3 Emergencies/Resuscitation

3.1 Systemic Infections in Newborns

Routes of infection

- Intrauterine ascending or perinatal infections
  - Listeriosis
  - Lues (syphilis)
  - Cytomegaly
  - Toxoplasmosis
  - Human immunodeficiency virus (HIV)
  - B-streptococcus
  - Hepatitis B, C
  - *Chlamydia*
- Catheters, wounds, airway tubes
  - *Staphylococcus epidermidis* and *S. aureus*

Clinical signs

- Clinical signs are given in Table 3.1

Table 3.1 Clinical signs of systemic infection in a newborn

	Signs
General signs	Feeding problems, lethargy, hypothermia or fever
Heart/circulation	Tachycardia >160 beats/min, hypotension, centralization, cold extremities
Breathing/respiration	Dyspnea, apnea attacks, intercostal retractions, acidosis
Skin	Pale, icteric, cyanotic, marbled skin, petechiae
Gastrointestinal	Abdominal distension, gastric stasis, diarrhea, dysphagia
Nervous system	Apathy, irritability, convulsion
Local	Pustules, omphalitis, mastitis, paronychia

Investigations

- Blood counts
  - Leukocytosis or leukocytopenia
  - Thrombocytopenia
  - C-reactive protein (CRP) can be high due to birth stress
- Infection detection in the mother
  - Vaginal swab
  - Placenta swab
- Infection detection in the child
  - Blood culture
  - Respiration tube swab
  - Urine culture
  - Gastric fluid culture
  - Stool culture
  - Ear and eye swab
  - Liquor culture (in special cases)
- Imaging procedures
  - Chest X-ray
  - Skull ultrasonography
  - Abdominal ultrasonography
  - Abdominal X-ray (suspicion of necrotizing enterocolitis)

3.2 Shock

Definition

- Clinical syndrome with cellular metabolic deficiency as a result of tissue hypoperfusion

3.2.1 Hypovolemic Shock

Definition

- Shock from loss of circulating volume

Common etiology

- External or internal hemorrhage
- Burns
- Dehydration (gastroenteritis, diabetes, ileostomy)

Signs of hemorrhage

- Signs of hemorrhage are listed in Table 3.2

Table 3.2 Signs of hemorrhage

	Blood loss <25%	Blood loss 25%–40%	Blood loss >40%
Heart rate	Tachycardia	Tachycardia	Tachycardia/bradycardia
Blood pressure	Normal	Normal or hypotensive	Hypotensive
Pulse pressure	Normal or reduced	Reduced	Reduced
Capillary refill time	Prolonged	Prolonged	Prolonged
Extremities	Cold and pale	Cold and pale	Cold and pale
Breathing	Tachypnea	Tachypnea	Gasping
Diuresis	Oliguric	Oliguric or anuric	Anuric
Consciousness level	Irritable	Lethargic	Coma, responds only to pain

Therapy

- Volume substitution fast and pre-warmed (colloid or crystalloid, $20\,ml \cdot kg^{-1}$)
- If no improvement, second bolus of $20\,ml \cdot kg^{-1}$
- If no improvement (hemorrhagic shock), blood $20\,ml \cdot kg^{-1}$
- Intubation and mechanical ventilation
- Resuscitation

3.2.2 Septic Shock

Definition

- Shock from maldistribution caused by microorganisms or their products

Signs

- Table 3.3 lists signs of septic shock

Table 3.3 Signs of septic shock

	Compensated shock	Uncompensated shock
Heart rate	Tachycardia	Tachycardia
Blood pressure	Normal	Hypotensive
Pulse pressure	Wide	Narrow
Capillary refill time	Prolonged	Prolonged
Extremities	Warm	Warm or cool
Breathing	Tachypnea	Respiratory insufficiency
Mental state	Anxious, confused	Lethargic

Investigations

- Blood analysis
  - White blood cell count with differentiation
  - Thrombocytes
  - CRP
- Lumbar puncture (cells, bacteria, glucose, protein)
- Cultures
  - Ear
  - Wounds
  - Umbilicus
  - Blood (temperature >38.5°C)
  - Stomach
  - Tracheal aspirate
  - Urine

  - Feces
  - Cerebrospinal fluid
  - Arterial blood in suspected *Candida* infection
- Chest X-ray and abdominal X-ray (if abdominal signs)
- Abdominal ultrasonography or computer tomography in suspected abdominal sepsis

Hematological data

- Normal hematological values (mean values) are given in Table 3.4

Table 3.4 Normal hematological values (means)

	Age				
	1 week	6 months	1 year	6 years	14 years
White cells (total) (10^6/ml)	12.2	11.9	11.4	8.5	7.8
Neutrophils (%)	45	32	31	51	57
Lymphocytes (%)	41	61	61	42	35
Monocytes (%)	9	5	5	5	3
Eosinophils (%)	4	3	3	3	3
Thrombocytes (10^6/ml)	300	300	300	300	300

Therapy

- Oxygen supply (mechanical ventilation may be needed)
- Volume substitution (mainly colloid, 20 ml · kg^{-1}; up to four boluses may be needed)
- Correct hypoglycemia
- Antibiotic treatment
  - Initiated as soon as possible in suspected sepsis
  - The recommended antibiotic therapy (and doses) for sepsis of unknown etiology varies among different age groups and institutions
  - It depends on the most likely causative organisms and antibiotic resistance
  - The antibiotic regimen is changed on the basis of culture results or after 2–3 days if it does not have the desired effect

- Inotropic drugs (dopamine, dobutamine)
  - Due to sepsis-associated depression of myocardial function, inotropic support is started together with the second fluid bolus
- Correct acidosis (bicarbonate)
- Suggested antibiotics to prescribe in suspected sepsis are given in Table 3.5

Table 3.5 Suggested antibiotics to prescribe in suspected sepsis

Patients	Antibiotics
Neonates 0–28 days old	Amoxicillin and aminoglycoside
Older infants and children	Amoxicillin/clavulanate and aminoglycoside or third generation cephalosporin

3.2.3 Cardiogenic Shock

Definition

- Shock from decreased cardiac function

Common etiology

- Myocarditis
- Cardiomyopathy
- Congenital malformations
- Arrhythmias

Signs

- Tachycardia
- Normal or reduced blood pressure
- Reduced pulse pressure
- Prolonged capillary refill time
- Cold and pale extremities
- Tachypnea, dyspnea (pulmonary edema)
- Oliguria
- Irritable to coma

Therapy

- Oxygen supply (may need mechanical ventilation)
- Decrease oxygen consumption (treatment of pain and hyperthermia, sedation)
- Optimize (reduce) circulatory volume (e.g., furosemide)
- Vasodilatation (nitroprusside, nitroglycerin, enoximone)
- Improve cardiac contractility (inotropic medication, reduce acidosis)

3.2.4 Anaphylactic Shock

Definition

- Shock from an acute hypersensitivity reaction caused by an allergen

Common etiology

- Medication (penicillin, radiographic contrast)
- Proteins
- Polysaccharide

Signs

- Signs of anaphylactic shock are shown in Table 3.6

Table 3.6 Signs of anaphylactic shock

Stage I	Stage II	Stage III	Stage IV
▪ Itching ▪ Nausea ▪ Light-headedness ▪ Abdominal pain ▪ Flushing ▪ Edema (facial swelling) ▪ Wheezing	▪ Dyspnea ▪ Tachycardia ▪ Sweating ▪ Pallor ▪ Vomiting ▪ Diarrhea	▪ Bronchospasm ▪ Difficulty breathing ▪ Hypotension ▪ Collapse ▪ Fecal incontinence	▪ Respiratory arrest ▪ Cardiac arrest

Therapy

- Remove allergen
- Oxygen supply
- Intubation or tracheostomy
- Volume replacement (colloid, 20 $ml \cdot kg^{-1}$)
- Medication
  - Antihistamine (diphenhydramine i.m. or slow i.v.)
  - Adrenaline (10 $\mu g \cdot kg^{-1}$ i.m., 5 mg 1:1000 nebulized)
  - Hydrocortisone 4 $mg \cdot kg^{-1}$ i.v.
  - Aminophylline, salbutamol

3.3 Hypoglycemia

Definition

- Blood glucose level below
  - 40 $mg \cdot dl^{-1}$ in children
  - 30 $mg \cdot dl^{-1}$ in neonates during the first week of life
  - 20 $mg \cdot dl^{-1}$ in prematures

Common etiology

- Decreased glycogen stores (preterm neonate)
- Increased glucose demand (hypothermia, infection, respiratory distress)
- Diabetic mother
- Islet cell adenoma

Signs

- Bradycardia and tachycardia
- Apnea periods
- Hypothermia
- Irritability, lethargy
- Sweating
- Vomiting
- Convulsion

Therapy

- If unconscious, intubate; resuscitate if necessary
- Serum glucose measurement
- Glucose 500 mg · kg^{-1} i.v. (5 ml · kg^{-1} glucose 10%) bolus
- Glucose infusion (glucose 5 mg · kg^{-1} · min^{-1})
- Tests to assess the cause of hypoglycemia (neonates and particularly prematures often present with hypoglycemia in other disorders such as infections)

3.4 Acid–Base Balance

Definition

- Metabolic acidosis: primary decrease in HCO_3^- concentration
- Metabolic alkalosis: primary increase in HCO_3^- concentration
- Respiratory acidosis: primary increase in arterial PCO_2
- Respiratory alkalosis: primary decrease in arterial PCO_2
- Estimated normal values are given in Table 3.7

Table 3.7 Estimated normal values in arterial blood

Age	PO_2 (mmHg)	pH	PCO_2 (mmHg)	Standard bicarbonate (mmol · l^{-1})
Birth (umbilical artery)	12.1–19.7	7.18–7.30	43.3–54.9	16.9–20.5
5–10 min	39.7–59.5	7.15–7.25	39.1–53.1	15.1–18.3
30 min	42.6–65.6	7.25–7.33	32.0–43.4	16.7–19.7
60 min	52.0–74.6	7.30–7.36	31.9–40.3	18.0–20.4
24 h	63.2–82.2	7.33–7.39	33.3–36.5	18.9–21.5
7 days	63.4–82.8	7.35–7.40	32.8–39.0	20.5–23.1
2 years	80–100	7.35–7.40	32–39	20–22
>2 years	80–100	7.35–7.45	35–45	22–24

Normal values of base excess (age independent) = –2.5 ± 2.5.

Diagnosis

- Diagnosis based on acid–base balance data is given in Table 3.8

Table 3.8 Interpretation of acid–base balance data

	pH	PCO_2	Bicarbonate
Metabolic acidosis	↓	= ↓	↓[a]
Metabolic alkalosis	↑	= ↑	↑[a]
Respiratory acidosis	↓	↑[a]	= ↑
Respiratory alkalosis	↑	↓[a]	= ↑

[a] Primary changes.

Etiology

- **Metabolic acidosis**
  - Increased endogenous acid production
    - Lactic acidosis (e.g., hypoxia, hypothermia, shock)
    - Diabetic ketoacidosis
    - Alcoholic ketoacidosis
    - Starvation
  - Ingestion of toxins
    - Salicylates
    - Paraldehyde
    - Methanol, ethylene glycol
  - Acute and chronic renal failure
  - Loss of HCO_3^-
    - Diarrhea
    - Renal failure
    - Treatment with acetazolamide
    - Ileus
    - Pancreatic fistula
- **Metabolic alkalosis**
  - Loss of acid
    - Gastrointestinal (vomiting)
    - Renal (hypocalcemia, loop diuretics, Cushing syndrome, primary hyperaldosteronism)

- Excessive HCO_3^- administration
  - Milk-alkali syndrome
  - Parenteral HCO_3^-
- Contraction alkalosis
  - Sweating (cystic fibrosis)
  - Massive diuretics

- **Respiratory acidosis**
  - Neuromuscular disease
    - Central nervous system disorders
    - Peripheral nervous system disorders
    - Muscular disorders (myopathies)
  - Cardiovascular disorders (patent ductus arteriosus, ventricular septal defect)
  - Respiratory disease
    - Upper airway obstruction (e.g., laryngitis, epiglottitis)
    - Impaired lung motion (pneumothorax)
    - Lower airway diseases (asthma, aspiration, pneumonia, acute respiratory distress syndrome (ARDS), cystic fibrosis)
- **Respiratory alkalosis**
  - Hyperventilation (psychogenic, mechanical, central nervous system disorders)

Therapy

- Treatment of acid-base imbalance is given in Table 3.9

Table 3.9 Treatment of acid–base imbalance

pH	Treatment
<7.15	Immediate infusion of 2.5 ml · kg^{-1} of 8.4% bicarbonate (add to glucose solution 1:4 to reduce osmolarity) Treatment of underlying cause
7.15–7.25	Correction of base deficit Treatment underlying cause
7.25–7.55	Treatment underlying cause
pH >7.65	L-Arginine-HCl (slow infusion over hours) HCl (100 mEq $H^+ \cdot l^{-1}$); infuse half of calculated dose through central line

Calculation of acid–base correction

- mmol bicarbonate = base deficit × weight (kg) × 0.6
  (only 50% of the calculated base deficit should be corrected at a time)
- mmol HCl = base excess × weight (kg) × 0.6
  (only 50% of the calculated base excess should be corrected at a time)

3.5 Resuscitation

Clinical assessment of children and infants

A, B, C, D, E assessment

(for normal values see Table 3.10; for neonatal assessment see Table 3.11)

Airway and Breathing

- Effort of breathing (recessions, grunting, accessory muscle use)
- Rate, thoracic excursions
- Stridor/wheeze
- Chest auscultation
- Skin color (pink, pale, cyanosis)

Circulation

- Heart rate (infants: brachial or inguinal artery, children: carotid artery)
- Pulse volume
- Capillary refill (normally less than 2 s)
- Peripheral skin temperature
- Urinary output

  Start cardiopulmonary resuscitation if necessary!

Disability

- Assess consciousness (alert, verbal reaction, reaction to pain, unconscious)
- Pupils (size and reaction)
- Posture

Exposure/Environmental control

- Body check
- Body temperature (avoid hypothermia)

Table 3.10 Normal parameters for ABC assessment

Age	Breathing rate (breaths per min)	Heart rate (beats per min)	Systolic blood pressure (mmHg)
Neonate	30–60	100–160	50–70
6 months	25–40	100–140	70–90
12 months	20–30	90–130	80–100
2 years	20–30	90–120	80–100
5 years	18–25	80–120	80–110
9 years	15–20	70–100	90–110
12 years	15–20	60–100	90–120
15 years	15–20	60–100	90–120

Table 3.11 Neonatal assessment

	Apgar score		
	0	1	2
Breathing	Absent	Slow, irregular	Good, crying
Heart rate	Absent	<100 beats · min^{-1}	>100 beats · min^{-1}
Color	Blue or pale	Blue extremities	Completely pink
Reflex irritability	No response	Grimace	Cough, sneeze, cry
Muscle tone	Limp	Some flexion	Active motion

Neonatal resuscitation treatment

- **Call for help and keep the infant warm!**
- A typical resuscitation plan is outlined in Table 3.12 and the guidelines are shown in Table 3.13

Table 3.12 Resuscitation plan

Time (min)	Breathing	Heart rate	Treatment	
0 –1	Inadequate	> 100	Stimulate by suction (mouth, nose, throat)	
	Inadequate	< 100	Suction, face mask ventilation	
2	Inadequate	> 100	Face mask ventilation	
	None	< 100	Intubation and ventilation	
	None	< 60	Intubation Ventilation	Neonates 3:1
				Children < 12 15:2
			Chest compression	Adolescents 30:2
5	None	< 60	Ventilation, chest compression Medication ▪ Adrenaline 10 µg · kg^{-1} i.v. or i.o. ▪ Sodium bicarbonate 1–2 mmol i.v. or i.o.	
8–10	None	< 60	Ventilation, chest compression Medication ▪ Adrenaline 100 µg · kg^{-1} i.v.	
			Repeat every 5 min	
20–30	None	None	Stop resuscitation, except if ▪ Poisoning with cerebral depressant drugs ▪ Core temperature below 32°C	

Table 3.13 Resuscitation guidelines. Sodium bicarbonate inactivates epinephrine and dopamine! The lines should be flushed between medications

Age	Weight (kg)	Mask size	Endotracheal tube inner diameter (mm)	Adrenaline (mg)	Atropine (mg)	Bicarbonate 8.4% (ml) 1 ml = 1 mmol	Defibrillation (J)
Premature neonate	< 2	0	2.5	0.02–0.2	–	2.0	5/10/10
Neonate	3	0	3.0–3.5	0.03–0.3	–	3.0	5/10/10
6 months	7	0–1	3.5–4.0	0.07–0.7	0.14	7.0	15/30/30
1 year	10	1–2	4.0	0.1–1.0	0.2	10	20/40/40
2 years	12	2–3	4.5	0.12–1.2	0.24	12	25/50/50
5 years	19	4.0	5.0–5.5	0.19–1.9	0.38	19	40/75/75
10 years	30	4–5	6.0	0.3–3.0	0.6	30	60/120/120
12 years	40	5	6.5	0.4–4.0	0.8	40	80/150/150
15 years	50	5–6	7.0–7.5	0.5–5.0	1.0	50	110/200/200
				0.01–0.1 mg · kg^{-1}	0.02[a] mg · kg^{-1}	1 ml · kg^{-1}	ca. 2/4/4 J/kg

[a]Minimum dose 0.1 mg.

Airway management

Airway obstruction can be caused by the tongue, blocking the pharynx. Chin lift and jaw thrust are the first maneuvers performed in order to establish an open airway.

- Chin lift (Fig. 3.1)
  - Tilt the head back with one hand
  - The chin is lifted forwards with the fingers of the other hand
- Jaw thrust (Fig. 3.2)
  - Keep the head in a neutral position with two hands
  - The fingers of both hands push the jaw forwards.

Fig. 3.1 Chin lift in infants

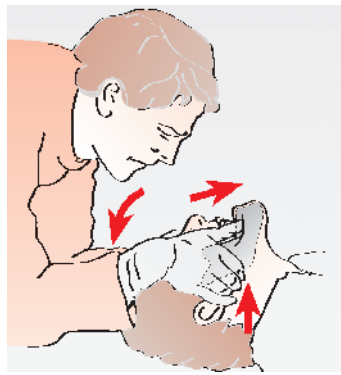

Fig. 3.2 Jaw thrust

Orotracheal intubation

- **General information**
- Emergency intubation is usually performed orotracheally (Fig. 3.3)
- In infants nasotracheal intubation may be preferred
- Uncuffed tubes are used for children less than 8 years old

- **Estimated internal diameter (mm)**
- (Age in years ÷ 4) + 4
- 3–3.5 mm (for neonates)
- 2.5 mm for prematures
- Same diameter as little finger
- Size just fitting into the nostril

- **Estimated tube length (cm)**
- (Age in years ÷ 2) + 12 (for oral intubation)
- (Age in years ÷ 2) + 15 (for nasal intubation)

- **Indication for intubation**
- Airway protection and maintenance
- Facial injury
- Airway obstruction
- Absent reflexes (coma)
- Need for mechanical ventilation

- **Intubation technique**
- Immobilize neck in trauma patients
- Clear pharynx and stomach by suction
- Ventilate by face mask
- Introduce laryngoscope with tip in the vallecula
- Insert endotracheal tube with tip 2–4 cm below vocal cords
- Check chest movement, auscultate chest and epigastrium
- Fasten tube
- Check tube position with X-ray
- If attempt is not successful within 30 s, discontinue and ventilate with face mask

- **Pit falls**
- Too much hyperextension of neck (in smaller children)
- Do not lean on the teeth
- Lift blade of laryngoscope towards ceiling, do not lever

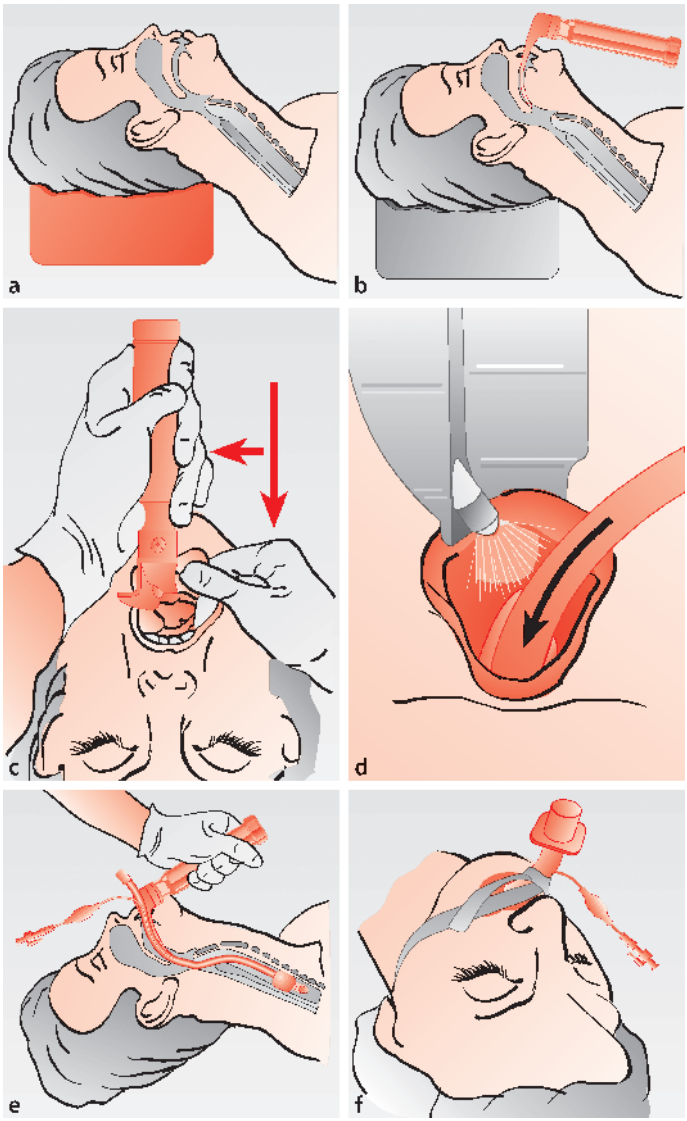

Fig. 3.3a–f Orotracheal intubation

- **Complications of endotracheal intubation**
- Acute
  - Traumatic
    - Cervical spine injury in trauma patient
    - Dental trauma
    - Vocal cord damage
    - Bleeding
    - Laryngeal edema
  - Mechanical
    - Tube malposition (bronchus, esophagus)
    - Tube obstruction
    - Accidental extubation
    - Tube kinking
  - Other
    - Pneumothorax (e.g., if endobronchial intubation)
    - Apnea
    - Hypoxia from prolonged attempt to intubate
    - Aspiration
- Chronic
  - Otitis media
  - Choanal stenosis
  - Subglottic stenosis
  - Granuloma
  - Necrotizing tracheobronchitis
  - Tracheal stenosis
  - Tracheomalacia

- **Complications of endotracheal suction**
- Bleeding
- Accidental extubation
- Pulmonary or bronchial perforation
- Bronchopulmonary fistula
- Hypoxia
- Bradycardia

- Increased cerebral perfusion and intracranial pressure
- Increased blood pressure

- **Checklist for intubation**
- Materials and instruments
  - Face mask with ventilation bag
  - Gloves
  - Stethoscope
  - Respiratory mask
    - Right mask size
    - Oxygen supply on
  - Suction devices
    - Suction tube on device
  - Prepared ventilation system
  - Oxygen supply
  - ECG monitor
  - Intubation set
  - Laryngoscopes
  - Endotracheal tubes and connectors
  - Silicon spray
  - Tube introducers
  - Magill's forceps
- Medication
  - Adrenaline, 1 ml = 1 mg dilute 1:9 NaCl
  - Atropine, 1 ml = 0.5 mg dilute 1:4 NaCl
  - Xylocaine 2%, 5 ml = 100 mg
  - Bicarbonate 8.4%, 1 ml = 1 mmol
  - Glucose 5%, 10 ml
  - Glucose 10%, 10 ml

Cricothyroidotomy

- Access to the airway through the cricothyroid membrane (Fig. 3.4)
- In infants the trachea is punctured below the cricoid cartilage instead of puncturing through the cricothyroid membrane
- In infants and small children needle cricothyroidotomy is advocated

- In older children and adolescents the airway can be established percutaneously or with an open surgical procedure
- Needle cricothyroidotomy is a temporary relatively small airway access, requiring more definite (surgical) airway access as soon as possible
- If prolonged airway access is required in a child, who cannot be tracheally intubated, tracheostomy is preferred over cricothyroidotomy

Indication

- Urgent need for an open airway if tracheal intubation is impossible

Needle cricothyroidotomy technique

- Hyperextension of neck (immobilize neck in trauma patients)
- Stabilize the cricoid and thyroid cartilage with one hand
- Puncture the trachea between the cricoid and thyroid cartilage with a cannulated needle on a syringe, penetrating the trachea at a slight caudal angle
- Withdraw needle when air is aspirated
- Introduce cannula further, recheck intraluminal position
- Attach Y-connector with oxygen flow at one leg
- Ventilate by opening (4 s) and closing (1 s) the other leg of the connector
- The required oxygen flow in liters is the child's age in years
- Establish a more definitive airway

Percutaneous cricothyroidotomy

- Hyperextension of neck (immobilize neck in trauma patients)
- Stabilize the cricoid and thyroid cartilage with one hand
- Puncture the trachea between the cricoid and thyroid cartilage with a cannulated needle on a syringe, penetrating the trachea at a slight caudal angle
- Withdraw needle when air is aspirated
- Introduce cannula further, recheck intraluminal position
- Introduce guide wire through the cannula
- Insert appropriately sized cannula on a dilator over the guide wire
- Remove dilator and guide wire
- Fasten cannula to the neck

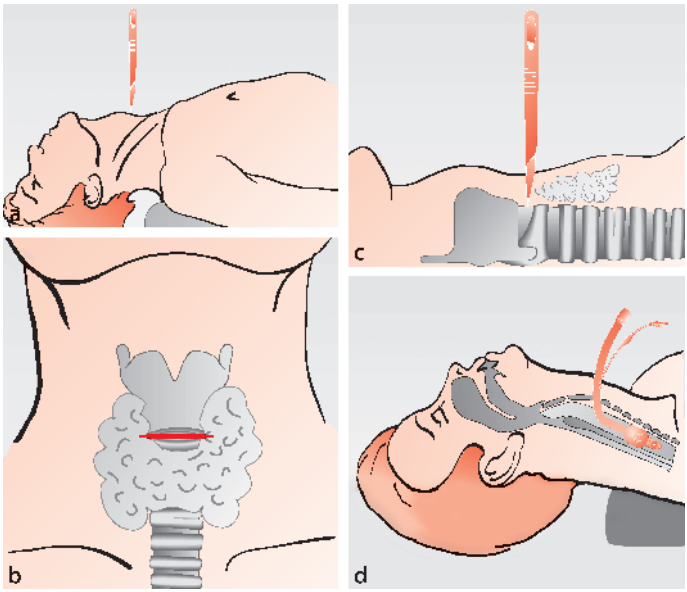

Fig. 3.4a–d Cricothyroiditomy

Surgical cricothyroidotomy

- Hyperextension of neck (immobilize neck in trauma patients)
- Infiltrate with local anesthetic
- Small midline incision over cricothyroid membrane
- Transverse incision through cricothyroid membrane
- Insert spreader into wound
- Insert appropriately sized cannula
- Fasten cannula

Complications of cricothyroidotomy

- Hemorrhage
- Tracheo-esophageal fistula
- Dislodgement of cannula
- Wound infection

- Pneumothorax, subcutaneous emphysema
- Subglottic stenosis
- Voice changes

Checklist for cricothyroidotomy

- Surgical blade
- Cannulated needle
- Guide wire
- Different size cannulas and dilators
- Tracheal spreader
- Y-connector
- Oxygen with flow meter

3.6 Ventilation

3.6.1 Ventilation Without Equipment

Mouth-to-mouth ventilation technique

- Chin lift or jaw thrust
- Mouth-to-mouth and -nose ventilation in smaller children, mouth-to-mouth ventilation (nose closed) in older children
- Administer slow breaths of 1 s duration at low pressure
- Check chest movements
- Rate: 30–60 per minute in neonates; 13 per minute in children <12; 7 per minute in adolescents
- Beware of too large a volume of inflation

Ventilation by mask (Fig. 3.5)

- Choose appropriately sized mask
  - Infant mask (<7 kg)
  - Children mask (7–30 kg)
  - Adult mask (>30 kg)
- In infants the mask may be used upside down

- If available, insert oro- or nasopharyngeal airway (Guedel tube) keeping airways patent
  - Length of the oropharyngeal airway: from center of the incisors to mandible angle
  - Length of the nasopharyngeal airway: from the tip of the nose to tragus of the ear)
- Slight hyperextension of neck
- Apply mask to the face with one hand (with the little, ring and middle finger the jaw is held forward to prevent air leak; with the thumb and index finger, the mask is pushed on the face)
- The bag is attached to the mask and squeezed with the other hand

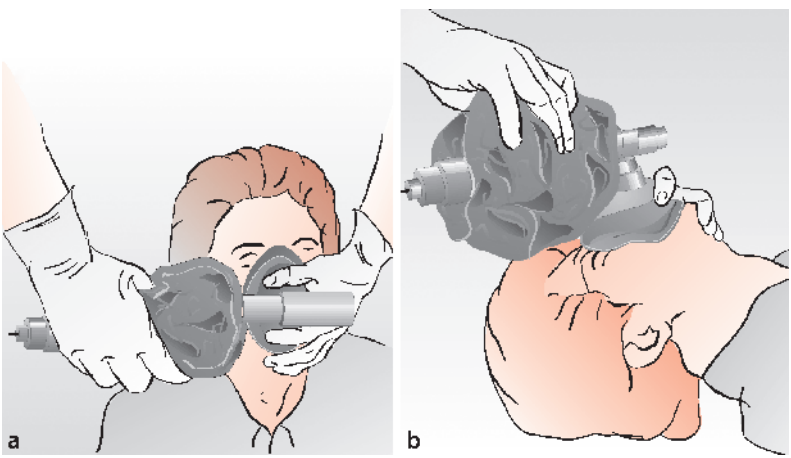

Fig. 3.5a,b Mask ventilation with ventilation bag

Advantages

- Can be applied in most circumstances
- No mouth-to-mouth contact
- Pressure-limiting valves in smaller self-inflating bags may prevent barotrauma
- Special valves for positive end-expiratory pressure (PEEP) ventilation

Disadvantages

- More difficult than generally considered (beware of insufficient ventilation)
- Danger of inadequate ventilatory volume

Checklist for mask ventilation

- Face masks
- Self-inflating bags
- T-piece and open-ended bag
- Oxygen supply

3.6.2 Mechanical Ventilation

Definitions

- Controlled ventilation: complete ventilatory effort is done by the ventilator
- Assisted ventilation: breaths are initiated by the patient; the ventilator delivers a preset volume or pressure
- Commonly encountered abbreviations are listed in Table 3.14

Table 3.14 Commonly encountered abbreviations

CMV	Controlled mechanical ventilation
CPAP	Continuous positive airway pressure
CPPV	Continuous positive pressure ventilation
HFPPV	High-frequency positive pressure ventilation
HFJV	High-frequency jet ventilation
HFOV	High-frequency oscillatory ventilation
IMV	Intermittent mandatory ventilation
IPPV	Intermittent positive pressure ventilation
PEEP	Positive end-expiratory pressure
PIP	Positive inspiratory pressure
SIMV	Synchronized intermittent mandatory ventilation
SIPPV	Synchronized intermittent positive pressure ventilation

Ventilation forms

- IPPV: during inspiration positive inspiratory pressure is generated, expiration is caused by elasticity of the lung and thorax (usually it is combined with PEEP)
- IMV: between mandatory breaths from the machine, the child can breathe spontaneously. This can be synchronized with the patient's own breaths
- PEEP: at the end of expiration the ventilator pressure remains positive
- CPAP: positive respiratory pressure in a spontaneously breathing patient

Ventilatory modes to be controlled

- Fraction of inspiratory oxygen (FiO_2)
- PEEP/CPAP level (cmH_2O)
- PIP (cmH_2O)
- Ventilatory frequency
- Inspiratory time to expiratory time ratio (*I*:*E* ratio)
- Respiratory minute volume ($l \cdot min^{-1}$), tidal volume (ml)
- Mean respiratory pressure
- Breaths may be volume controlled or pressure controlled (Table 3.15)

Table 3.15 Advantages and disadvantages of the various types of ventilation

	Advantages	Disadvantages
Volume-controlled ventilation	▪ Fixed tidal volume	▪ Risk of barotrauma
Pressure-controlled ventilation	▪ Small risk of barotrauma	▪ Variable tidal volume
PEEP/CPAP	▪ Prevents alveolar collapse ▪ Increases functional residual capacity ▪ Decreases intrapulmonary right–left shunt	▪ Decreases cardiac output ▪ Increases intracranial pressure ▪ Barotrauma ▪ Decreases pulmonary compliance
Increased ventilatory frequency	▪ Lower PIP necessary ▪ Lower mean respiratory pressure if hyperventilation required	▪ Air trapping
Decreased ventilatory frequency	▪ Improves oxygen exchange	▪ Relatively high PIP necessary
High PIP	▪ Improved oxygen exchange ▪ Prevents atelectasis	▪ May hinder venous return ▪ Decreases cardiac output ▪ Side-effects, such as pulmonary air leak

Indications for mechanical ventilation

- Failure of breathing (pulmonary, non-pulmonary such as apnea)
- Ventilatory failure (hypercapnia)
- Hypoxemia
- Chest wall instability
- To decrease respiratory effort (e.g., sepsis, cardiac failure)
- To control respiratory function (e.g., in high intracranial pressure)

Clinical criteria for mechanical ventilation

- Tachypnea
- Apnea
- Grunting
- Stridor

- Flaring of alae nasi
- Recessions
- Tachycardia
- Bradycardia
- Cyanosis
- Agitation
- Lethargy

Laboratory criteria for mechanical ventilation

- $PaO_2 < 50$ mmHg with $FiO_2 > 0.5$
- $PaCO_2 > 55$ mmHg with acidosis
- $PaCO_2 > 40$ mmHg with severe breathlessness
- Vital capacity $< 15\ ml \cdot kg^{-1}$

Guideline pediatric respiratory setting

- FiO_2 up to 1.0 to achieve required PaO_2, preferably below 0.6
- PEEP generally between 3 and 5 cmH_2O. Higher in reduced functional capacity with hypoxia if hemodynamically tolerated
- Aim for the physiological frequency corresponding to the age. Increase ventilatory frequency if $PaCO_2$ is high
- *I*:*E* ratio approximately 1:2; increase expiration time in obstructive pulmonary disease
- Tidal volume between 12 and $15\ ml \cdot kg^{-1}$
- Neonates, infants, and small children are generally ventilated with pressure control, in older children volume control may be preferred
- Estimated normal values of breathing are given in Table 3.16

Table 3.16 Estimated normal values of breathing

Age	Breathing rate (breaths per min)	Tidal volume (ml)
Neonate	30–60	20–35
12 months	20–30	40–100
5 years	18–25	150–200
9 years	15–20	300–400
15 years	15–20	300–500

Control of mechanical ventilation

- Auscultate bilateral ventilation
- Check hemodynamic side-effects such as heart rate, blood pressure, and peripheral perfusion
- Check transcutaneous oxygen saturation and the expiratory CO_2 concentration
- Control blood gases

Complications of mechanical ventilation

- Acute and chronic interstitial emphysema
- Pneumothorax, pneumomediastinum, pneumopericardium
- Pneumoperitoneum
- Subcutaneous emphysema
- Respiratory air trapping
- Air embolus

3.7 Circulatory Resuscitation

Indications for cardiac compression

- Pulseless patient
- Pulse less than 60 beats per minute in infants

Technique of cardiac compression

- Child flat on its back
  - Neonates (Fig. 3.6)
    - Hands encircle chest, compression with thumbs
    - Compress sternum 1.5 cm below nipples
    - Frequency 120 per minute
    - Press down to a depth of about 1.5 cm
    - Compression:breath ratio 3:1

- Infants (Fig. 3.7)
  - Use two fingers
  - Compress the lower third of the sternum
  - Frequency 100 per minute
  - Press down to a depth of about one-third of the depth of the chest
  - Compression:breath ratio 15:2
- Small children (Fig. 3.8)
  - Use one or two hands
  - Compress the lower third of the sternum
  - Frequency 100 per minute
  - Press down to a depth of about one-third of the depth of the chest
  - Compression:breath ratio 15:2

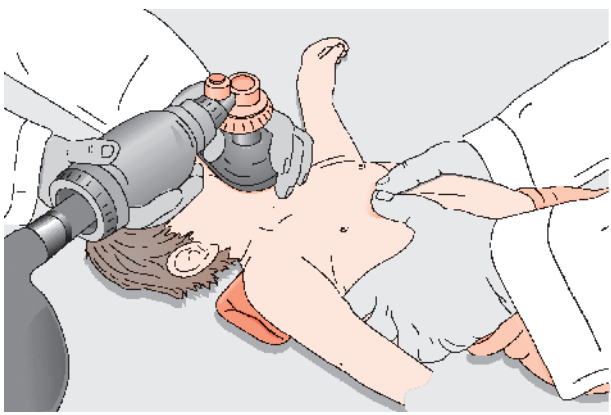

Fig. 3.6 Cardiac compression in neonates

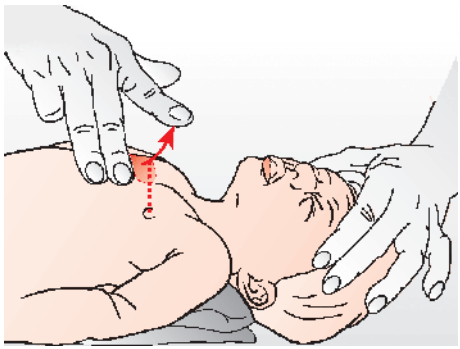

Fig. 3.7 Cardiac compression in infants

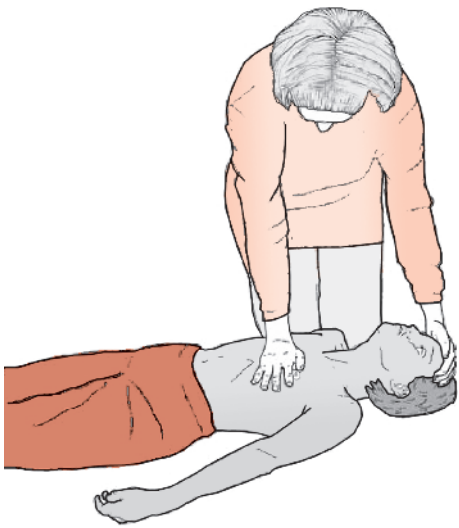

Fig. 3.8 Cardiac compression in small children

Complications of cardiac compression

- Rib or sternum fractures
- Pulmonary contusion
- Hematothorax, pneumothorax
- Liver, spleen rupture

3.8 Defibrillation

Indication

- ECG has confirmed ventricular fibrillation
- Pulseless ventricular tachycardia

Technique of defibrillation (Fig. 3.9)

- Cardiopulmonary resuscitation (CPR)
- Consider intubation
- Apply self-adhesive defibrillation pads below right clavicle and lateral to left nipple
- Apply paddles with firm pressure (infants <10 kg: 4.5-cm paddle; children, 8-cm paddle)
- Shock three times initially with 2, 4, and 4 $J \cdot kg^{-1}$ respectively with pauses to assess the rhythm
- Continue CPR for 2 min, adrenaline 10 $\mu g \cdot kg^{-1}$ i.v. or i.o.
- Assess rhythm
- If required shock three times with 4 $J \cdot kg^{-1}$
- Continue CPR for 3 min, adrenaline 100 $\mu g \cdot kg^{-1}$ i.v. or i.o., correct acidosis and so on
- Correct reversible causes
  - Hypoxia
  - Hypothermia
  - Hypovolemia
  - Electrolyte imbalance
  - Tension pneumothorax
  - Tamponade
  - Drugs

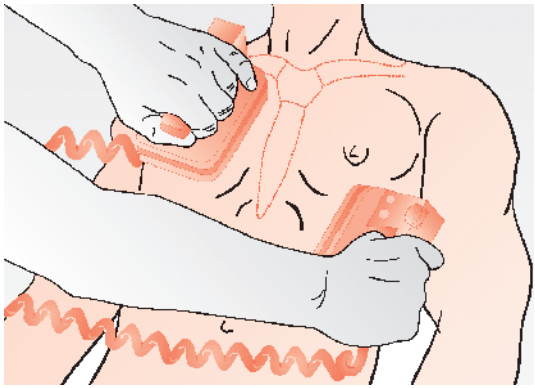

Fig. 3.9 Electrode position for defibrillation

Checklist

- Defibrillation pads
- Defibrillator
- ECG monitor
- Venous or intraosseous access
- Medication, e.g., adrenaline, amiodarone