital syndromes/diseases: Pierre-Robin syndrome, Treacher Collins syndrome, cleft palate, ocular hyper/hypotelorism, orofacial clefts, Apert's syndrome, acromegaly, etc.
2. Anatomical: Short muscular neck, receding lower jaw, micrognathia, prominent maxillary incisors, high arched palate, restricted mobility of mandible, decreased thyromental distance, decreased distance between occiput and spinous process of C_1
3. Acquired: Restriction of jaw/neck movement, instability of cervical spine, swelling of neck and face, laryngeal/tracheal stenosis, neck contracture.
4. Others: Morbid obesity, intraoral tumour, instrumental fault.

- Incidence of difficult tracheal intubation is much higher in obstetric cases.

It is mostly due to:

1. Decreased mobility
2. Increased size of tongue
3. Laryngeal oedema
4. Full dentition
5. Large breasts.

Prediction

Malampati et al. classification of the visibility of oropharyngeal structures with maximal mouth opening.

Grade 1: Visualise soft palate, uvula, tonsillar pillars, fauces.
Grade 2: Visualise soft palate, possibly uvula and fauces.
Grade 3: Visualise hard palate only.

Samsoon and Young's modification

Grade 1: Visualise soft palate, uvula, tonsillar pillars and fauces.
Grade 2: Visualise soft palate, uvula and fauces.
Grade 3: Visualise soft palate, base of uvula only.
Grade 4: Visualise hard palate only.

Cormach and Lehane classified on the anatomy visualised on direct laryngoscopy.

Grade 1: Larynx easily visualised.
Grade 2: Only the posterior area of glottis seen, but cricoid pressure helps better visualisation of larynx.
Grade 3: Only epiglottis seen.
Grade 4: Neither epiglottis nor any other airway structures are seen.

Prevention

1. Identify high risk patients
2. Assess airway anatomy
3. Detect any other related anatomic features
4. X-ray of the head and neck
5. Thyromental distance less than 6 cm may cause difficulty
6. Observe adequate mouth opening, jaw/neck movement
7. A second opinion in doubtful cases
8. Review available old anaesthetic records, medical card, if any.

EXPECTED DIFFICULT INTUBATION

Management

Preparation

1. Multiple laryngoscopic blades, endotracheal tubes, introducer, stilet, light wand
2. Suction apparatus. Good table with tilting arrangement
3. Emergency equipment for
    i. Transtracheal jet ventilation
    ii. Cricothyrotomy/tracheostomy
    iii. Fibreoptic laryngoscope.
4. A trained and undistracted assistant to apply cricoid pressure
5. A person qualified to perform tracheostomy
6. Do not use iv barbiturates and muscle relaxants
7. Establish iv infusion and administer iv atropine
8. iv lignocaine 1mg/kg prior to attempt intubation.

Management

1. Avoid general anaesthesia as far as practicable, regional anaesthesia may help
2. General anaesthesia via mask/nasal airway

3. Awake intubation
4. General anaesthesia via mask and then attempt intubation
5. Blind nasal intubation
6. Fibreoptic laryngoscopy
7. Retrograde intubation over guidewire
8. Light wand/lighted stilet
9. Anaesthesia through laryngeal mask airway
10. Tracheostomy: Transtracheal intubation.

- Success may be maximised and patient mortality/morbidity minimised through
  1. Patience and experience on the part of anaesthetist
  2. Thorough understanding of patient's airway anatomy and instruments used in airway management.

UNEXPECTED DIFFICULT INTUBATION

Failed Intubation Drill

1. Summon help
2. Ventilation with 100% oxygen under face mask
3. Maintain cricoid pressure. Patient positioned head down on left side
4. Assess adequacy of ventilation and oxygenation
5. Allow the patient to recover
6. General anaesthesia may be reattempted with all precautionary measures
7. Regional anaesthesia or General anaesthesia under mask may be attempted
8. If ventilation is impossible
   a. Transtracheal jet ventilation
   b. Cricothyrotomy
   c. Tracheostomy.

- Following difficult intubation
  1. The complication should be recorded
  2. Patient should obtain a Medical alert card to inform the potential problem in future.

Complications

1. Trauma/bleeding/obstruction in the airway
2. Laryngospasm
3. Hypoxaemia
4. Bradycardia, cardiac arrest
5. Oesophageal intubation
6. Gastric distension
7. Aspiration of gastric contents
8. Damage to cervical spine.

Transtracheal Ventilation/Oxygenation

1. Inability to both intubate and mask ventilate make the situation grave and critical. At that time transtracheal ventilation or oxygenation may be life saving
2. It consists of 14 gauze over the needle catheter, Luer lock adaptor, noncompressive oxygen tubing, connector and a source of pressurised oxygen
3. Cricothyroid membrane is pierced by the needle to enter the trachea. Catheter is kept *in situ*. It is then attached to some device to administer oxygen under pressure.

CHAPTER

16 Eye and ENT Anaesthesia

EYE ANAESTHESIA

- Mostly similar as in other branches of surgery, but requires expertise in ocular anatomy and physiology.

Intraocular Pressure

i. Normal 10 to 22 mm Hg.
ii. Factors causing increase in IOP :
    a. External pressure, contraction of orbicularis oculi
    b. Variation in vascular (choroidal) volume
       Raised venous pressure
       Airway obstruction, coughing, straining
       IPPV
       Hypercarbia, hypoxia
       Sudden increase in blood pressure
    c. Increase in aqueous and vitreous volume
    d. Certain drugs :
       Atropine in narrow angled glaucoma only
       Opioids/neurolepts
       Ketamine
       Suxamethonium.
iii. Factors causing decrease in IOP :
    Low CVP
    Low arterial blood pressure
    Head up tilt
    Low $PaCO_2$, hyperventilation, hyperoxaemia
    Reduction of vitreous volume : Diuretics
    Most anaesthetic drugs.

Oculocardiac Reflex

1. A trigeminal-vagal reflex precipitated by pressure on eyeball or traction of extraocular muscles particularly medial rectus
2. Long and short ciliary nerves to ciliary ganglion is the *afferent* pathway and motor nucleus of vagus is the *efferent* pathway
3. May occur in strabismus surgery, during retrobulbar block or following pressure on eyeball. Predisposing factors include hypoxia, hypercarbia, light anaesthesia
4. Manifestations : Bradycardia, A-V block, premature ventricular contractions, ventricular fibrillation, cardiac asystole.
5. Management :
    i. Continuous monitoring of vital signs to detect the condition early
    ii. Removal of stimulus
    iii. iv atropine in presence of bradycardia.

Drug Interactions

1. Acetazolamide : Carbonic anhydrase inhibitor, diuresis, hypokalaemic metabolic acidosis. decreases IOP
2. Atropine : Anticholinergic, mydriatic, central anticholinergic syndrome
3. Cyclopentolate : Potent mydriatic. Can cause CNS toxicity with disorientation, psychosis and convulsion
4. Ecothiopate : Long acting anticholinesterase used to treat glaucoma. Can cause bronchospasm and prolong the effect of suxamethonium
5. Adrenaline : Alpha adrenergic agonist, causes mydriasis and vasoconstriction. Can cause tachycardia, hypertension and dysrhythmias
6. Timolol : A beta adrenergic blocking agent used to treat glaucoma. Can induce bradycardia, and bronchospasm
7. Phenylephrine : Produces capillary decongestion and mydriasis, but can induce tachycardia, rise of BP and dysrhythmias
8. Acetylcholine: Miotic used afer lens extraction. Can cause bradycardia, hypotension, bronchospasm, salivation
9. Cocaine: Local anaesthetic. Can induce dysrhythmia
10. Betaxolol: Beta adrenergic blocker oculospecific for glaucoma. Additive effect with other beta blockers.

ANAESTHESIA FOR EYE SURGERY

Criteria Needed

1. Control of IOP
2. Intense analgesia
3. Motionless eye
4. Avoidance of oculocardiac reflex
5. Smooth recovery without straining, coughing, vomiting
6. Safe.

Effect of Anaesthetics on IOP

A. Premedication
   i. Little effect on IOP provided it does not alter $PaCO_2$
   ii. Opioid analgesics may cause vomiting, retching and respiratory depression
   iii. Anticholinergic drugs in routine premedication have no effect on glaucomatous eye provided the topical treatment is maintained.

B. Induction
   i. Thiopentone : Moderate and transient decrease in IOP
   ii. Etomidate: Immediate and prolonged decrease in IOP
   iii. Ketamine increases IOP.

C. Muscle relaxants
   i. Suxamethonium increases IOP, maximum in 2 min and returns to baseline by 5 min
   ii. Nondepolarising muscle relaxants : No direct effect
   iii. Tubocurarine : Marked decrease in IOP.

D. Volatile anaesthetics
   i. Halothane and enflurane : Decrease in IOP
   ii. Ether and isoflurane : Decrease in IOP

E. Nitrous oxide : No effect in the absence of air in the globe.

General Anaesthesia

1. Premedication : Diazepam
2. Induction of anaesthesia : Fentanyl
   Etomidate
   Suxamethonium
3. Larynx and trachea should be sprayed with 4% lignocaine
4. Endotracheal intubation should be gentle and smooth
5. IPPV
6. $N_2O + O_2$ + halothane/enflurane
7. Reversal with atropine and neostigmine at the end of anaesthesia
8. iv administration of antiemetics (droperidol or ondansetron) near the end of anaesthesia can minimise the incidence of nausea and vomiting.

Retrobulbar Block (Fig. 16.1)

1. Provides effective sensory and motor block (akinesia) for intraocular surgery
2. Affects mainly the ciliary ganglion and the long and short ciliary nerves
3. Often combined with facial nerve block to produce paralysis of orbicularis oculi
4. Technique: Patient is asked to look straight forward. A needle is passed through the reflection of conjunctiva below the lateral limbus and gently advanced parallel to the floor of the orbit in a depth of about 15 mm. Then the needle tip is redirected slightly medially and upwards to enter the muscle cone at a depth of about 30 mm. After negative aspiration test 3 to 5 ml of lignocaine 2% is deposited

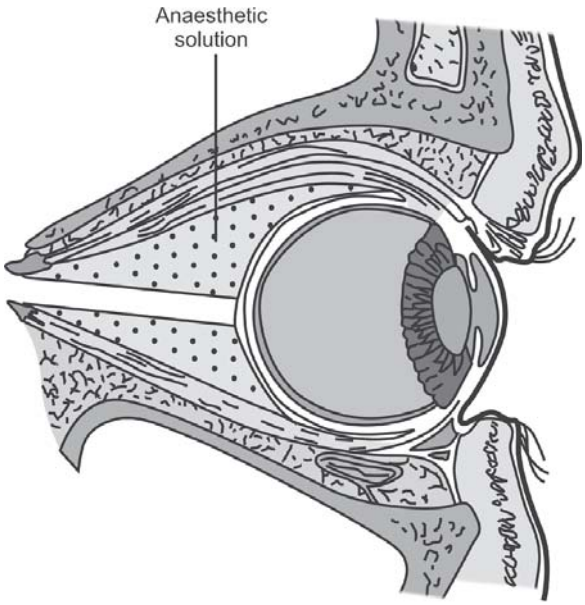

Fig. 16.1: Retrobulbar block

5. Complications: Retrobulbar haemorrhage, intravascular/intraneural injection, systemic toxicity, injury to globe, central retinal occlusion, subdural/subarachnoid injection, oculocardiac reflex. Brainstem anaesthesia (due to passing of local anaesthetic along optic nerve sheath into CNS).

Peribulbar Block

1. A good alternative to retrobulbar block. Injection is given around the eye
2. Technique : Patient is asked to look straight forward. A needle is inserted through the conjunctival reflection below the lateral canthus vertically. It is passed parallel to the floor of orbit and tangential to globe to place the needle point outside the muscle cone. After negative aspiration test about 10 ml lignocaine 2% is injected. A second injection of about 5 ml anaesthetic solution is given through the conjunctiva in the medial canthus medial to the caruncle.
3. Advantages :
    i. Low incidence of serious complications
    ii. No facial nerve block needed.
4. Disadvantages :
    i. Requires two injections
    ii. Onset time longer
    iii. Large volume of local anaesthetic needed, risk of toxicity.

Strabismus Surgery

Problems

1. Suxamethonium is better avoided as it can produce sustained contraction of extraocular muscles. Malignant hyperthermia can occur in some of these patients
2. Increased risk of oculocardiac reflex. Injection of atropine sulphate iv or local infiltration of the extraocular muscle with lignocaine may be used to prevent or treat the oculocardiac reflex
3. Increased incidence of postoperative nausea and vomiting. Prophylactic use of iv droperidol or ondansetron may be helpful
4. Risk of inducing malignant hyperthermia is always there. Adequate screening is essential.

Glaucoma

Special considerations :

1. Drug induced miosis should be maintained throughout the perioperative period
2. Venous congestion should be avoided
3. Adverse drug interactions should be borne in mind.

Note :

1. Miotic eyedrops should be continued on the day of operation
2. Atropine can be used in routine premedication as the drug reaches the eye in negligible amount
3. The use of anticholinergic drugs with anticholine sterase drug is also recommended during reversal of nondepolarising block
4. Suxamethonium should be used cautiously, transient rise of IOP can occur
5. Prolonged hypotension should always be avoided.

Cataract Extraction

1. Common eye operation in the aged. These patients may suffer from concurrent systemic diseases
2. Usually done with retrobulbar/peribulbar block. Complete local anaesthesia and the akinesia of globe are essential. Nausea/vomiting, straining and retching should be avoided
3. General anaesthesia may be needed in selected cases. Smooth induction, and quiet recovery are needed. Prophylactic use of antiemetic drugs (droperidol, ondansetron) is helpful.

OPEN EYE INJURY

Special Considerations

1. Prevention of aspiration of gastric contents
2. Prevention of increases in IOP
3. Succinylcholine should be used cautiously in rapid sequence induction of anaesthesia
4. Proper measures should be taken to blunt the cardiovascular and IOP responses to laryngoscopy and intubation
5. Nausea/vomiting, straining, coughing should be avoided.

RETINAL DETACHMENT SURGERY

Special Considerations

1. IOP should be kept decreased during the operation. Use of acetazolamide or manntol is helpful.
2. Traction of extraocular muscles can activate oculocardiae reflex. Monitoring of the vital signs is essential
3. Nitrous oxide anaesthesia may cause problems as it may increase the volume of the bubble created during retinal reattachment. A sulphur hexafluoride SF_6 bubble is injected in the vitreal cavity. It remains in place for about 10 days in position. Some newer gases may reamin for about 28 days. Nitrous oxide is 34 times more soluble than nitrogen and 117 times more soluble in SF_6 and it rapidly enters the bubble and increases the volume and IOP. Thus nitrous oxide should be discontinued for at least 20 minutes before SF_6 injection and avoided for 4 weeks after retinal operation
4. Special care is needed, if laser is used for repair. Eye protection with a protective shield or eye glasses is essential for the patient and OT personnels.

ANAESTHESIA FOR EAR SURGERY

Special Considerations

1. *Facial nerve preservation:* Facial neve is adjacent to structures of ear and may be injured during operation. Some skeletal muscle response to direct nerve stimulation should remain to identify and preserve the nerve even if muscle relaxant is used. Volatile anaesthetics may be helpful as it preserves the ability to identify the nerve by using peripheral nerve stimulator.
2. *Use of adrenaline:* Adrenaline is often used to produce vasoconstriction and to get a dry operative field. It helps to minimise the blood loss. But it can cause hypertension and cardiac dysrhythmias. Some volatile anaesthetics like halothane can cause dysrhythmias in presence of exogenous catecholamines.
3. *Nitrous oxide and middle air pressure:* Middle ear is an air-filled noncompliant space. Normally pressure is vented by the eustachian tube. During N_2O anaesthesia, N_2O can accumulate in middle air and increase the pressure. This can cause rupture of tympanic membrane and dislodgement of tympanic graft. So it is recommended that inhaled N_2O should be discontinued at least 30 minutes before placement of graft.

   Rapid absorption of N_2O after discontinuation of the gas can produce negative pressure in middle ear manifesting as serious otitis and/or transient hearing loss.

Note :

- Microsurgery of middle ear is delicate and anaesthesia should provide minimum bleeding, dry operative field, smooth emergence and minimum postoperative disturbances
- Postoperative nausea due to labyrinthine disturbances is common
- Impaired hearing, if present may make communications difficult.

ANAESTHESIA FOR NOSE AND THROAT SURGERY

Special Considerations

1. Topical vasoconstrictors like cocaine and adrenaline are often used to minimise bleeding. These can adversely affect the patients
2. Volatile anaesthetics are mostly safe. Hypoxia, hypercarbia and hypotension should be avoided
3. Posterior pharyngeal pack and nasal packs need special care. It should be removed before extubation
4. iv infusion and blood transfusion may be needed
5. Extubation should be done only when protective airway reflexes return
6. N_2O can be used satisfactorily even in nasal sinus (airfilled cavities) surgery
7. Endoscopic sinus surgery can be done under local anaesthesia with adequate sedation
8. Oversedation should be avoided.

Compromised Airway

1. May be due to oedema, infection, tumour of the airway
2. Problems increase when operation involves the airway
3. Good surgical access and a safe ventilatory pathway are needed
4. Adequate evaluation, airway anatomy, airway management plan are important
5. Anaesthesia:
    i. Proper premedication. Antisialagogue agent should be given
    ii. Endotracheal intubation
    iii. Patency of the airway and anaesthetic delivery system ensured
    iv. Hypoxia, hypercarbia and hypotension should be avoided
    v. Monitoring is essential
    vi. iv infusion, blood transfusion may be needed
    vii. Prevent pulmonary aspiration of gastric contents.

Anaesthesia for Adenotonsillectomy

1. Common in paediatric age group
2. Proper evaluation and routine investigations needed
3. Adequate premedication. Trimeprazine syrup
   Atropine sulphate
4. Endotracheal intubation. Volatile anaesthetics and suitable muscle relaxants are helpful. Mandibular and pharyngeal muscle relaxation are needed. Laryngeal reflexes must be suppressed
5. Blood loss may be significant. iv infusion of fluids, blood transfusion may be necessary
6. Adenoids are curetted and the postnasal space is packed for haemostasis. After a few minutes the pack should be removed
7. After the end of operation, extubation should be done when the child is awake. Patient should be kept in *tonsillar position*.

Postoperative Bleeding Tonsil

1. May pose a major anaesthetic problem. Patient is hypovolaemic, anaemic, hypotensive, tachycardiac and dehydrated
2. Rehydration is most important. Blood transfusion may be needed
3. Blood may be swallowed and may pose full stomach; so all precautions should be taken against aspiration
4. Rapid sequence induction with iv thiopentone and suxamethonium with cricoid pressure followed by quick endotracheal intubation
5. Stomach may be emptied through an orogastric tube after placement of endotracheal tube.
6. Anaesthesia may be maintained with $N_2O + O_2$ + halothane or isoflurane.
7. At the end of operation, extubation should be done when the child is awake. Rapid smooth recovery with return of protective airway reflex is most important.

Laser Surgery

1. Laser is the light amplification by stimulated emission of radiation. It can produce an intense beam of light that can be focussed for controlled coagulation, incision or vaporisation of tissues.
2. Main advantages : Minimum damage of adjoining tissue, rapid healing, immediate control of bleeding.
3. Indications : Polyp/tumour of vocal cord, larynx, trachea
4. Anaesthesia :
    i. Patient must be kept immobile
    ii. Oxygen should be given below 40% concentration
    iii. N_2O should be avoided. Use of air oxygen mixture may be helpful
    iv. Helium can be used instead of air as its thermal conductivity can delay ignition
    v. Volatile anaesthetics should be avoided
    vi. Cuff of the endotracheal tube should be inflated with saline.
5. Hazards :
    i. Atmospheric pollution
    ii. Damage of normal tissues due to misdirected beam
    iii. Venous gas embolism
    iv. Eye protection is needed for OT personnels
    v. Fire of endotracheal tube can occur. Wrapping the tube in protective silver foil or use of aluminised silicone is helpful
    vi. Airway fire can occur. Some measures should be taken promptly :
        a) Remove the ignition source
        b) Stop ventilation, extubate and extinguish the flamming material with water
        c) Ventilation through mask with oxygen
        d) Assess the damage and remove the debris
        e) Examine the oropharynx and face
        f) Chest X-ray is needed to evaluate lung condition.

CHAPTER

17 Obstetric Anaesthesia

PHYSIOLOGICAL CHANGES OF PREGNANCY

1. **Respiratory system:**
   i. Minute ventilation is increased
   ii. Tidal volume and respiratory rate increase
   iii. PaO_2 increases and $PaCO_2$ decreases, no change in pH
   iv. O_2 consumption increases
   v. Alveolar ventilation increases
   vi Functional residual capacity, expiratory reserve volume and vital capacity decrease. No change in vital capacity.
      - Oedema, weight gain and increased breast size may pose difficult intubation
      - Capillary engorgement of the mucosal lining of upper airway. Avoid use of nasal airways and nasal intubation.
2. **Cardiovascular system:**
   i. Heart rate increases
   ii. Stroke volume and cardiac output increase
   iii. Total peripheral resistance decreases
   iv. No changes in central venous pressure
   v. Blood pressure (systolic and diastolic) decreases
   vi. Intravascular volume, plasma valume, RBC volume increase
      - Supine hypotensive syndrome : Decreased venous return due to obstruction of the inferior vena cava and/or abdominal aorta by the enlarged gravid uterus
      - Aortocaval obstruction : Causes uteroplacental insufficiency and foetal hypoxia due to decreased uterine blood flow
      - Left uterine displacement is helpful in moving the gravid uterus of the inferior vena cava and/or aorta.
3. **Gastrointestinal system:**
   i. Gastric emptying time slowed, gastric motility decreased
   ii. Intragastric pressure increased

iii. Lower oesophageal sphincter pressure decreased
iv. Stomach position more up and horizontal
v. Increased risk of pulmonary aspiration
vi. Transaminases increase
vii. Pseudocholinesterase decreases
viii. Alkaline phosphatase increases
ix. Serum cholesterol may increase.

4. **Haematologic system:**
   i. Haemoglobin content decreases
   ii. Coagulation factors may increase. Increased coagulability
   iii. Platelet count less.
5. **Nervous system:**
   i. Anaesthetic requirement less
   ii. MAC value decreases
   iii. Endorphin levels increase.
6. **Renal system:**
   i. Renal blood flow/glomerular filtration rate decrease
   ii. Glycosuria, proteinuria
   iii. Creatinine clearance may increase.

DIAGNOSIS OF PREGNANCY

A. At about 6 to 8 weeks
   i. Amenorrhoea
   ii. Morning sickness
   iii. Breast discomfort, engorgement, pigmented nipple and areola
   iv. Uterus just felt per abdomen at about 12 weeks
   v. Sonography.

B. At about 16th week
   i. Amenorrhoea
   ii. Breast changes
   iii. Uterus palpable per abdomen
   iv. Uterine souffle
   v. Internal ballotment.
   vi. X-ray : Foetal shadow.

C. At about 28th weeks
   Same as above with:
   i. Contractions
   ii. External ballotment
   iii. Palpable foetal parts
   iv. Foetal movements
   v. Foetal heart sound.

- **Absolute signs of pregnancy**
  1. Palpation of foetal parts
  2. Foetal movements
  3. Foetal heart sound
  4. Radiology
  5. Ultrasonography.
- **Assessment of foetal maturity**
  1. Ultrasonography
  2. Amniocentesis, analysis of amniotic fluid for it lecithin/sphingomyelin ratio to evaluate lung maturity
  3. Radiological assessment
  4. Clinical assessment.

PLACENTAL TRANSFER/EXCHANGE

Exchange of the nutrients and waste products between mother and foetus. Depends on:

1. Physical properties of the substances
2. Extent and functional integrity of exchange membrane
3. Rate of maternal and foetal blood flow.

Mechanism

1. Simple diffusion
2. Facilitated diffusion
3. Active transport.

Factors Determining the Rate and Extent of Transfer

1. Maternal protein binding
2. Molecular weight of the substances
3. Lipid solubility
4. Degree of ionisation
5. Concentration at placental site
6. Foetal uptake and distribution.

Placental Transfer of Drugs

Mostly by diffusion, governed by Fick's equation

$Q_d = K_d \times A \times [P_d (m) - P_d (f)]/b$

Q_d = Quantity of drug transferred per unit time
K_d = Diffusion constant of the drug
A = Surface area of placenta
$P_d (m)$ = Mean drug concentration of maternal blood
$P_d (f)$ = Mean drug concentration of foetal blood
b = Thickness of placenta

- Some of these factors can be controlled but factors like surface area and thickness of placenta are not within control.

Pain During Labour and Delivery

Two components :

1. Visceral pain caused by dilatation and effacement of the cervix during uterine contractions. It is mostly in the first stage of labour
2. Somatic pain occurs during stretching of the vagina and perineum during descent of foetus. It dominates the second stage.
   There may be considerable overlap of the two types.

- Visceral pain is referred to the lower abdomen between the umbilicus and pubis and to the lower back. Intense pain may be referred to hips and thighs. These pain sensations are mediated by small unmyelinated fibres those pass from the cervix through the pelvis and hypogastric plexuses to enter the sympathetic chain at L_3 to L_5. It reaches the posterior root ganglia and spinal cord through the white rami communicates of T_{10} to L_1.
- Somatic pain starts due to descent of foetus through the vagina. Initially it is something as a need to defaecate. But with further ascent there is uncontrollable urge to bear down. This pain is conveyed mostly through pudendal nerve to posterior nerve roots S_2 to S_4.
- Other contributing factors :
  Pressure on bladder, urethra and rectum (sacral segments), traction of uterine adnexae (T_{10} to L_1) and stretch and pressure on muscles and ligaments of pelvis (lower lumbar and sacral segments).

Pain Relief During Labour

Criteria :

1. Satisfactory analgesia for the mother
2. Progress of labour will not be interfered
3. Safe for both mother and foetus
4. Provision of safe and comfortable delivery
5. Early interaction between mother and baby just after the delivery.

Methods :

A. Nonpharmacological methods
   i. Parental education, encouragement and reassurance by doctors, nurses and other personnels
   ii. Acupuncture, hypnosis : Mostly unpredictable.

B. Systemic analgesia
   i. Opioids to control pain in first stage
   ii. Buterophenol
   iii. Fentanyl
   iv. Pentazocine
   v. Ketamine in small iv doses 0.25 mg/kg
   vi. Midazolam 0.5 to 1 mg iv

- iv access to provide for hydration, transfusion or rapid administration of drugs is important.

C. Inhalational analgesia
   i. Low concentrations of inhaled anaesthetics, continuous 30 to 50% nitrous oxide in oxygen
   ii. Intermittent inhalation of 0.35% methoxyflurane in air
   iii. Trichlorethylene 0.5% or 0.35% in air from special vaporisers.

D. Regional analgesia
   i. Paracervical block (T_{10}–L_1) provides perineal anaesthesia only. Foetal bradycardia can occur
   ii. Lumbar epidural analgesia block (T_{10}–S_5) is helpful in first and second stage of labour. Can preserve pelvic muscle tone
   iii. Caudal analgesia (T_{10}–S_5), continuous caudal epidural block
   iv. Spinal anaesthesia T_{10}–S_5 ; Saddle block S_1–S_5
   v. Pudendal nerve block (S_2–S_4).

E. Other methods
   i. Extradural injection of opioids (morphine, pethidine, fentanyl)
   ii. Intraspinal opioids
   iii. Transcutaneous nerve stimulation : Not much accepted.

ANAESTHESIA FOR CAESAREAN SECTION

Caesarean section is performed as:

A. An elective procedure
B. An urgent procedure
   i. When progress of labour is not satisfactory
   ii. Deteriorating intrauterine conditions
   iii. Extreme foetal distress, prolapsed umbilical cord, maternal haemorrhage, etc.

Anaesthetic techniques

1. Spinal or epidural analgesia
2. General anaesthesia
3. Local infiltration.

Regional anaesthesia

- Preferred for caesarean delivery as:
   i. Neonatal depression is insignificant
   ii. Decreased risk of pulmonary aspiration
   iii. Mother remains awake and can share in the birth experience
   iv. But it takes some time to perform.
- Contraindications
   i. Hypovolaemia
   ii. Infection near the site of injection
   iii. Septicaemia

iv. Neurologic abnormality, raised intracranial tension
v. Coagulopathy
vi. Patient refusal.

Disadvantages

A. Spinal anaesthesia :
   1. Hypotension
   2. Inability to control the spread of anaesthesia
   3. Postspinal puncture headache.

B. Epidural anaesthesia :
   1. Time needed to place the needle/catheter
   2. Potential for local anaesthetic toxicity.

- Spinal anaesthesia is technically easy to perform and can produce rapid and reliable block.
- Epidural anaesthesia is technically difficult to perform. Continuous epidural offers better control over spread and allows unlimited duration of block
- Subarachnoid or epidural block upto the level of T_4 is mostly satisfactory for caesarean section. Continuous epidural block is also used for analgesia in labour, the level of block can be well-extended by injecting the local anaesthetic to perform caesarean section
- Postoperative analgesia can be provided by addition of opioid in local anaesthetic solution injected in subarachnoid/epidural space.

General anaesthesia

1. Preoperative medication
   i. Benzodiazepine to allay anxiety and tension
   ii. Parturients are at special risk of pulmonary aspiration. Clear antacids, metoclopramide and H_2 blockers may be used.
2. Preoxygenation
3. Induction of anaesthesia : Thiopentone and suxamethonium, Crash induction. Rapid endotracheal intubation
4. Maintenance of anaesthesia : Only N_2O until delivery, thereafter volatile anaesthetics can be added. Opioids can also be given.

Advantages

1. Short preoperative preparation
2. Patient remains unconscious.

Disadvantages

1. Maternal pulmonary aspiration
2. Neonatal depression
3. Immediate maternal bonding not possible.

HYPERTENSIVE DISORDERS OF PREGNANCY

A. Chronic hypertension
B. Preeclampsia/eclampsia
C. Chronic hypertension with superimposed preeclampsia
D. Gestational hypertension.

- Hypertension : A systolic pressure above 140 mm Hg or 30 mm Hg above baseline, diastolic pressure above 90 mm Hg or 15 mm Hg above baseline. A mean pressure above 105 mm Hg or a mean increase 20 mm Hg above baseline
- Chronic hypertension is the state that predates pregnancy, diagnosed before 20 week of pregnancy
- Gestational hypertension occurs after 20th week of pregnancy with no signs of preeclampsia. It is mostly essential hypertension that is unmasked in pregnancy.

Preeclampsia/eclampsia

Preeclampsia : Often manifest after 20th week of pregnancy with:
Hypertension
Proteinuria
Oedema.

- Preeclampsia may turn to eclampsia when generalised seizures manifest.

A. Pathophysiology

i. Vasospasm secondary to increased levels of renin, aldosterone, angiotensin and catecholamines
ii. Aldosterone causes sodium and water retention, generalised oedema
iii. Cerebral oedema, cerebral vasospasm, raised intracranial tension, headache, hyperreflexia, blurred vision, vertigo, blindness, convulsion, coma
iv. Laryngeal and upper airway oedema, airway congestion, pulmonary capillary leak, intrapulmonary shunt, deterioration of alveolar arterial oxygen gradient
v. Generalised vasoconstriction, hypertension, impaired tissue perfusion, cellular hypoxia
vi. Intravascular hypovolaemia, haemoconcentration
vii. Left ventricular hypertrophy, dysfunction, congestive heart failure
viii. Renal blood flow reduced, renal dysfunction.
Damaged glomeruli lead for renal loss of proteins, oliguric renal failure.
ix. Hepatocellular damage, elevated liver enzymes
x. Coagulation abnormalities
xi. HELLP syndrome : (Haemolysis, elevated liver function tests and low platelet count)

B. Obstetric management

i. Control the disease. Progression should be prevented
ii. Bed rest, left uterine displacement
iii. Monitoring : Blood pressure, weight gain, renal function, coagulation function. CNS irritability.
iv. Restrict oral fluid and sodium intake
v. Routine use of diuretics

vi. Monitor the foetal well being
vii. Delivery of foetus and condition of the mother should be considered.
   a. Foetal causes: Foetal distress, cessation of foetal maturity
   b. Maternal causes : Worsening preeclampsia, medical control not satisfactory.

C. Medical treatment

i. Magnesium sulphate
ii. Antihypertensive drugs : hydralazine, trimetaphan, nitroprusside
iii. Digitalis
iv. Mannitol
v. Furosemide.

D. Anaesthetic management

i. a. Continuous lumbar epidural anaesthesia
   b. Prehydration is essential
   c. Coagulation studies must be done before hand.
ii. Spinal anaesthesia may be recommended when vaginal delivery is imminent
iii. Caesarean section may be done under general anaesthesia, endotracheal intubation may pose difficulty, extensive monitoring is essential. Regional anaesthesia (spinal/epidural block) is often helpful.

HAEMORRHAGE IN THE PARTURIENT

A. Bleeding during third trimester
   i. Placenta previa
   ii. Abruptio placentae
   iii. Placenta accreta/increta/percreta
B. During labour
   i. Uterine rupture
C. Postpartum haemorrhage
   i. Retained placenta
   ii. Uterine atony
   iii. Cervical/vaginal lacerations
D. Miscellaneous
   i. Cervical pathology : Polyp, carcinoma
   ii. Preeclampsia
   iii. Intrauterine death of the foetus
   iv. Preexisting coagulopathy.

- **Antepartum haemorrhage :**
  It is the bleeding from or into the genital tract after 28th weak of pregnancy but before the birth of the baby. Commonest cause is placenta previa or abruptio placentae.

- **Postpartum haemorrhage :** Bleeding from or into the genital tract following birth of the baby upto the end of puerperium. It is mostly due to atonic uterus or retained products of conception.
- **Placenta previa :** Painless vaginal bleeding, bright red blood, blood clot, blood loss not concealed. Common in advanced age and/or multiple parity. Low implantation of placenta in uterus. Diagnosis confirmed by ultrasound.
- **Abruptio placentae :** Separation of a normally implanted placenta after 20 weeks of gestation. Painful vaginal bleeding, portwine blood, nonclotting blood. Blood loss often concealed. DIC is common. Diagnosis confirmed by ultrasound. Acute renal failure and foetal distress can occur.
  - ✓ If the maternal and foetal condition is not critical, continuous epidural anaesthesia is helpful for labour and vaginal delivery. Otherwise, in critical situation general anaesthesia is needed for emergency caesarean section. Ketamine induction and maintenance with nitrous oxide and volatile anaesthetics may be indicated. Neonates are usually acidotic and hypovolaemic. They need special care.
- **Uterine rupture**

  May be
  i. Spontaneous
  ii. Separation of previous uterine scar
  iii. Rapid spontaneous delivery
  iv. Excessive oxytocin stimulation.

  Management :
  i. iv fluids, blood transfusion, vasopressors
  ii. Urgent laparotomy
  Hysterectomy
  Repair and sterilisation.
- **Retained placenta :** Needs manual exploration of uterus. Inhalation anaesthesia is mostly satisfactory for manual removal of placenta. If lumbar epidural or spinal anaesthesia is used for vaginal delivery, this may be sufficient for manual exploration.
- **Uterine atony :**
  1. Disordered uterine contraction
  2. Noncontracting uterus seems boggy and large
  3. Continuing painless bleeding per vagina after delivery
  4. Blood loss, shock.

Management

1. Try to increase myometrial tone
2. Massage the uterus
3. Oxytocin
4. Ergometrine
5. Prostaglandin F_2a.

Anaesthesia

1. Maternal resuscitation, iv fluid, blood transfusion
2. Vasopressors
3. Hypogastric artery ligation or even hysterectomy may have to be done under general anaesthesia.

ANAESTHETIC MANAGEMENT FOR NONOBSTETRIC SURGERY DURING PREGNANCY

Main Objectives

1. Avoid teratogenic drugs
2. Avoid intrauterine foetal hypoxia and acidosis
3. Prevent premature labour.

Certain points need adequate considerations

1. Avoid major surgery during pregnancy, whenever possible
2. Emergency surgery may have to be done knowing fully the risks
3. First trimester is most critical. Avoid anaesthesia and surgery during this period
4. Operation should be done by experts with minimum handling the uterus
5. Anaesthesia and monitoring and postoperative care should be meticulous.

Anaesthesia

1. Local or regional anaesthesia is mostly satisfactory. Drug doses should be carefully judged. Avoid hypotension
2. General anaesthesia:
   i. Take preventive measures of pulmonary aspiration
   ii. Cautious transportation with left uterine displacement
   iii. Careful evaluation of airway
   iv. Preoxygenation with 100% oxygen
   v. Rapid sequence induction of anaesthesia
   vi. Maintenance with N_2O, O_2, muscle relaxant and intermittent doses of analgesics
   vii. Avoid hypoxia, hypercarbia and hypotension
   viii. Monitoring of vital signs of mother and foetal condition throughout the procedure
   ix. Some drugs may be used to stop premature labour in postoperative period. Beta sympathomimetics (terbutaline, ritodrine) or magnesium sulphate are commonly used
   x. Prostaglandin inhibitors and calcium channel blockers can also be used.

Note :

- Critical period of organogenesis is 15 to 56 days of gestation. Most of the anaesthetic drugs are safe. But nitrous oxide should be used in parturients cautiously
- Muscle relaxants are highly ionised and thus undergo minimum placental transfer. Most of them are safe
- Ketamine can increase the uterine tone
- Halogenated volatile anaesthetics may be used as they relax the uterus.

POSTPARTUM TUBAL LIGATION

1. Fallopian tubes are ligated or occluded for female sterilisation during the puerperium usually 24 to 48 hours following delivery
2. Technically simple, hospital stay and rest at home help to recover simultaneously
3. Can also be done beyond 3 months following delivery or abortion, preferably following the menstrual period in proliferative phase
4. Laparoscopic sterilisation can be done 6 weeks postpartum. It is not done early as it is technically difficult
5. Anaesthesia :
    i. General anaesthesia
    ii. Spinal block upto T_{10}
    iii. Epidural block
    iv. Local infiltration over the abdominal wall.

LAPAROSCOPIC STERILISATION

1. It should be done at least 6 weeks following delivery
2. Thorough preoperative check up and routine investigations needed
3. Valid consent for anaesthesia and ligation.
4. Usually done under local anaesthesia
    i. Infiltration of 1% lignocaine at the site of incision
    ii. Lithotomy position, about 15° Trendelenburg position
    iii. Pneumoperitoneum produced by Verres needle by inflating with about 2 litres of gas like carbon dioxide, nitrous oxide or oxygen or room air
    iv. Trocar and laparoscope introduced and the ring is slipped into the base of the loop of the tube under direct vision. Repeated on the other side
    v. Laparoscope removed, abdomen deflated, wound closed.
5. Advantages
    i. Can be done in OPD or even in camps
    ii. Minimum (8 to 10 hrs) hospital stay
    iii. Rapid wound healing
    iv. Reversal anastomosis easier, if needed
    v. Least damage of the fallopian tube.
6. Disadvantages
    i. Risk of cardiorespiratory embarrassment, pneumothorax, injury to intestine and vessles
    ii. Cardiac arrest
    iii. Instrument is costly
    iv. Needs sufficient training to adopt the technique.

DILATATION AND EVACUATION (D AND E)

1. Dilatation of the cervix and evacuation of the products of conception.
2. Indications :
    i. Incomplete abortion, inevitable abortion
    ii. Medical termination of pregnancy (6 to 8 weeks)
    iii. Hydatidiform mole in the way of expulsion.
3. Anaesthesia:
    i. Usually done under general anaesthesia
    ii. After the operation ergometrine 0.25 mg im or methargin 0.2 mg im may be needed.
4. Dangers :
    i. Excessive bleeding ; shock
    ii. Pelvic infection
    iii. Cervical incompetence
    iv. Uterine perforation.

HYSTEROTOMY

1. Operative procedure to extract the products of conception out of the uterine cavity before 28th week by incising the anterior wall of uterus.
2. Indications :
    i. Medical termination of pregnancy in mid trimester.
    Where other methods are failed or otherwise contraindicated.
    ii. Evacuation of molar pregnancy.
3. Anaesthesia:
    Can be done under either general anaesthesia or spinal/epidural anaesthesia.
4. Complications :
    i. Uterine bleeding
    ii. Peritonitis
    iii. Scar endometriosis
    iv. Scar rupture in subsequent pregnancy
    v. Anaesthetic complications : Aspiration pneumonitis, local anaesthetic toxicity, hypotension, etc.

CHAPTER

18 Paediatric Anaesthesia

Neonates differ from adults in a number of ways. The first 28 days of life is neonatal period.

Airway

1. Obligate nose breathers
2. Tongue relatively large, larynx higher and more anterior, epiglottis large, floppy, Vshaped, small mouth
3. Narrowest part of larynx is the cricoid ring
4. Trachea is short and soft.

Respiratory System

1. Metabolic rate is high 7-9 ml/kg/min
2. Respiratory rate is faster, about 35/min
3. Tidal volume is 7 ml/kg, vital capacity 35 ml/kg, functional residual capacity 25 ml/kg, alveolar ventilation 130 ml/kg/min
4. Neonatal respiration relies on diaphragmatic movement
5. Small airways contribute airway resistance
6. Work of breathing is higher
7. CO_2 production is about 6 ml/kg/min.

Cardiovascular System

1. Persistent patent ductus arteriosus and patent foramen ovale shunt blood away from the lung and into the systemic circulation. The shunt may be exacerbated with hypoxaemia, hypercarbia, acidosis and high airway pressure
2. Cardiac output may be 2 to 3 times than that of adult
3. Bradycardia is common
4. Hypotension
5. Systolic blood pressure is about 65 mm Hg
6. Heart rate ranges from 120 to 130 beats/min

7. Blood volume is about 85 ml/kg
8. Haemoglobin is about 17 gm%.

Renal and Hepatic System

1. Mostly immature, poor function
2. Glomerular filtration rate and renal drug clearance reduced
3. Concentrating power limited
4. Hepatic drug metabolism limited
5. Total body water is about 75% of the weight of newborn
6. Physiological jaundice is common
7. Hypoglycaemia can occur easily
8. Hypocalcaemia occurs commonly.

Haematologic System

1. Foetal hemoglobin present. Slight left ward shift of oxyhaemoglobin dissociation curve
2. Physiologic anaemia is common
3. Haematocrit ranges from 50 to 60%.
4. Platelet function reduced. Reduced plasma coagulation factors. Vit K dependent factors (II, VII, IX and X) deficient. More at risk of bleeding.

Thermoregulation

1. Infant's surface/body weight ratio is greater than that of the adult. It predisposes more rapid heat loss. Thermoregulatory mechanism is mostly chemical
2. Heat production mostly depends on metabolism of brown fat. Newborns cannot produce heat by shivering
3. Babies are prone to develop hypothermia in cold exposure.

Central Nervous System

1. Myelination of nerve fibres is incomplete in newborn
2. Cerebral cortex and blood-brain barrier not much developed
3. More sensitive to opioids and general anaesthesia.

Body Fluids

1. Total body water content is higher (about 70%) than adults (60%)
2. A relative excess of extracellular fluids (about 38% 1 month, 26% in 1 year and 27% in adult)
3. Intracellular water is about 32% in 1 month, 36% in 1 year and 33% in adults
4. Limited ability to cope with excess water and sodium.

Psychological Aspects

Depends on age and personality of the child, proposed operation, parental response and hospital/doctor/staff response.

PREOPERATIVE EVALUATION

1. Preoperative visit is vital to allay fear, anxiety and tension and to gain confidence of the child.
2. i. Age
   ii. Body weight
   iii. Consent of parents/guardian
   iv. Previous anaesthesia, any medication, past history of illness
   v. Present illness
   vi. Operative site
   vii. Physical examination : General survey, colour, nutrition, hydration, oral hygiene, teeth, cardiovascular system, respiratory system.
   viii. Vital signs : Pulse, respiration, blood pressure, body temperature.

Investigations

i. Haemoglobin, total count, DC bleeding time, clotting time
ii. Urine analysis
iii. Blood urea, electrolytes
iv. Acid base status
v. Liver function tests in selected cases
vi. Chest X-ray in some cases.

- Veins should be examined with relation to iv induction and/or the establishment of iv infusion.

PREOPERATIVE PREPARATION

1. Adequate reassurance, explanations and a good rapport between the child and doctor are essential
2. Food should be restricted for at least 4 hours before induction of anaesthesia. Clear fluid like—5% dextrose solution 10 ml/kg may be given in infants under 1 year and milk 10ml/kg can be given in children of 1 to 5 years of age
3. Prolonged preanaesthetic fasting may lead to hypoglycaemia.

PREMEDICATION

1. Ideal premedication should be safe and easy to administer. It should allay preoperative fear, anxiety and tension, sedate, lessen secretions, prevent vomiting and undesirable vagal reflexes. It should not affect the vital centres
2. Should be according to the need of the patient. Many children may not require any premedication
3. **Method of Administration**
   i. Oral : Well-tolerated but unpredictable effect
   ii. Intramuscular : Reliable, popular, may have needle fear
   iii. Intravenous : Only for anticholinergics
   iv. Rectal : Not well-tolerated, unpredictable.

4. **Usual Drugs**
   i. Atropine 0.02 mg/kg
   ii. Hyoscine 15 mg/kg
   iii. Pethidine 2 mg
   iv. Diazepam 0.4 mg/kg
   v. Trimeprazine 2 to 4 mg/kg orally
   vi. Droperidol 0.2 to 0.4 mg/kg orally
   vii. Glycopyrrolate 5 mg/kg.

ANAESTHETIC EQUIPMENT

1. Face mask : Rendell-Baker-Saucek Mask (Fig. 18.1)—face fitting shape, low dead space
2. Laryngoscope : Magill straight bladed laryngoscope is popularly used as it aids better visualisation of larynx and to lift floppy epiglottis. Small size Macintosh laryngoscope can also be used. Laryngoscope should be light weight and can be easily handled
3. **Endotracheal Tubes :**
   i. Uncuffed tubes must be used
   ii. Various types of PVC and red rubber tubes are being used
   iii. Single use sterile endotracheal tubes are also available
   iv. Size of the tube

$$\frac{\text{Age}}{4} + 4\text{-internal diameter in mm}$$

   v. Length of the tube

+ 12-length of oral tube in cm

+ 15-length of nasal tube in cm.

   vi. Tube should pass 2.5 cm in vocal cords
   vii. Size of the tube must always be such to ensure a leak is present.

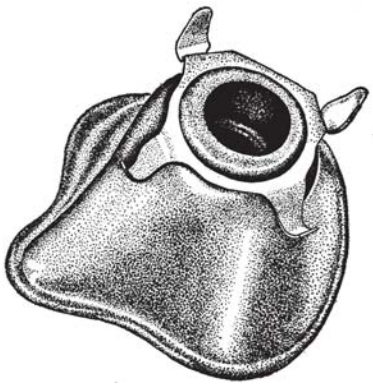

Fig. 18.1: Rendell-Baker-Saucek face mask for paediatric use

4. **Breathing System :**
   A. Mapleson Systems
   Jackson Rees circuit
   Bain circuit
   i. Recommended for infants weighing less than 10 kg
   ii. Light and simple
   iii. No valves and CO_2 absorbers
   iv. Fresh gas flow should be 2.5 to 3 times the minute ventilation.
   B. Circle System
   i. Should be used in older children
   ii. Unidirectional valves prevent rebreathing and the CO_2 absorber removes CO_2 and conserve heat
   iii. Complex, valves are heavy
   iv. Controlled ventilation is recommended while using paediatric circle systems.
5. **Special Endotracheal Tubes**
   i. RAE tubes: Preformed disposable PVC tube with a bend at the mouth to prevent kinking. Provides a connector at the level of chin, length should be adjusted carefully.
   ii. Cole tube : Wide proximal and a narrow distal part. The shouldered part of the tube may cause laryngeal damage. Narrowing may increase turbulance and work of breaking.
   iii. Armoured tubes: These are latex and silicone reinforced tubes, floppy, incompressible and unkinkable. Needs introducer for intubation. These cannot be cut, thus the position should be carefully checked.
6. **Ayre's T-piece** (Fig. 18.2)
   i. Small T-shaped metal tube consisting of a straight tube and 2 side arms. Fresh gas inlet is at right angle to the body. Side arms are longer and wider, one end is connected to the endotracheal tube and the other end is attached to a short tube which acts as reservoir.
   ii. Reduces dead space to a minimum
   iii. Low resistance (no valves)
   iv. Fresh gas flow should be at least 2.5 times the minute volume.

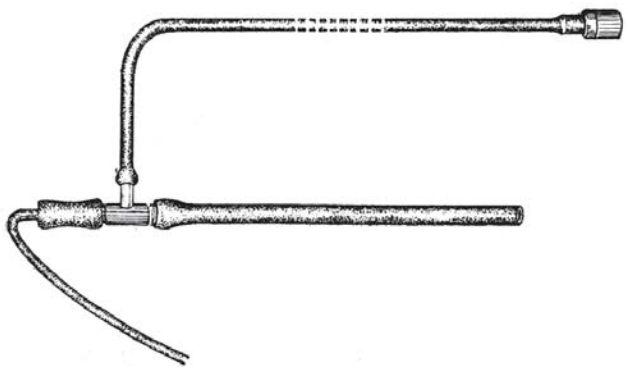

Fig. 18.2: Ayre's T-piece with its connections

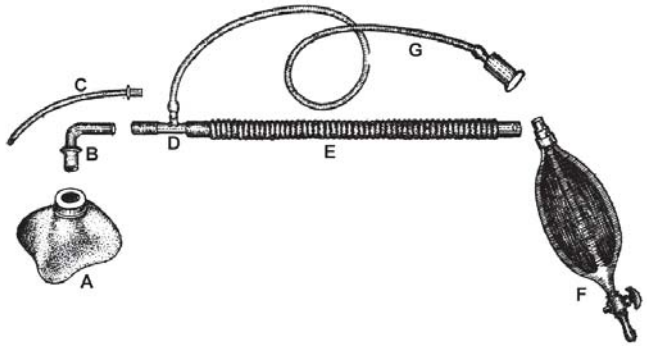

Fig. 18.3: Rees modification of Ayre's T-piece.
Key : A=Rendell-Baker-Sancek face mask; B=Metal adaptor; C=Endotracheal tube; D=T-piece; E=Corrugated rubber tube; F=Rat-tailed reservoir bag with stop cock; G=Fresh gas inlet tube

7. **Jackson Rees Modification of Ayre's T-piece** (Fig. 18.3)
   i. T-piece with an addition of an open ended reservoir bag
   ii. Simple, light weight
   iii. No valves, small dead space
   iv. Used for spontaneous respiration or IPPV
   v. High flow of fresh gas needed
   vi. Humidification is not easy
   vii. Scavenging may be difficult
   viii. Recommended for children under 20 kg. body weight.
8. **Ventilators**
   - Main criteria needed for a paediatric ventilator
     i. Accurate control of inspired O_2,
     ii. Respiratory rate
     iii. Tidal volume
     iv. Inspiratory/expiratory ratio
     v. Provision of humidification
     vi. Special features: IMV, PEEP, CPAP
     vii. Reliable alarms
     viii. Safe and reliable
     ix. Light weight tubing.

MONITORING DURING ANAESTHESIA

1. Precordial or oesophageal stethoscope
2. Blood pressure : Automatic monitors
3. Electrocardiogram
4. Pulse oximeter
5. End tidal CO_2

6. Temperature
7. Neuromuscular block
8. Urine output
9. Monitoring on special cases :
   a. CVP
   b. Transcutaneous O_2 and CO_2 monitors
   c. Pulmonary artery pressure
   d. Cardiac output.

ANAESTHETIC MANAGEMENT

- Check the equipment and circuit
- An iv infusion is established
- All monitors are attached.

1. **Induction**
   i. Intravenous induction
   Thiopentone 2.5 mg/kg
   Ketamine, methohexitone, etomidate, propofol can also be used, but can cause pain on injection.
   ii. Inhalational induction
   Halothane
   Cyclopropane
   Isoflurane.
   iii. Intramuscular
   Ketamine can be used.
   iv. Rectally : Not used now a days.
2. Mask anaesthesia
   Inhalational anaesthetics can be administered via a face mask. Mask must fit the face. An oropharyngeal airway may be helpful.
3. Endotracheal intubation
   Indications :
   i. To control the ventilation
   ii. Surgery around head and neck, thoracic, abdominal neurosurgery
   iii. Prolonged anaesthetic procedures
   iv. To prevent aspiration
   v. Airway problems
   vi. Ventilatory problems
   vii. Prone/sitting posture
   viii. To provide adequate muscular relaxation.
   Procedure :
   i. Preoxygenation
   ii. Laryngoscopy

iii. Introduction of endotracheal tube. A gentle cricoid pressure may help to visualise the larynx
iv. Check the position of the tube
v. Secure the tube firmly.

Dangers :

i. Malposition of the tube
ii. Disconnection
iii. Obstruction in the tube
iv. Accidental extubation
v. Sore throat
vi. Stridor, subglottic oedema
vii. Trauma
viii. Infection.

4. Maintenance of anaesthesia
   i. A mixture of nitrous oxide and halothane/enflurane/isoflurane
   ii. Analgesia may be provided with intermittent doses of pethidine.
   iii. Muscular relaxation is provided with muscle relaxants like suxamethonium, vecuronium, atracurium, pancuronium, etc.
5. Recovery from anaesthesia
   i. All potent anaesthetics should be stopped
   ii. Antagonism of nondepolarising muscle relaxant needed with atropine and neostigmine
   iii. Extubation done gently and carefully
   iv. Check the vital signs.
6. Postoperative analgesia may be needed.
   i. Morphine 0.1 to 0.2 mg/kg im
   ii. Pethidine 1mg/kg
   iii. Narcotics should be avoided in children less than 6 months.

FLUID MANAGEMENT

1. Any dehydration: Preoperative fasting, abnormal loss of fluids as in vomiting, burns.
2. Maintenance of fluid requirements
3. Surgical injury : Blood loss
4. Body temperature
5. Environment : OT airconditioned or not ; high ambient temperature.

SIGNS OF DEHYDRATION

i. 5% loss of fluid : Dry tongue and mouth, pale
ii. 10% loss of fluid : Dry tongue, lethargic child, skin flaccid, fontanelle sunken, tachypnoea, tachycardia, low blood pressure, urine output diminished
iii. 15% loss of fluid : Child not responsive, dry tongue, loose skin, fontanelle sunken, thready pulse, severe hypotension, oliguria, respiratory distress, rise of body temperature

iv. Laboratory studies:
   a. Hb%
   b. Haematocrit
   c. Electrolytes
   d. Urea, creatinine
   e. Osmolality of urine and blood.

v. Fluid replacement
   a. Physiological saline
   b. Dextrose/saline
   c. 5% albumin
   d. Plasma
   e. Blood.

MAINTENANCE OF FLUID REQUIREMENT

i. First 10 kg body weight 4 ml/kg/hr
ii. Second 10 kg body weight 2 ml/kg/hr
ii. Excess of 20 kg 1 ml/kg/hr

SURGICAL FLUID/LOSS

1. Correct estimation of loss should be done by weighing of swabs and mops, drapes and measuring suction material
2. Fluid is also lost by evaporation, lack of humidification
3. Rise of body temperature of 1°C can increase fluid loss by 10%
4. Estimated fluid loss
   i. Superficial surgery 0-2 ml/kg/hr
   ii. Mild to moderate surgery 3-5 ml/kg/hr
   iii. Extensive surgery 6 ml/kg/hr.

BLOOD LOSS REPLACEMENT

1. More than 10% of the estimated blood volume is lost :
   Blood should be replaced millilitre for millilitre
2. If crystalloid solution is used to replace the blood loss, the replacement volume is 3 to 4 times the blood loss.

PRACTICAL RECOMMENDATIONS

A. Before induction of anaesthesia administer 20 to 25 ml/kg in children below 3 years of age and 10 to 15 ml/kg in older children
B. Thereafter,
   Basic 2 ml/kg/hour
   +

For minor surgery 2 ml/kg/hr
For moderate surgery 4ml/kg/hr
For extensive surgery 6 ml/kg/hr
+
Additional replacement of blood

COMMONLY USED DRUGS DURING PAEDIATRIC ANAESTHESIA

Atropine	0.02 mg/kg
Glycopyrrolate	5 µg/kg
Thiopentone	4 mg/kg
Suxamethonium	1 to 2 mg/kg
Pancuronium	0.1 mg/kg
Vecuronium	0.1 mg/kg
Atracurium	0.5 mg/kg
Ketamine	2 mg/kg; 5 to 8 mg/kg im
Etomidate	0.3 mg/kg
Fentanyl	1 to 2 µg/kg
Diazepam	0.2 to 0.4 mg/kg
Trimeprazine	2 to 4 mg/kg
Lignocaine	5 mg/kg (maximum safe dose)
Bupivacaine	2 mg/kg (maximum safe dose)

CHAPTER

19 Anaesthesia for Day-case Surgery

OUTPATIENT SURGICAL UNIT

1. Should have adequate facilities to deal with sufficient number of cases
2. Should have adequate space with OT, preoperative check up, preanaesthetic room and postanaesthetic recovery rooms
3. Recovery room should be large enough to accommodate all cases to remain for several hours
4. All anaesthetic drugs, equipment, monitors, emergency drugs should be available
5. Should provide adequate number of anaesthetists, nurses and other personnels in both OT. and recovery room. One senior anaesthetist should take the responsibility of the unit
6. Should have facility for indoor admission in case of adverse situations.

Advantages of Outpatient Surgical Unit

1. A significant reduction of medical cost
2. Increased availability of indoor beds
3. Better comfort and greater control over the patient's personal lives
4. Some protection from hospital-related infections
5. Decreased psychological problems
6. Reduced separation induced anxiety particularly in paediatric cases.

PATIENT SELECTION

A. Patient related

i. ASA physical status I and II and some selected cases of grade III
ii. Patient and accompanying person must be able to follow the directions and advice
iii. A capable person must take care and help the patient at home
iv. Extremes of ages should be avoided. Premature babies are at risk
v. Morbid obesity, physical and mental handicaps are difficult subject for day-case surgery.

B. Related with surgical procedure

i. Operations of short duration

ii. Surgery involving less bleeding, minimum postoperative complications and physiological derangement can be accepted
iii. Patients with risk of airway obstruction should be avoided
iv. Infected cases should be avoided
v. Emergency cases are not suitable
vi. Operations anticipating extensive blood loss, patients requiring large fluid therapy, prolonged surgery may be risky for day-case
vii. Surgical procedures anticipating much postoperative pain may be risky.

PREOPERATIVE EVALUATION

1. Identical to those for any indoor operation
2. Preanaesthetic visit is essential. Careful history, and examination should always be done
3. Medical and anaesthetic history are also important
4. Necessary laboratory studies should always be done. Routine blood and urine exam, chest X-ray and ECG may also be done. Relevant blood biochemistry (sugar, urea, NPN, creatinine) is needed for the aged patients
5. Patients should receive written special preoperative instructions such as time of last feed, reporting time, arrangements of transportation home after discharge, the need for an accompanying adult person to care for the patient
6. Written consent of operation and anaesthesia is mandatory.

PREANAESTHETIC PREPARATION

1. Nothing by mouth after midnight or at least 8 hours prior to anaesthesia. Clear fluids may be allowed upto 2 hours before surgery
2. H_2 receptor antagonists, soluble antacids, metoclopramide may be given in patients at risk
3. Premedication
   i. May not be needed in all patients
   ii. Children should have some premedication like diazepam/trimeprazine
   iii. Atropine sulphate may be indicated in some cases
4. i. Should report at scheduled time and date
   ii. Laboratory reports should be verified
   iii. Physical condition reassessed
   iv. Patient should wear OT dresses
   v. No cosmetics, ornaments, shoes, contact lens, etc. are allowed.

- **Postponement of surgery may be indicated :**

1. No written consent
2. No responsible escort available
3. Unusual late reporting in clinic
4. Full stomach
5. Change of medical conditions.

ANAESTHESIA

Choice of anaesthesia depends on:

1. Patient choice
2. Surgical requirement
3. Period of surgical procedure
4. Age of the patient
5. Physical condition of the patient
6. Duration of drug action
7. Requirement of postanaesthetic care
8. Judgement of anaesthetist concerned.

REGIONAL ANALGESIA

1. Local anaesthesia, peripheral nerve block, spinal block or epidural block are mostly helpful
2. Peribulbar or retrobulbar block can be used in ophthalmic surgery
3. Local anaesthesia and mandibular block are widely used in dental surgery
4. Advantages :
    i. Anaesthesia in surgical site
    ii. Patient awareness
    iii. Less physiological derangements
    iv. Condition at the time of discharge is mostly satisfactory.
5. Disadvantages :
    i. Needs sometime to do block
    ii. Failure/incomplete block can occur
    iii. Awareness
    iv. Specific hazards for particular block
    v. Not always predictable.

GENERAL ANAESTHESIA

1. Essential criteria : Smooth induction, easy maintenance, early uneventful recovery
2. Halothane/enflurane/isoflurane/sevoflurane mostly popular
3. iv agents such as propofol, etomidate, thiopentone, methohexitone can be used as inducing agent. Propofol can induce and maintain anaesthesia. Midazolam, alfentanil or fentanyl can also be used with propofol. Ketamine can be used as sole anaesthetic agent, but it can cause hallucinations, dreams and delirium. Total intravenous anaesthesia is mostly popular for short surgical procedures.
4. Endotracheal intubation can be done, whenever needed
5. Muscle relaxants can be used for intubation and muscle relaxation. Suxamethonium is mostly used for endotracheal intubation. Vecuronium, atracurium, mivacurium, etc. are also suitable for outpatient anaesthesia. Patient should be fully decurarised in case of nondepolarising muscle relaxants at the end of anaesthesia

6. Advantages :
    i. Immediate speedy effect
    ii. Patient comfort
    iii. Generalised effect — mostly guranteed.
7. Disadvantages :
    i. Loss of protective airway reflexes
    ii. Risk of vomiting, aspiration
    iii. Cardiovascular depression.

MONITORED ANAESTHESIA CARE

1. Local anaesthesia and monitored anaesthesia care with sedation are combined
    - Local anaesthesia : Local infiltration, nerve blocks
    - Physical and emotional comfort by sedative drugs
    - Midazolam, propofol, fentanyl, alfentanil, sufentanil, remifentanil can be used cautiously.
2. Advantages :
    i. Maintenance of protective airway reflexes
    ii. Rapid recovery
    iii. Patient awareness, patient can cooperate.
3. Disadvantages :
    i. Inadequate local anaesthesia can occur
    ii. Side effects of sedative drugs.
4. Note :
    i. Provide patient comfort
    ii. Choose appropriate drugs, minimum effective dose in small increments
    iii. Reassurance and psychological support.

POSTOPERATIVE CARE

1. Patient should be fully awake
2. Monitor the vital signs
3. Some complications can occur such as pain, nausea, vomiting, delayed awakening, restlessness, hypotension and so on.

- **Patient may need indoor admission**

1. Persistent vomiting
2. Aspiration pneumonitis
3. Prolonged surgery, surgery extended beyond expectation
4. Poorly controlled coexisting medical diseases
5. Severe blood loss
6. Needs blood transfusion
7. Myocardial ischaemia
8. Airway and respiratory problems
9. Patients refuses discharge
10. Surgeon requires overnight observation.

CRITERIA FOR DISCHARGE

1. Can maintain patent airway unassisted, no respiratory depression, no threat of airway obstruction
2. Heart rate, blood pressure near normal. No hypovolaemia
3. Orientation to person, place and time
4. No drowsiness, clear vision
5. Not much pain, no vomiting, no dehydration, absence of surgical bleeding
6. No fever, no hypothermia
7. Able to sit/little walk with minimal assistance
8. Complete recovery, stable vital signs
9. Responsible adult person present to accompany and to take care
10. Recovery criteria at the time of discharge must be recorded.

- Instructions at the time of discharge :
  i. Regarding activity, medication, care of dressing, diet, bathing restrictions, etc.
  ii. If any complications arise, they should know what to do and where to contact and report
  iii. Avoid alcohol or any depressant drug
  iv. Should not drive automobile and handle complex equipment.

CHAPTER

20 Anaesthesia in Obese Patients

A person is said to be obese when he exceeds the ideal weight corrected for age and sex by more than 10%. Morbid obesity is said when the body weight is more than 20% above the ideal weight.

PATHOPHYSIOLOGY

1. Excessive neutral fat in the fat storage depots of the body
2. Common in both sexes after middle age
3. High metabolic rate, abnormal appetite
4. Exogenous type : Superalimentation and with less muscular activity
5. Endogenous type : Deficiency of one or more endocrine glands: hypothyroidism, hypogonadism, increased activity of adrenal cortex, Cushing syndrome
6. Can occur after encephalitis and following psychological disturbances
7. Obesity shortens the expected span of life
8. Usually prone to hypertension, myocardial disease, diabetes mellitus, adrenal, renal and hepatic dysfunction, cardiomegaly
9. Decreased lung functions, restrictive ventilation defect, hypoxaemia and hypercapnia, pulmonary hypertension, emphysema, right heart failure
10. General lassitude, dyspnoea on exertion, osteoarthritis, various aches and pains in the body, sleep apnoea
11. Pickwickian syndrome : Obesity hypoventilation syndrome characterised by massive obesity, daytime somnolence and hypoventilation ultimately leading to pulmonary hypertension and right ventricular failure
12. Hypercholesterolaemia and hypertriglyceridaemia.

PROBLEMS OF ANAESTHESIA

1. Fatty and heavy, difficult to move and lift
2. Veins may be inaccessible

3. Coexisting diseases : Hypertension, diabetes, atherosclerosis, cardiomegaly, deranged respiratory functions, endocrine and metabolic disorders, hepatic and renal dysfunction and so on
4. Laryngoscopy and endotracheal intubation may be difficult. Difficult to get a clear patent airway, needs IPPV
5. Induction of anaesthesia may be hazardous
6. Surgery is technically difficult, much muscle relaxants needed
7. High serum cholinesterase level in obesity, so the effects of suxamethonium quickly pass off
8. Risk of pulmonary aspiration. Raised intraabdominal pressure. Hiatus hernia may be present
9. Tolerate abnormal position badly
10. Tolerate blood loss badly
11. Postoperative lung complications, thromboembolic complications common
12. Preoperative dieting may be helpful. But drastic dieting can cause acidosis, hypokalaemia and hyperuricaemia
13. Regional anaesthesia may be difficult to achieve. Landmarks are often ill-defined.

PREANAESTHETIC ASSESSMENT

1. Preoperative evaluation is essential
2. History of taking drugs, any addiction, any coexisting disease
3. Thorough examination, particularly cardiovascular and respiratory system
4. Laboratory investigations : Routine blood and urine test, ECG, chest X-ray, blood biochemistry
5. Blood transfusion may be needed.

PREMEDICATION

1. Preoperative night sedation
2. Relieve fear, anxiety and tension
3. Atropine is useful to get antisalivary effect
4. Narcotic analgesics should be used cautiously
5. H_2 receptors antagonists : Cimetidine, ranitidine as obese patients have increased risk of aspiration.

ANAESTHESIA

A. Induction of anaesthesia

i. Inhalation or intravenous agents with caution
ii. Decreased mandibular and cervical spine mobility may pose difficult intubation
iii. Adequate preoxygenation is always helpful
iv. Cuffed endotracheal tube should be used
v. IPPV is essential
vi. Rapid sequence of anaesthesia induction may be used.

B. Maintenance

i. Volatile anaesthetic agents can be used
ii. Controlled ventilation
iii. CO_2 absorption technique is the method of choice
iv. Muscle relaxant should be used cautiously and complete decurarisation is mandatory at the end of anaesthesia
v. Hypoxia, hypercarbia and hypotension should be avoided
vi. Adequate monitoring of vital signs
vii. Extreme postures should be avoided. Avoid prone and head down position
viii. Fluid therapy should be accurate.

C. Postoperative Care

i. Hypoventilation, hypoxia, hypercarbia, acidosis and hypotension can occur easily. Monitor arterial oxygenation. Oxygen therapy
ii. Narcotic analgesics should be used in small doses
iii. Respiratory physiotherapy and early ambulation are helpful
iv. Common complications : Pulmonary complications, deep vein thrombosis, wound infection, etc.

CHAPTER

21 Geriatric Anaesthesia

Arbitrarily old age starts from 65 years of age. There may not be any correlation between biologic and chronologic age. It is accompanied with unavoidable decreases in organ function, increased atrophy, rigidity and fibrosis of body tissues and decreased adaptability and growth.

Cardiovascular System

Myocardial fibrosis, hypertrophy of the heart, myocardial ischaemia, cardiac enlargement, coronary artery disease.

Heart rate and cardiac output decrease, decreased responsiveness to an increase in adrenergic drive. Baroreceptor reflex diminished. Arrhythmias, conduction defect and congestive cardiac failure are common.

Respiratory System

Impairment of mechanical ventilatory function and efficiency of gas exchange. Tidal volume and vital capacity diminish. Decreased FEV_1 and forced vital capacity. Maximum breathing capacity decreases.

Emphysema, chronic bronchitis, asthma, chronic obstructive pulmonary disease are common.

Genitourinary System

Progressive reduction in kidney mass, renal vascular bed and renal blood flow. Diminished tubular function and glomerular filtration rate. Renal excretion of certain drugs hampers. Less able to concentrate urine with fluid deprivation, risk of hyponatraemia. Prostatic hypertrophy is common in old age.

Nervous System

Overall atrophy of brain, cerebral atherosclerosis, thrombosis, hypertensive encephalopathy can occur. Decline in central nervous system activity.

Slow impaired memories, labile emotions, mental psychological and personality changes. Parkinsonism, mental confusion, dementia are common. Disturbances in sleep pattern.

Endocrine System

Endocrine dysfunction, diabetes mellitus, hypothyroidism are common.

Other Changes

Metabolism is low, subnormal body temperature, poor physiological response to injury. Nerve deafness, poor vision, cataract.

Obesity, osteoarthritis, neoplastic diseases, anaemia, hypoproteinaemia, vitamin deficiency are common.

Hepatic blood flow decreased, functions deranged. Drug clearance is delayed.

Bones rarefied, fractures are common. Old becomes edentulous and the mandible becomes shorter.

Common Co-Existing Diseases in the Aged

1. Coronary artery disease
2. Hypertension
3. Strokes
4. Diabetes mellitus
5. Chronic obstructive pulmonary disease
6. Renal insufficiency/dysfunction
7. Anaemia
8. Parkinson's disease
9. Osteoarthritis
10. Congestive cardiac failure.

PREANAESTHETIC ASSESSMENT

1. Proper history of the illness
2. Any coexisting other ailment
3. Any addiction, any medication
4. Thorough clinical examination
5. Laboratory investigations : Routine blood and urine examination, chest X-ray, ECG, blood biochemistry (glucose, urea, NPN, creatinine, electrolytes)
6. Blood transfusion may be needed
7. Psychological status needs evaluation.

PREOPERATIVE PREPARATION

1. Night sedation
2. Tranquilliers like promethazine, diazepam
3. Minimum sedative/analgesic drugs, whenever needed
4. H_2 receptor antagonists
5. Preoperative visit is essential
6. Use of anticholinergic drugs is controversial. Avoid hyoscine in elderly patients.

ANAESTHESIA

- Anaesthetic requirement may be decreased in old age
- Aspiration of gastric contents is common due to decreased reactivity of protective airway reflexes
- Regional anaesthesia may be helpful in selected cases. Dose of local anaesthetics in epidural block decreases with increasing age and there is risk of high spread due to osteoarthritic blocking of intervertebral foramina
- General anaesthesia
    i. Proper mask fit is difficult in edentulous patients
    ii. Risk of dislodgement of loose teeth
    iii. Cuffed endotracheal tube should always be used
    iv. Assisted/controlled ventilation
    v. Hypoxia, hypercarbia and hypotension should be avoided
    vi. MAC value of all volatile anaesthetics is reduced in the aged
    vii. Halothane, enflurane or isoflurane can be used
    viii. Adequate monitoring during anaesthesia is essential
    ix. Fluid therapy should be accurate. Estimated blood loss should be replaced
    x. Extreme posture should always be avoided
    xi. Adequate decurarisation at the end of anaesthesia.

POSTOPERATIVE CARE

i. Monitor the vital signs
ii. Oxygenation may be needed
iii. Fluid therapy needs attention
iv. Personal hygiene, care of the eyes, skin, bowel and bladder
v. Nutritional care
vi. Early ambulation and physiotherapy recommended.

CHAPTER

22 Cardiopulmonary Resuscitation

A series of well-defined steps and protocols to revive a collapsed patient, to deliver oxygen to the heart and brain and to restore native circulation and ventilation.

Stages

1. Basic cardiac life support: Resuscitation without the aid of equipment
2. Advanced cardiac life support: Resuscitation with the help of advanced techniques and equipment.

Basic Cardiac Life Support (BCLS)

It should be started immediately and continued till the ACLS support arrives.
It should provide:

a. Adequate patent airway
b. Artificial breathing by expired air respiration
c. Artificial circulation by external chest compression.

Airway

Tongue may fall to the back of the pharynx: Tilt the head back and lift the chin forward:
Clear the mouth and airway. Airway tube may be used.

Breathing

In cases of no effective breathing, artificial ventilation should be started by expired air respiration.

Patient's mouth should be covered by the mouth of the rescuer while the patient's nose is pinched closed by fingers.

The expired air should be blown to the patient to raise the chest. Then the mouth should be removed to allow the patient exhale. This mouth to mouth respiration should be given at 12-15 breaths per minute.

Circulation

If there is no heart beat, no pulse in big arteries like carotid, femoral, etc. the artificial circulation in the form of closed chest cardiac massage should be started.

Chest compressions should be given on lower third of sternum using the overlapping palm of both hands. Sternum is depressed 4 to 5 cm, about 80 times per minute. The effectiveness of compression should be verified by peripheral pulses.

- After 15 compression, 2 mouth-to-mouth respirations are to be given
- Resuscitation sequence should be continued till ACLS service comes
- In case of 2 rescuers available, the chest compression should be given 60 times per minute and the second rescuer interposes expired air ventilation after every 5th compression.

Note :

- **Resuscitation of children**
  Sternal compression : 2.5 to 3.87 cm depth
  rate: 80 to 100/minute
  Sternal compression/ventilation ratio: 5 : 1
  Sternal compression: Depression of sternum by using 3 fingers.
- **Resuscitation in infants**
  Sternal compression: 1.25 to 2.5 cm depth
  rate: at least 100/min.
  Sternal compression /Ventilation ratio: 5 : 1
  Sternal compression: Chest is encircled with both hands and depression of mid sternum with thumbs.

Mechanism for blood flow during closed chest cardiac compression :

1. Compression of cardiac ventricles
2. Increased intrathoracic pressure produces antegrade blood flow (thoracic pump mechanism)
3. Patient-related factors:
   a. Heart size
   b. Anteroposterior chest distance
   c. Thoracic compliance
   d. Compression depth and duration
   e. Manual/mechanical compression.

Early diagnosis of cardiac arrest is essential:

1. No pulse in big vessels
2. Silent precordium
3. No respiration/gasping
4. Unconscious
5. Widely dilated pupils, unresponsive to light
6. Sudden cessation of bleeding on operation site
7. Electrocardiogram
   (a) Asystole: Cardiac standstill, no contraction of myocardium

(b) Ventricular fibrillation: Uncoordinated ineffectual contraction of myocardium
(c) Electromechanical dissociation: QRS complex is present, but no palpable pulse.

Advanced Cardiac Life Support (ACLS)

A. Airway:

Use of Guedel airway
Use of nasopharyngeal airway
Tracheal intubation with a cuffed endotracheal tube.

B. Breathing :

Use of self inflating resuscitation bag
Use of anaesthetic machine and application of manual ventilation
Use of mechanical ventilators.

C. Circulation :

iv access
Administration of fluids
Vasopressors: Dopamine

i. Cardiac asystole
Adrenaline 1 mg. iv
Cardiac pacing
Consider possible causes: Hypoxia, hyper or hypokalaemia, acidosis, hypothermia, drug overdose.

ii. Ventricular fibrillation
Defibrillation, 200J.
If fails, defibrillation again 200J.
If fails, defibrillator with 360J.
If fails, adrenaline 1 mg iv and then defibrillation with 360J.
If still fails administer lignocaine 100 mg iv
Then repeat defibrillations with 360J.
Other antiarrhythmic drugs may be used ; consider termination of efforts.

iii. Electromechanical
a. Adrenaline 1 mg iv
b. Specific treatment should be done when the cause is known such as hypovolaemia, cardiac tamponade, hypothermia.
Pneumothorax or pulmonary embolism, massive acute myocardial infraction.
c. Calcium chloride 10 ml of 10% solution for hyperkalaemia, hypocalcaemia, overdose of calcium antagonists.

Role of Sodium bicarbonate

50 ml of 8.4% sodium bicarbonate may be helpful provided the effective ventilation has established.

Excess sodium bicarbonate may cause alkalosis, hyperosmolality and hypernatraemia and may lead to failure of effective resuscitation.

Postresuscitation complications

1. Cerebral oedema
2. Pulmonary oedema
3. Kidney failure.

Criteria for Brain Death

1. i. Coma
   ii. Exclude hypothermia and depressant drug overdose and metabolic or endocrine disturbances.
2. i. Absent brainstem activity
   ii. Fixed and unreactive pupils.
   iii. Apnoea despite normal to raised inspired $PaCO_2$ above 8kPa.
3. i. Absent cortical activity
   ii. Flat electroencephalogram
4. Absent cerebral circulation; cerebral angiographic study.

Following tests / functions demonstrate brainstem death:

i. Apnoea
ii. Fixed pupils
iii. Absent corneal reflex
iv. Absent vestibuloocular reflex (Caloric test):
20 ml ice cold water poured in ear drum, no movement of the eye will be detected. Patency of the ear canal should be intact.
v. Absent motor response in the cranial nerve distribution to any stimulation.
vi. Absent gag reflex
vii. Oculocardiac reflex: Patient's head is turned from side-to-side, eye movement is observed.
   a. Nonfunctioning brainstem: No movement of the eyes (China doll)
   b. Functioning brainstem: Eyes move (swivel-eyed doll).

CHAPTER

23 Anaesthesia and Common Coexisting Diseases

HYPERTENSION

A systolic blood pressure more than 160 mm Hg and/or a diastolic pressure above 90 mm Hg indicates hypertension.

Types

A. Essential or primary hypertension : Cause not known.
B. Secondary hypertension : Aetiology is known.

Causes:

i. Renal disease (pyelonephritis, glomerulonephritis, chronic nephritis, renal artery stenosis, polycystic kidney
ii. Coarctation of aorta
iii. Pheochromocytoma
iv. Intracranial hypertension
v. Primary aldosteronism, Cushing syndrome
vi. Drugs : Oral contraceptives
vii. Preeclampsia, eclampsia.

Complications

1. Ischaemic heart disease, congestive heart failure, left ventricular failure
2. Renal failure
3. Cardiovascular accident
4. Hypertensive crisis
5. Retinopathy

Degree of hypertension:

- Mild hypertension : Diastolic blood pressure of 90 to 104 mm Hg
  Moderate hypertension : Diastolic pressure of 105 to 114 mm Hg
  Severe hypertension : Diastolic pressure is equal to or more than 115 mm Hg

Malignant hypertension : Presence of papilloedema on fundoscopic examination independent of the absolute level of blood pressure.

Assessment

Clinical assessment : BP measurement, physical examination on end organ damage

i. Kidneys: Blood urea nitrogen, creatinine, electrolytes
ii. Heart: Cardiomegaly, ischaemia, left ventricular failure
iii. Brain: Dizziness/syncope
iv. Peripheral vascular disease: Claudication.

Laboratory Investigations

i. Urine analysis
ii. Haematocrit
iii. Plasma glucose, potassium, creatinine, urea, uric acid
iv. Fasting serum cholesterol, triglycerides, calcium
v. ECG
vi. Chest X-ray.

Treatment

1. Moderate sodium restriction
2. Weight reduction
3. Regular isotonic exercise
4. Avoid stress and strain
5. Avoid alcohol, smoking
6. Drug treatment
    i. Diuretics : Thiazides (chlorthiazide, hydrochlorthiazide), Loop diuretics (furosemide, ethacrynic acid), Potassium sparing diuretics (spironolactone triamterene),
    ii. Antiadrenergic drugs : Centrally acting clonidine, methyldopa, peripherally acting reserpine, guanithidine
    iii. Alpha adrenergic antagonists : Phenoxybenzamine, phentolamine
    iv. Beta adrenergic antagonists : Propranolol, practolol, atenolol, metopralol
    v. Directly acting vasodilators : Hydralazine, minoxidil
    vi. Calcium channel blockers : Nifedipine, verapamil, diltiagem
    vii. Angiotensin converting enzyme inhibitors : Captopril, ramipril, enalapril.

Hypertensive Crisis

1. Diastolic blood pressure is more than 130 mm Hg.
2. Causes : Chronic hypertension, renovascular hypertension, pheochromocytoma, eclampsia, head injury, spinal cord injury.
   Drugs : Cocaine, LSD, tricyclic antidepressants
   Sudden stoppage of antihypertensive drugs.

3. Management
   iv nitroprusside
   Monitor intraarterial blood pressure, urine output.

Management of Anaesthesia for Hypertensive Patient

A. **Note :**
   1. The severity of end organ dysfunction
   2. Present antihypertensive medication
   3. Preoperative blood pressure. Adequate control of BP
   4. Antihypertensive drugs should be continued on the day of surgery, otherwise rebound increase in sympathetic outflow can occur
   5. Diuretics can be discontinued as they decrease intravascular volume and the patient may suffer hypotension due to blood loss, fluid restriction and vasodilation caused by volatile anaesthetics
   6. Maintain BP and pulse rate within a range of 20% of baseline, otherwise ischaemia can occur in vital organs
   7. Use of vasopressors and iv infusion of fluid should be cautious
   8. Associated organ dysfunction should be noted :
      a. Orthostatic hypotension
      b. Ischaemic cardiac dysfunction
      c. Cerebrovascular disease
      d. Peripheral vascular disease
      e. Renal dysfunction.

B. Induction of anaesthesia:
   1. Exaggerated BP changes can occur during laryngoscopy and endotracheal intubation
   2. Surgical anaesthesia may be done with volatile anaesthetics
   3. Short duration of laryngoscopy is needed
   4. Laryngeal spray of lignocaine, iv lignocaine, esmolol, nitroprusside may be helpful.

C. Maintenance of anaesthesia:
   1. Volatile anaesthetics are mostly satisfactory.
   2. Intraoperative monitoring is essential.

D. Postoperative management:
   1. Hypertension can occur
   2. Monitoring should be continued.

CONGESTIVE CARDIAC FAILURE

1. Causes :
   i. Heart valve abnormalities/malfunction
   ii. Impaired myocardial contractility due to ischaemic heart disease or cardiomyopathy
   iii. Systemic hypertension
   iv. Pulmonary hypertension

2. Features of left ventricular failure:
    i. Dyspnoea, orthopnoea, paroxysmal nocturnal dyspnoea
    ii. Acute pulmonary oedema
    iii. Tachycardia, tachypnoea
    iv. Pleural effusion
    v. Oliguria.
3. Features of right heart failure:
    i. Systemic venous congestion, raised CVP
    ii. Enlarged liver
    iii. Peripheral oedema
    iv. Ascitis.
4. Management of congestive cardiac failure:
    i. Digitalis
    ii. Diuretics
    iii. Vasodilators
    iv. Beta agonists : IV infusion of dopamine and/or dobutamine.
5. Anaesthetic considerations :
    A. General anaesthesia:
        i. Preoperative treatment of infection, if any
        ii. Maintain a clear patent airway. IPPV
        iii. Ketamine can be used for induction of anaesthesia
        iv. Opioids can be used
        v. Monitoring of vital signs, invasive monitoring of blood pressure
        vi. Dopamine may be needed to support cardiac output
        vii. Avoid hypoxia, hypercarbia and hypotension
        viii. Drug interaction in digitalised patients should be borne in mind
    B. Regional anaesthesia : May be well-considered in cases of peripheral operation.

MITRAL STENOSIS

1. A manifestation of rheumtic heart disease affecting the mitral valve
2. Clinical features : Atrial fibrillation, arterial embolism, pulmonary hypertension, pulmonary oedema, right heart failure.
3. Problems :
    i. Usually receiving digoxin, diuretics and anticoagulants. Interaction of drugs can occur
    ii. Control atrial fibrillation
    iii. Treat pulmonary oedema
    iv. Management of anticoagulant therapy needed.
4. Anaesthesia
    i. Control heart rate. Tachycardia and bradycardia should be avoided
    ii. Avoid hypoxia, hypercarbia and hypotension
    iii. Drugs causing vasodilation should be avoided

iv. Avoid/treat acidosis
v. Opioid analgesics should be given carefully
vi. Avoid airway obstruction
vii. Avoid increase in central blood volume. Overinfusion should be avoided.

ISCHAEMIC HEART DISEASE

1. A previous myocardial infarction, within 3 months increases the risk of reinfarction. Elective surgery should better be postponed at least 6 months after infarction
2. There may be symptomless ischaemic heart disease
3. Unstable angina should always be controlled before surgery with beta blockers, nitrates or calcium antagonist
4. Various factors may precipitate further infarction. Avoid increase of myocardial work and hence oxygen requirement. Avoid decrease of coronary blood flow.
5. Anaesthetic implications :
   i. Treat the congestive cardiac failure with diuretics and digoxin, if necessary
   ii. Anaemia should be corrected preoperatively
   iii. Premedication should be adequate. Anxiolytic drugs are often helpful
   iv. Avoid tachycardia/bradycardia
   v. Avoid hypotension/hypertension
   vi. Avoid hypoxaemia
   vii. Beta blockers is maintained
   viii. Maintain normocapnia. Hypercapnia may initiate arrhythmia and hypocapnia can cause peripheral and coronary vasoconstriction and leftward shift of oxygen dissociation curve
   ix. Avoid fluid overload. Monitor fluid therapy meticulously
   x. Close monitoring is vital
   xi. Choice of anaesthetic agent should be carefully judged
   xii. Postoperative care :
   Adequate monitoring
   Management of analgesia
   Control the blood pressure precisely.

Note :

- Laryngoscopy and endotracheal intubation should be of short duration. Blood pressure and/or heart rate response to endotracheal intubation should be minimised by:
  i. Laryngotracheal lignocaine
  ii. iv lignocaine
  iii. Nitroprusside iv
  iv. Esmolol iv
- Volatile anaesthetics with N_2O are mostly satisfactory
- Muscle relaxants : Vecuronium, doxacurium, pipecuronium are with minimum circulatory effects. Pancuronium increases heart rate and blood pressure.

BRONCHIAL ASTHMA

1. The disease is characterised by recurrent, reversible, generalised airways obstruction mostly due to bronchial smooth muscle spasm, mucons plugs and local oedema
2. Increased responsiveness of the airways in various stimuli
3. Chronic inflammatory changes in bronchial submucosa
4. Pathophysiology :
   i. Release of chemical mediators like histamine, prostaglandins, etc.
   ii. May have abnormalities of autonomic nervous system to regulate airway tone in a balanced way
   iii. Chronic inflammation/infection of the airway.
5. Classification :
   A. Extrinsic : External allergen detectable
   B. Intrinsic : Occurs in adults, more chronic and continuous, requires long-term steroid therapy.
6. Precipitating factors :
   i. Inhaled/ingested allergens/irritants
   ii. Airway infection
   iii. Strenuous exercise.
7. Manifestations :
   i. Wheezing
   ii. Cough
   iii. Dyspnoea
   iv. Tachypnoea
   v. FEV_1 and maximum midexpiratory flow rate depends on severity of the disease.
   vi. PaO_2 decreases
   vii. $PaCO_2$ increases.
8. Treatment :
   i. Bronchodilator drugs : Theophylline, β_2 agonist like albuterol by metered dose inhaler
   ii. Antiinflammatory drugs : Steroids, Cromoglycate by metered dose inhaler
   iii. Antibiotics
   iv. Oxygen.
9. Anaesthetic management:
   i. Preoperative assessment:
      a. Current state should be assessed by proper history, examination and pulmonary function tests
      b. Blood gas study may be helpful in severe cases
      c. Chest physiotherapy, systemic hydration and suitable antibiotics and bronchodilator drugs are much useful to improve the condition.
   ii. Asthma must be controlled before elective surgery
   iii. Patients with steroid therapy should have adequate steroid coverage

iv. Premedication : A sedative (diazepam) with atropine may be given. Pethidine and promethazine are mostly satisfactory. Opioids, H_2 receptor antagonist are better avoided. Bronchodilator drugs should be continued

v. a. Induction of anaesthesia should be smooth
   b. Cautious laryngoscopy and endotracheal intubation
   c. Volatile anaesthetics like ether, halothane are better tolerated. Ketamine is bronchodilator
   d. Bronchospastic drugs should to be avoided
   e. Beta blockers, tubocurarine, morphine should be avoided. Extubation should be done when the patient is still unconscious.

vi. Regional anaesthesia is a better choice and mostly satisfactory

vii. Muscle relaxants those do not cause histamine release should be used

viii. Mechanical ventilation of the lungs, a prolonged expiratory phase may be needed. Inspiratory time should be adequate. Humidification may be needed, if IPPV is prolonged.

- **Intraoperative bronchospasm**

A. Causes :
   1. Airway obstruction, secretions, kinking of tube, overinflation of the cuff
   2. Inadequate depth of anaesthesia
   3. Endobronchial intubation
   4. Aspiration of gastric contents
   5. Acute asthmatic attack.

B. Differential diagnosis :
   1. Pneumothorax
   2. Pulmonary oedema
   3. Pulmonary embolism.

C. Management :
   1. Patent clear airway should be guaranteed
   2. Oxygenation
   3. Deepen anaesthesia with halothane
   4. i. Aminophylline iv
      ii. Salbutamol
   5. iv hydrocortisone although it has no immediate effect.

CHRONIC OBSTRUCTIVE AIRWAYS DISEASE

1. Limitation of airflow secondary to either airway disease (chronic bronchitis) or destruction of lung parenchyma (emphysema) or both
2. Two groups:
   i. Bronchitis group (blue bloaters) : Clinical features include hypoxia, hypercapnia and right ventricular failure
   ii. Emphysematous group (pink puffers) : These patients are usually severely dyspnoeic.

3. Preoperative management:
    i. Active infection, if any should be treated with broad spectrum antibiotics. Chest physiotherapy, humidification of inspired gases
    ii. Treat airway obstruction : Bronchodilator therapy
    iii. Chest X-ray
    iv. Treat congestive cardiac failure : Digoxin, diuretic therapy.
    v. Weight reduction in cases of obesity.
4. Premedication:
    i. Avoid opioids
    ii. Atropine sulphate to reduce secretions
    iii. Diazepam.
5. Regional anaesthesia may be advantageous as it offers freedom from respiratory ill effects and avoids complications of general anaesthesia.
6. General anaesthesia:
    i. Minimum sedation, avoid opioids. Maintain spontaneous/assisted ventilation as far as practicable
    ii. Controlled oxygen therapy
    iii. a. In cases of major surgery, cautious endotracheal intubation. IPPV. Muscle relaxants and anaesthetic agents should be used carefully
        b. Optimal ventilation. Avoid hyperventilation
        c. High inflation pressure increases the risk of pneumothorax.
    iv. Judicious administration of fluids. Overhydration should be avoided.
    v. Postoperative care :
        a. Elective postoperative controlled ventilation
        b. Adequate oxygenation. Controlled oxygen therapy
        c. Analgesia without respiratory depression
        d. Tracheobronchial toilet
        e. Avoid fluid overload
        f. Chest physiotherapy
        g. Bronchodilators
        h. Antibiotics
        i. Adequate monitoring in postoperative period is vital.

DIABETES MELLITUS

Types

A. Insulin dependent diabetes mellitus:
    i. Usually starts below the age of 16 years, abrupt onset, manifested with polyphagia, polydipsia and polyuria
    ii. They need insulin exogenously. Prone to ketoacidosis
    iii. Wide variations of blood glucose concentration.

B. Noninsulin dependent diabetes mellitus.
Usually starts above the age of 35 years, gradual onset, may be asymptomatic. May not need exogenous insulin. Boold glucose concentration relatively stable. Ketoacidosis may not always occur.

Complications

1. Ketoacidosis
2. Hypoglycaemia
3. Atherosclerosis
4. Nephropathy
5. Autonomic neuropathy : Impotence, orthostatic hypotension, cardiac dysrhythmia, gastroparesis
6. Sensory neuropathy : Carpal tunnel syndrome
7. Stiff joint syndrome.

Treatment

1. Diet
2. Oral hypoglycaemic agents : Tolbutamide, acetohexamide, tolazamide, chlorpropamide, glyburide
3. Exogenous insulin : Regular insulin, semilente isophane, protamine zinc, ultralente.

Management of Anaesthesia

1. Preoperative assessment:
   i. Previously undiagnosed or controlled by diet/oral drugs/ insulin.
   ii. Any evidence of complications :
   angina, myocardial infarction, hypertension, postural hypotension, anaemia, neurological impairment, pain, numbness, paraesthesia, leg ulcer, skin infection, etc.
   iii. Concurrent drug therapy, if any.
   iv. Investigations :
   Blood count, blood glucose level, urine analysis, ECG, X-ray chest.
   v. There should be no glucose in urine. Blood pressure and heart rate should be near normal.
   vi. Avoid hypoglycaemia, prevent hyperglycaemia, ketoacidosis and electrolyte disturbances. Exogenous insulin and glucose should be provided.
2. Diabetes must be controlled. Switch on short acting soluble insulin usually on twice daily basis at least for 3 days prior to surgery.
3. On the day of operation:
   i. No subcutaneous insulin
   ii. 10% glucose 500 ml with soluble insulin 10 units and 10 mmol of potassium chloride should be started in the morning and subsequent insulin therapy should be adjusted depending on blood sugar level. Potassium should be given according to plasma potassium level.

4. Postoperative:
   Infusion of glucose and insulin should be continued until oral intake is established. Subcutaneous insulin can be then be given.
5. Anaesthesia:
   Choice of drugs for induction and maintenance of anaesthesia should be carefully judged. Controlled ventilation with N_2O and O_2 is always helpful. Muscle relaxants can be used. Avoid hypoxia, hypercarbia and hypotension. Monitoring of blood glucose at regular intervals is mandatory.
   Regional anaesthesia may have some definite advantages in diabetic patients.

Management in presence of Ketoacidosis

1. Basic pinciples:
   i. Control of blood sugar by soluble insulin
   ii. Correction of dehydration
   iii. Electrolyte management.
2. Investigations :
   Blood glucose, electrolytes, urea
   Hb%, blood gas study
   ECG
   Chest X-ray
   Urine analysis.
3. Management:
   i. iv infusion of glucose saline with CVP monitoring
   ii. Soluble insulin 20 units iv start and then iv infusion at 10 units/hour. Low doses of insulin 6 to 8 units/hr by continuous infusion is mostly satisfactory and reliable
   iii. Potassium supplementation
   iv. Bicarbonate in severe acidosis in doses of 1 mmol/kg
   v. Broad spectrum antibiotics
   vi. Suction through nasogastric tube is helpful to prevent aspiration.
      • Once blood sugar starts falling, it indicates that insulin is acting successfully, then and only then surgery can be started.
   vii. Anaesthesia:
      a. N_2O, O_2 and relaxant technique with IPPV is safe
      b. Crash induction with cricoid pressure
      c. Frequent blood gas studies
      d. Reversal of relaxants may be impaired in presence of acidosis
      e. Ventilatory assistance may be needed in postoperative period.
   viii. Sliding scale insulin : When acute episode subsides, insulin can be given on a sliding scale based on sugar percentage on urine test. Soluble insulin should be given afterwards when the patient is settled and is eating normal food. The dose should be based on blood sugar.

- Monitoring blood glucose every hour is recommended during operation. Blood glucose less than 100 mg% indicates additional glucose and more than 250 mg% indicates additional exogenous insulin.

THYROID DYSFUNCTION

Thyroid Function Tests

1. Total plasma thyroxine (T_4) level
2. Resin triiodothyronine uptake R T_3 U
3. Total plasma triiodothyronine (T_3) level
4. Thyroid stimulating hormone TSH
5. Thyroid scan
6. Ultrasonography
7. Antibodies to thyroid gland components.

Note :

Hyperthyroidism :

T_4, RT_3U and T_3 increased

TSH normal

Primary hypothyroidism :

T_4, RT_3U, T_3 decreased

TSH increased

Secondary hypothyroidism

T_4, RT_3U, T_3 and TSH decreased.

HYPERTHYROIDISM

Manifestations: Increased BMR.

Enlarged thyroid, increased pulse rate, nervousness, anxiety, tremor, fatigue, increased appetite, weight loss, muscle weakness, exophthalmos, heat intolerance, sweating, atrial fibrillation.

Treatment

1. Assess the condition carefully
2. Antithyroid drugs : Propylthiouracil, methimazole, Beta blockers (propranolol) relieves symptoms of excessive sympathetic nervous system activity
3. Surgery : Subtotal thyroidectomy
4. Radioactive iodine.

Management of Anaesthesia

1. Patient must be made euthyroid before elective surgery
2. Avoid tachycardia. Avoid anticholinergic drugs
3. Prepare the patient for surgery wih beta antagonist

4. Upper airway should be evaluated, chance of difficult intubation
5. Induction of anaesthesia should be smooth
   Thiopentone, suxamethonium or nondepolarising muscle relaxants that lacks cardiovascular effects can be used.
6. Anaesthesia can be maintained with N_2O, isoflurane
7. Vital signs should be monitored
8. Avoid hypoxia, hypercarbia and hypotension
9. Regional anaesthesia may be considered in selected cases
10. Following subtotal thyroidectomy
    i. Airway obstruction can occur due to haematoma, tracheomalacia
    ii. Damage of recurrent laryngeal nerve can occur. Causes hoarseness, aspiration, etc.
    iii. Hypoparathyroidism may occur due to inadvertent removal of parathyroids
    iv. Laryngospasm can occur due to hypocalcaemia.

Thyroid Strom/Thyrotoxic Crisis

1. Abrupt exacerbation in intensity of features of thyrotoxicosis
2. Precipitated by surgery infection, ketosis, burns, trauma, etc. particularly in poorly controlled thyrotoxicosis, following radioactive iodine therapy or excessive administration of exogenous thyroid hormone.
3. Manifestations :
   High fever, tachycardia, atrial fibrillation, heart failure, sweating, dehydration, electrolyte imbalance, confusion, delirium, agitation, stupor, coma.
4. Prevention :
   i. Surgery should be done is euthyroid state
   ii. Hyperthyroidism should be treated adequately
   iii. Beta blocker should be given in perioperative period.

Treatment

1. Restoration and maintenance of vital functions :
   Fluids, electrolytes, iv infusion of glucose, oxygen.
2. Control of high fever : Tepid sponging, cooling fans, cooling blanket, ice cold saline.
3. Antithyroid drugs : Sodium iodide, carbimazole
4. Hydrocortisone
5. Correction of sympathetic overactivity : Propranolol, esmolol
6. Digitalis, inotropes, diuretics, IPPV to manage heart failure
7. Treat the precipitating factor, if any
8. Monitoring the vital signs is essential.

HYPOTHYROIDISM

1. Causes : Hyposecretion of the hormone due to idiopathic atrophy, medical treatment of hyperthyroidism or surgical removal of gland.

2. Manifestations :
    i. Bradycardia, decreased cardiac output, peripheral vasoconstriction, orthostatic hypotension, arrhythmias, pericardial effusion
    ii. Ventilatory failure, pleural effusion
    iii. Intolerance to cold
    iv. Lethargy, myopathy, anaemia, peripheral oedema
    v. Atrophy of adrenal cortex
    vi. Hyponatraemia
    vii. Decreased BMR.
3. Treatment :
   Oral administration of thyroxine
4. Management of anaesthesia
    i. Needs supplemental cortisol administration
    ii. IV ketamine may be used for induction of anaesthesia
    iii. Maintenance of anaesthesia:
       N_2O with supplementation of short acting opioid, benzodiazepine or ketamine
    iv. Extubation should be done when the patient is fully awake
    v. Regional anaesthesia is mostly satisfactory provided intravascular fluid volume is maintained.
    vi. **Note :**
        a. These patients have increased sensitivity to depressant drugs
        b. Cardiovascular system is hypodynamic
        c. Slow metabolism of drugs
        d. Baroreceptor reflexes are unresponsive
        e. Associated with hypervolaemia, hyponatraemia, hypothermia, anaemia, hypoglycaemia, adrenal insufficiency
        f. Impaired ventilatory response to hypoxaemia or hypercarbia.

PHEOCHROMOCYTOMA

1. Catecholamine secreting tumour may arise in adrenal medulla or any sympathetic ganglion.
2. Manifestations :
   Palpitation, paroxysmal hypertension, diaphoresis, tachycardia, headache, fits, blurred vision, increased BMR and O_2 consumption, haemoconcentration, retinopathy, increased blood concentration of glucose, lactic acid and free fatty acid.
3. Diagnosis confirmed by excessive catecholamine level in blood. Computed tomography may also be helpful to localise the tumour. Urinary excretion of catecholamines or of their metabolites is also increased.
4. Complications :
    i. Congestive cardiac failure
    ii. Myocardial infarction
    iii. Intracerebral haemorrhage.

5. Treatment:
   i. Surgical removal of the tumour
   ii. Medical control by alpha blockers and beta blockers.
6. Management of anaesthesia:
   i. Do not stimulate the sympathetic nervous system
   ii. Use invasive monitoring
   iii. Alpha and beta antagonist therapy should be continued
   iv. Supplemental cortisol may be needed
   v. Smooth iv induction of anaesthesia, maintenance may be done with N_2O and isoflurane.
   vi. Endotracheal intubation should be gentle and smooth. Circulatory responses should be minimised
   vii. Nondepolarising muscle relaxant devoid of circulatory effects may be used
   viii. Nitroprusside, esmolol, lignocaine may be needed, whenever necessary
   ix. Monitoring of arterial blood gases, electrolytes and blood glucose is essential. Pulmonary artery catheter is often helpful
   x. Monitoring should be continued in postoperative period
   xi. Adequate pain relief is needed in postoperative period.

LIVER DISEASES

Liver Function Tests :

1. Bilirubin level of serum (0.3-1.1 mg%)
   i. Conjugated or direct bilirubin
   ii. Unconjugated or indirect bilirubin.
2. Enzyme tests
   i. Alkaline phosphatase 3-13 KA units/100 ml
   ii. Transaminases
   SGOT (aspertate aminotransferase) 5-30 IU/litre
   SGPT (alanine aminotransferase) 2-53 IU/litre
   iii. Lactic dehydrogenase 100-300 IU/litre
3. Plasma proteins 6-8g% albumin 3.5-5g% ; globulin 1.5–3 g%
4. Prothrombin time 14 sec
5. Radiology
   i. Oral cholecystogram
   ii. Intravenous cholecystogram
   iii. Percutaneous cholecystogram.
6. Radioactive scans
7. Liver biopsy.

Problems Relevant to Anaesthesia

1. Acid: base and fluid balance fluid overload is common. Hypoalbuminaemia causes oedema, ascitis. Secondary hyperaldosteronism causes sodium retention and hypokalaemia. In hepatic failure combined respiratory and metabolic alkalosis can occur.

2. Hepatorenal syndrome: Jaundiced patients may develop renal failure.
3. Bleeding problems
   i. Factors II, VII, IX and X reduced
   ii. Factor V and fibrinogen reduced
   iii. Thrombocytopenia.
4. Drug metabolism:
   i. Slow elimination of many drugs such as anaesthetic drugs, opioids, benzodiazepines, suxamethonium, local anaesthetics, etc.
   ii. Some drugs have toxic effects on liver
   iii. Halothane can cause hepatitis.
5. Hepatic failure:
   i. Avoid all sedative drugs, opioids, benzodiazepines
   ii. Need intensive management including close metabolic, fluid and electrolyte monitoring
   iii. Avoid hypoglycaemia.

Anaesthetic Management

A. Preoperative preparation
   i. Hypovolaemia and electrolyte imbalance should be corrected
   ii. Vitamin K, coagulation factors, fibrinogen, platelets, fresh blood transfusion may be needed
   iii. Paracentesis in cases of huge ascitis
   iv. Broad spectrum antibiotics
   v. Anaemia should be treated properly
   vi. Monitoring of intracranial pressure is needed
   vii. Control cerebral oedema.

B. Premedication

   Most of sedative and hypnotic drugs should be given in reduced doses. Prolonged effect is common.

C. Monitoring of vital signs, urine output, CVP, pulmonary arterial pressure is essential. Frequent determination of glucose, electrolytes, blood gases, acid-base status, coagulation status, haematocrit are needed.

D. Regional anaesthesia:
   i. Least physiologic disturbances
   ii. Severe coagulopathy may limit the choice of the block
   iii. Hypotension and toxic reactions can occur.

E. General anaesthesia:
   i. Endotracheal intubation ensures the tidal volume and $F10_2$, reduces the risk of aspiration
   ii. Rapid sequence induction and intubation is helpful
   iii. Avoid hypoxia, hypocarbia, hypercarbia and hypotension
   iv. N_2O can cause bowel distension
   v. Isoflurane/desflurane in oxygen can be used with small doses of narcotics. Controlled ventilation to a normal $PaCO_2$ is important.

F. Intravenous anaesthetics should be given in small increments. Ketamine may reduce the risk of hypotension.

G. Muscle relaxants:
Pseudocholinesterase level is decreased, the effect of suxamethonium may be prolonged. Most nondepolarising muscle relaxants can be used with due caution. Pancuronium is mostly satisfactory for its cardiovascular stability.

H. i. Fluid management should always be judicious.
ii. Urine output, cardiac output, CVP and pulmonary arterial pressure should be adequately maintained.

Hepatic Encephalopathy

1. Inability of the damaged liver to detoxicate nitrogenous substances derived from gastrointestinal breakdown
2. Precipitating factors : Azotaemia, misuse of opioid, sedative, hypnotic drugs, gastro-intestinal bleeding, constipation, high protein diet, etc.
3. Grading:
Grading of hepatic encephalopathy.

	Mental State	*EEG*
Grade 1	Confusion, euphoria	Normal
Grade 2	Mood change, altered behaviour	Generalised slowing
Grade 3	Stupor, rousable	Delta activity
Grade 4	Comatose, responds to pain	Triphasic waves
Grade 5	Deep coma	Flat

4. Other factors responsible for clinical manifestations :
    1. Cerebral oedema
    2. Acid-base balance disorders
    3. Depletion of neurochemical transmitters
    4. Increased level of short chain fatty acids.
5. Treatment :
    i. Avoidance and correction of predisposing factors
    ii. Protein restriction
    iii. Mag. sulph enema once or twice daily
    iv. Antibiotics : Poorly absorbed neomycin is the antibiotic of choice
    v. Lactulose: Synthetic disaccharide is not hydrolysed or absorbed in intestine but metabolised to lactic acid and acetic acid in colon. It increases foecal acidity and inhibits bacterial urease.
    vi. Exchange blood transfusion
    vii. Steroids
    viii. Charcoal haemoperfusion
    ix. Haemodialysis
    x. Liver transplant.

- Modified child's grouping of the severity of liver disease

Prognostic Scoring	*Score 1*	*Score 2*	*Score 3*
Encephalopathy	None	Gr 1 and 2	Gr 3, 4, 5
Bilirubin μ mol/lit	< 25	25-40	> 40
Albumin g/lit	35	28-35	< 28
Prothrombin time (sec prolonged)	1-4	4-6	> 6
Ascitis	absent	slight	moderate

✓ Score less than 6 denotes good risk, 7, 8 or 9 denotes moderate risk and more than 10 is poor operative risk

EPILEPSY

1. A seizure disorder resulting from the excessive discharge of an aggregate of neurones that depolarise in a synchronous fashion either localised or spread.
2. Probable causes include birth injury, hypoglycaemia, hypocalcaemia, high fever, head injury/tumour, cerebrovascular disease, drug withdrawal, etc.
3. Treatment of chronic epilepsy
   Anticonvulsant drugs: Valproic acid, phenytoin, carbamazepine, diazepam, etc.
4. Anaesthesia in patients with chronic epilepsy
   i. Maintain anticonvulsant drugs throughout the perioperative period
   ii. Avoid drugs which may have cerebral excitatory effects:
      a) enflurane
      b) methohexitone
      c) atracurium.
   iii. Local anaesthetics may cause convulsion
   iv. Phenobarbitone and phenytoin induce hepatic enzymes and enhance the elimination of drugs metabolised in liver
   v. Some drugs are mostly safe and may not cause seizure activity, are:
      a. Thiopentone
      b. Benzodiazepine
      c. Opioids
      d. Halothane/isoflurane/desflurane.

OBSTRUCTIVE JAUNDICE

1. Jaundice is due to posthepatic biliary obstruction resulting in failure to excrete bile and leading to hyperbilirubinaemia. Commonly occurs with gallstones in common bile duct.
2. Investigations needed : Full blood count, blood bio-chemistry, urine analysis, coagulation studies, liver function tests. X-ray of chest and abdomen, cholangiogram, ultrasound and CAT may be needed in some cases.

3. Preoperative assessment:
    i. Preserve hepatic function by maintaining hepatic blood flow and adequate oxygenation.
    ii. Risk of renal failure is high in cases of hyperbilirubinaemia. Hypovolaemia can initiate renal failure. Preoperative fasting should be kept minimum. iv fluid (glucose saline) should be started at least 4 hours before surgery. Urine volume should be at least 1 ml/kg/hour
    iii. Vit K should be given parenterally at least 24 hours before surgery
    iv. Suitable antibiotic may be needed to treat endotoxaemia
    v. Bradycardia is common in jaundiced patients. Atropine should be given in premedication
    vi. Pethidine can be given as it constricts sphincter of Oddi less.
4. Anaesthesia:
    i. Avoid hypoxia, hypercarbia and hypotension
    ii. Maintain hepatic and renal blood flow
    iii. Normocarbia should be maintained
    iv. Patient should be well-hydrated
    v. Monitoring of vital signs, CVP, ECG and urine volume
    vi. Induction and maintenance of anaesthesia:
    - ✓ Thiopentone in usual doses
    - ✓ Pancuronium maintains cardiovascular stability
    - ✓ Atracurium : Elimination is independent of liver and kidney function, lacks major cardiovascular effects
    - ✓ Suxamethonium can cause bradycardia
    - ✓ Ventilation should be controlled and normocapnia maintained
    - ✓ Adequate oxygenation
    - ✓ At the end of anaesthesia, neuromuscular block should be well-reversed.

    vii. Postoperative care: Oxygenation, narcotic analgesics in low doses.

MYASTHENIA GRAVIS

1. It is a chronic autoimmune disease characterised by episodes of increased muscle fatiguability caused by decreased numbers of acetylcholine receptors at the neuromuscular junction.
2. Clinical features:
    i. Muscle weakness, extraocular, bulbar and facial
    ii. Ptosis and diplopia
    iii. Cardiomyopathy
    iv. Hypothyroidism.
3. Treatment:
    i. Anticholinesterase drugs (neostigmine or pyridostigmine with vagolytic agent)
    ii. Steroids
    iii. Thymectomy.

4. Anaesthetic management:
   A. Preoperative preparation:
      i. Maintain adequate respiration
      ii. Antibiotics to combat infection
      iii. Atropine to diminish secretion
      iv. Avoid opioids
      v. Chest physiotherapy
      vi. Serum potassium should be kept normal.
   B. Local and regional anaesthesia—mostly satisfactory.
      Doses of local anaesthetics should be kept minimum.
   C. General anaesthesia:
      Minimum possible inducing agent.
      Relaxant is better avoided. For major surgery relaxants may be given in low doses.
      IPPV following endotracheal intubation.
      Maintenance of anaesthesia: Volatile agents, short or intermediate acting muscle relaxants.
      At the end of surgery, adequate decnurarisation is mandatory.
   D. Postoperative care :
      i. Monitoring of vital signs
      ii. Lungs should be ventilated for 24 to 48 hours in postoperative period.
      iii. Good chest physiotherapy
      iv. Steroid cover
      v. Anticholinesterase drugs should be continued.

Myasthenic Syndrome

1. Usually associated with carcinoma, thyrotoxicosis, Cushing syndrome, hypokalaemia, hypocalcaemia.
2. Clinical features :
   i. Proximal limb weakness, exercise improves strength
   ii. Muscle pain, reflexes absent or diminished.
3. Sensitive to muscle relaxants
4. Poor response to anticholinesterase drugs.

DISSEMINATED INTRAVASCULAR COAGULATION

1. It is also known as consumption coagulopathy often characterised by uncontrolled activation of the coagulation system with consumption of platelets and procoagulants.
2. Causes :
   Eclampsia, placental abruption, retained placenta, intrauterine foetal death, amniotic fluid embolism, malignancy, burns, malaria, infection, crush injury, haemorrhagic shock, intracranial haemorrhage, incompatible blood transfusion, malignant hyperthermia, snake bite, fat embolism, pulmonary embolism, severe shock, etc.

3. Laboratory findings :
    i. Reduction of fibrinogen
    ii. Elevation of fibrinogen degradation products
    iii. Thrombocytopenia
    iv. Red cell distortion/fragmentation
    v. Prothrombin time, partial thromboplastin time and thrombin time prolonged.
    vi. Serum creatine phosphokinase increased ; serum lactate level increased.
4. Clinical features :
    a. Haemorrhagic manifestations in different part of the body. Hypotension, shock, profound acidosis, hypoxia, circulatory failure, respiratory failure, shock lung syndrome.
    b. Thrombotic manifestations :
        i. Poor organ perfusion, oliguria, cyanosis
        ii. Circulatory failure, coma.
5. Management
    i. Treatment of underlying cause
        a. Correct hypoxia and acidosis
        b. Antibiotics to treat infection
        c. Drainage in case of abscess
        d. Adequate blood volume expansion in hypovolaemic shock
        e. Emptying of uterus in cases of retained placenta, intrauterine foetal death.
    ii. Fresh frozen plasma
        a. Cryoprecipitate
        b. Platelets
        c. Heparin
    iii. Steroids
    iv. Antifibrinolytic therapy: Epsilon aminocaproic acid.

ANAEMIA

1. The red cell mass is reduced below normal. A fall in the quantity of red cells or haemoglobin in a unit volume of blood. Haemoglobin concentration 10 gm/100 ml or less is regarded as anaemia
2. Iron deficiency anaemia is most common
3. Causes :
    i. Blood loss
    ii. Failure of erythropoiesis : Inadequate supplies of nutrients like iron, vitamin B_{12}, folate, protein and certain hormones to bone marrow
    iii. Bone marrow infiltration in leukaemia
    iv. During pregnancy due to increased demand of iron
    v. Ankylostomiasis.
4. Manifestations :
   Lassitude, tiredness, anorexia, indigestion, palpitation, dyspnoea, pallor, swelling of legs, oedema, soft systolic murmur, tachycardia, etc.

5. Haematological findings :
   Moderate fall in red cell count ; greater reduction of Hb ; MCV, MCH and MCHC reduced. Red cells are microcytic, hypochromic, anisocytosis.
6. Treatment :
   i. Causative factors should be diagnosed and treated
   ii. Balanced diet, proteins, iron, vitamins, folic acid
   iii. Digestive enzymes
   iv. Specific therapy : Iron therapy oral or parenteral
   v. Blood transfusion
      a. increases oxygen carrying capacity of blood
      b. increases and improves coagulation and immunity
      c. improves circulatory status.
7. Anaesthetic management
   i. Minimum acceptabe Hb concentration is 10 gm%
   ii. Transfusion of RBC can increase oxygen carrying capacity
   iii. Indication of blood transfusion preoperatively depends on various factors such as duration of anaemia, cause of anaemia, intravascular fluid volume, urgency of operation, blood loos during surgery and coexiting other diseases
   iv. Avoid hypotension and decrease in cardiac output
   v. Avoid leftward shift of oxyhaemoglobin dissociation curve that can occur in respiratory alkalosis, PaO_2 less than 100 mm Hg
   vi. Anaesthetic drugs should be used cautiously. Overdose should be avoided
   vii. Operative blood loss should be replaced promptly
   viii. Postoperative shivering or rise of body temperature can increase tissue oxygen requirement. Preventive measures should be taken.

Appendix

PHYSIOLOGICAL DATA

Blood

Acid phosphatase 1–5 KA units/100 ml
Alkali reserve 24–35 mEq/L
Alkaline phosphatase 3-13 KA units/100 ml
Bicarbonate 22–28 mEq/L
Bilirubin 0.1–1 mg/100 ml
Calcium 9–11 mg/100 ml
Chloride 95–110 mg/100 ml
Cholesterol 145–280 mg/100 ml
Cortisol 9 AM : 6–26 µg/100 ml
midnight : 6–8 µg/100 ml
Creatine phosphokinase (CPK) 0–35 IU/L
Creatinine 1–2 mg/100 mg
Glucose fasting : 70–120 mg/100 mg
after meal : up to 180 mg/100 ml
I^{131} uptake 11–33% at 4 h
Magnesium 1.5 to 3 mEq/L
Nonprotein nitrogen 20–40 mg/100 ml
P_aCO_2 35–45 mm Hg
P_aO_2 90–100 mm Hg
pH 7.3–7.5
Phosphate 3–4.5 mg/100 ml
Potassium 3–5 mEq/L
Protein bound iodine 4-8 µg/100 ml

Proteins

Albumin 4–5.5 g/100 ml
Globulin 1.5–3 g/100 ml
Fibrinogen 0.2–0.5 g/100 ml
Total 6–8 g/100 ml
Pseudocholinesterase 40–100 units/100 ml
Sodium 135–150 mEq/L
Thyroxine 5.5–12.5 µg/100 ml
T_3 resin uptake 88–110%
Thyroid stimulating hormone (TSH) 0.8–3.6 mU/L

Transaminases

SGOT : 0–25 units/L
SGPT : 0–20 units/L
Triglyceride (fasting) 60–100 mg/100 ml
Urea 15–40 mg/100 ml
Uric acid 2–6 mg/100 ml

Haematological

Blood volume 3.5–7 L
85 ml/kg in adults
90 ml/kg in infants.

Haemoglobin (Hb)

males 13.5–18 g/100 ml
females 11.5–16.5 g/100 ml
at birth 17–20 g/100 ml
Red blood cell count
males 4.5–6.5 million/mm^3
females 3.9–5.6 million/mm^3
Bleeding time 2–5 min

Coagulation time
- Wright (capillary) 10–15 min
- Lee and White (venous) 5–7 min

Colour index 0.85–1.15
Erythrocyte Sedimentation Rate (ESR)
- 2–12 mm in 1 h

Packed cell volume (PCV)
- males 40–54%
- females 35–47%

Mean Corpuscular Diameter (MCD) 6.7–7.7 μ
Mean Corpuscular Haemoglobin (MCH) 27-32 μg (pg)
Mean Corpuscular Haemoglobin Concentration (MCHC) 32–36 g%
Mean Corpuscular Volume (MCV) 80–92 μ^3
Reticulocyte count 0.2–2%
White blood count
- Total 4000–11000/mm^3
- Neutrophils 2500–7500/mm^3 (65–70%)
- Lymphocytes 1500–3500/mm^3 (20–25%)
- Eosinophils 40–400/mm^3 (0–4%)
- Basophils 0–100/mm^3 (0–1%)
- Monocytes 200-800.mm^3 (5–6%)

Platelet count : 250,000–500,000/mm^3
Prothrombin time : 14 sec

Cerebrospinal Fluid

Amount 120–150 ml
Cells 0–10/mm^3
Chlorides 700–750 mg/100 ml
Pressure 70–180 mm H_2O
Protein 10–45 mg/100 ml
Sugar 40–70 mg/100 ml

Metabolism

Basal Metabolic Rate (BMR) + 14 to– 14
Urine
Specific gravity 1010–1025
Amount 1500–2000 ml/24 h
Catecholamines
- Adrenaline in 24 h save 119–338 μg
- Noradrenaline in 24 h save 3 methoxy, 4 hydroxy mandelic acid (VMA) in 24 h save 2.6–6.5 μg

Calcium 0.1–0.3 g/24 h
Chloride 170–250 mEq/24 h
pH 4.8–7.4 (average 6)
Phosphates 30–90 mEq/24 h
Potassium 35–90 mEq/24 h
Sodium 110–240 mEq/24 h
Urea 10–35 g/24 h
Urobilinogen 0–4 mg/24 h
Ammonia 0.14–1.47 g/24 h
Creatine 0.15–0.25 gm/24 h
Creatinine 16–21 mg/kg/24 h
Uric acid 0.2–0.7 gm/24 h

Some Normal Values

Air

Nitrogen conent 78.08%
Oxygen conent 20.93%
Carbon dioxide content 0.04%
Argon content 0.93%
Other gases-trace

Alveolar Air

Oxygen conent 14.2%
PaO_2 104 mm Hg
$PaCO_2$ 40 mm Hg

Arterial Blood

Oxygen saturation 97%
PaO_2 100 mm Hg
$PaCO_2$ 40 mm Hg
Oxygen capacity 19.8 vol %

Mixed Venous Blood

Oxygen saturation 75%
PvO_2 40 mm Hg
$PvCO_2$ 46 mm Hg

Other Data

Oxygen content of expired air 16.3%

Partial pressure of oxygen in air 160 mm Hg
Solubility of oxygen in arterial blood 0.3 ml/100 ml
Oxygen capacity of haemoglobin 1.34 ml/g Hb

Body Water (expressed as percentage of body weight)

Total body water :
- Adult male 60%
- Adult female 50%
- Infant 75%

Intracellular water :
- Adult male 40%
- Adult female 30%
- Infant 40%

Extracellular water :
- Adult male 20% (intravascular 4% + interstitial 16%)
- Adult female 20% (intravascular 4% + interstitial 16%)
- Infant 35% (intravascular 5% + interstitial 30%)

Water Intake Output in Adults Per 24 Hours

Intake :
- As liquid 1500 ml
- As food 1000 ml (includes 300 ml water of oxidation)

Total 2500 ml

Output :
- Skin 500 ml
- Lungs 400 ml
- Faeces 100 ml
- Urine 1500 ml

Total 2500 ml

Some Useful Facts in Infant and Adult

	Infant (average)	*Adult (average)*
Body weight (kg)	3.5	70
Surface area (m^2)	0.21	1.9
Tracheal diameter (mm)	8	18
Respiratory frequency at rest (mm)	40	20
Tidal volume (ml/kg)	6	7
Dead space (ml/kg)	2.2	2.2
Vital capacity (ml/kg)	33	52
Minute volume (ml)	650	6000
Resting alveolar ventilation (ml/kg/min)	125	60
Resting oxygen consumption (ml/kg/min)	6.9	3.3
Lung weight (g)	50	800
Left ventricular output (ml/kg/min)	350	100
Arterial oxygen tension (mm Hg)	75	95
Arterial CO_2 tension (mm Hg)	35	40

The Apgar Scoring System

Sign	*0*	*1*	*2*
Heart rate	absent	less than 100/min	more than 100/min
Respiratory effort	absent	slow, irregular;	good, crying
Colour	blue	body pink, extremities blue	pink
Reflexes	absent	grimace	cough, sneeze
Muscle tone	limp	some flexion of extremities	active movements

The baby is to be evaluated individually at 1 and 5 min of birth and scored from 0 to 2 accordingly. The total score is the sum of the scores of the individual variables.

Average Pulse, Respiration and Blood Pressure in Children

Age	*Pulse/min*	*Resp/min*	*BP (mm Hg)*
Newborn	160–180	50–40	80/50
1–4 yrs	100–110	35–25	85/60
5–7 yrs	80–100	25–20	90/60
8–9 yrs	80–100	25–20	95/65
10 yrs	80–100	25–20	100/65

Doses of Some Drugs in Children

Thiopentone sodium 2.5% solution 2 to 4 mg/kg iv
Methohexitone 1% solution 1 to 1.5 mg/kg iv
Suxamethonium 1 to 2 mg/kg iv
Gallamine 2 mg/kg iv
Tubocurarine 0.6 to 0.8 mg/kg iv
Pancuronium bromide 0.12 mg/kg iv
Neostigmine 0.07 mg/kg iv
Morphine 0.125 mg/kg iv or im
Pentazocine 0.25 mg/kg iv
Fentanyl 0.001 mg/kg iv
Pethidine 1 mg/kg im
Trimeprazine 1 mg/kg i.m.
Trimeprazine syrup 4 mg/kg orally
Codeine phosphate 1 mg/kg im
Promethazine 1 mg/kg im

Endotracheal Tubes

Age	*Approx. tube length (cm)*	*Approx. int. diam. (mm)*
Newborn	10–12	3–3.5
1–12 months	12–16	3.5–5
1–3 years	16–18	5–6
4–6 years	18–20	5.5–6.5
7–15 years	20–24	6–7.5
Adults	24–28	7.5–9.5

Size of endotracheal tubes

Magill *size*	French *gauze*	Ext. diam. (*mm*)	Int. diam. (*mm*)
00	13	4.4	3.2
OA	15	4.8	3.6
0	16	5.5	4.4
1	19	6.3	4.8
2	21	7.1	5.2
3	24	7.9	5.6
4	25	8.3	6
5	27	9.1	6.7
6	29	9.5	7.1
7	31	10.3	7.5
8	33	10.7	7.9
9	36	11.9	8.7
10	38	12.7	9.5

Some Anatomical Measurements

Adults

Average distance from lips to carina : 26 cm approx
Average distance from base of nose to carina : 30 cm approx
Average distance from lips to vocal cords : 14 cm approx
Length of trachea : 12–14 cm approx
Diameter of trachea : 12 mm approx.

Children

Distance from incisor teeth to vocal cords :
1 year : 8 cm

2–4 years: 9 cm
5–7 years: 10 cm
8–10 years: 11 cm
11–12 years: 12 cm.

Approximate Length and Diameter of Endotracheal Tube in Children

Length or oral tube: Age in years/2 + 12 cm
Length of nasal tube: Age in years/2 + 15 cm
Diameter of the tube: 4.5 + age in years/4, in mm.

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