Obstetric and paediatric anaesthesia in low resource settings

The Safe Anaesthesia Working Group of the World Health Organisation’s ‘Safe Surgery Saves Lives’ global initiative updated the 1992 International Standards for the Safe Practice of Anaesthesia in 2010. The aim of these Standards is to contribute to decreased patient morbidity and mortality worldwide, particularly in lesser resourced countries where regions have not adopted their own standards.

The fundamental principle of these Standards is the continuous presence of an appropriately trained, vigilant anaesthesia professional. The Standards also highly recommend pulse oximetry during anaesthesia, which means it is mandatory, although compromise may be unavoidable in emergencies.

Compliance with these International Standards should be advocated by health care workers in all facilities where anaesthetics are given.

Obstetric anaesthesia

The limiting factor is often the availability of doctors and nurses trained in anaesthesia; women, babies and children die because of the lack of trained staff.

Remember that there are two patients – the mother and the baby. The condition of the mother affects the condition of the baby. Therefore maintaining adequate oxygenation and reuscitation of the mother is the best initial way of treating and preventing fetal distress.

All pregnant mothers after 20 weeks’ gestation who are lying down must be put in the left lateral tilt position to avoid aorto-caval compression and supine hypotension.

Conduct of anaesthesia

Considerations in the obstetric patient in addition to routine anaesthesia include those listed below.

1 Physiological Hypoxaemia

Pregnant women are at risk of hypoxia. They use oxygen faster than non-pregnant women, and because of the pregnancy it is more difficult for them to breathe deeply.

Hypovolaemia

Signs of hypovolaemia eg. due to bleeding occur later than in the non-pregnant, because blood volume increases during pregnancy. This means that blood pressure, a late sign of blood loss, may be maintained in the hypovolaemic patient until induction of anaesthesia, when there may be catastrophic hypotension. Estimation of blood loss is difficult and it may be concealed eg. placental abruption or retroplacental bleeding. Placental perfusion is compromised before blood pressure, so fetal distress may be a warning of possible maternal circulatory compromise.

Acid regurgitation

Hormonal effects cause relaxation of the lower oesophageal sphincter, and pressure effects from the gravid uterus contribute to an increased risk of regurgitation and aspiration if laryngeal reflexes are impaired (eg. during anaesthesia or eclamptic fits). An H<sub>2</sub> receptor antagonist and sodium citrate or other appropriate non-particulate antacid should be given to all pregnant women beyond the first trimester before general anaesthesia, which should involve a rapid sequence induction with cricoid pressure.

2 Pregnancy-related disease

- Pre-eclampsia/eclampsia
  - blood pressure control
    - Blood pressure should be controlled prior to anaesthesia if possible. Spinal anaesthesia is recommended for Caesarean section if there are no contraindications (signs of coagulopathy or raised intracranial pressure). If general anaesthesia

is needed, attempts should be made to obtund the hypertensive response to intubation (see general anaesthesia for Caesarean section).

- Treatment with magnesium
  - Magnesium potentiates the effect of non-depolarising muscle relaxants, so smaller doses of muscle relaxant are needed if general anaesthesia is necessary.
- HELLP (Haemolysis, elevated liver enzymes, low platelets)
  - If platelet count is less than 100 000 x 10^9/L, a coagulation profile is indicated prior to spinal anaesthesia. If platelet count is less than 75 000 x 10^9/L, there is a risk of a spinal haematoma and so spinal anaesthesia is contraindicated. This has to be considered against the risks to the patient of alternative anaesthesia (general or local infiltration).

- Oedema of tissues
  - This includes facial and airway oedema. The larynx and vocal cords may be involved and a smaller than usual diameter endotracheal tube may be required eg. 6.5 mm, 6.0 mm.

- Risk of increased intra-operative blood loss eg. if there has been antepartum haemorrhage, placenta praevia, long labour, maternal dehydration and ketosis or blood clotting abnormality (due to pre-eclampsia and HELLP syndrome, or anticoagulant medication). Ensure IV access with 2 wide bore patent cannulae prior to induction of anaesthesia.
- Sepsis (due to ascending genital tract infection or intrauterine infection). Early recognition of sepsis may be difficult, so it is important to suspect it from the patient’s history (e.g. prolonged rupture of membranes).

3 Underlying medical conditions
- Examples include known cardiac abnormalities, previous cardiac surgery, and diabetes, all of which may be affected by pregnancy.
- Symptoms of chest pain or dyspnoea may indicate an undiagnosed heart valve abnormality, which may be either congenital or acquired (e.g. from rheumatic fever), unmasked by the circulatory changes in pregnancy and labour.

4 Drugs
- Ketamine: This causes an increase in blood pressure, so should not be given to women with hypertension, but it can be used for induction of anaesthesia for women needing general anaesthesia for Caesarean section. It may increase uterine tone, which may cause fetal distress, or difficulty delivering the baby at Caesarean section.
- Opioids: These drugs cross the placenta, so ideally should not be given until the cord is clamped, otherwise the baby may be slow to establish regular breathing.

5 Equipment
- It is vital to ensure that all resuscitation equipment is available and working, in order to prevent avoidable delays if there is an emergency. Check the bag-valve-mask, airway equipment, oxygen, IV fluids, suction, saturation monitor and blood pressure machine before every operation. Ensure that difficult airway equipment (e.g. stylets, bougies) is readily available.

Choice of anaesthesia for Caesarean section
- The choice of anaesthesia for major surgical procedures such as Caesarean section depends on the clinical condition of the patient, the anaesthetist’s experience, and the equipment and drugs available. It should be decided after a balance of risks and benefits has been considered.
  1. Most Caesarean sections are performed with spinal anaesthesia unless there are contraindications (see below).
  2. General anaesthesia is used when spinal anaesthesia is contraindicated. Intubation as part of a rapid sequence induction is needed to minimise the increased risk of regurgitation and aspiration in a pregnant woman.
  3. Local anaesthetic infiltration can be used in situations where there is no trained anaesthetist, or if the patient is moribund.

Spinal (sub-arachnoid) anaesthesia for Caesarean section
- A spinal injection gives a dense block of rapid onset (within 5–15 minutes) that lasts for about 2 hours, and can be ideal for Caesarean section. The mother remains conscious. Spinal anaesthesia can also be used perinatally for evacuation of residual products of conception, manual removal of placenta, repair of third- and fourth-degree tears.
- Spinal anaesthesia causes vasodilatation with consequent hypotension. This can be prevented with fluid loading before spinal insertion, and treated with IV fluid boluses and a vasoconstrictor (e.g. ephedrine).

Uses of spinal anaesthesia
- It can be used for:
  - Caesarean section
  - Laparotomy (not optimal)
  - Evacuation of residual products of conception
  - Manual removal of placenta
  - Repair of third- and fourth-degree tears.

Precautions
- Correct hypovolaemia first.
- Be aware of the presence of a coagulation disorder (e.g. with severe pre-eclampsia, eclampsia or placental abruption), which can lead to a dangerous bleed around the spinal cord. Spinal anaesthesia should not be used in these circumstances.

Contraindications
- These include the following:
  - Maternal refusal
  - Inadequate resuscitation facilities
  - Uncorrected hypovolaemia
  - Coagulopathy (e.g. if there is spontaneous bruising)
  - Fixed cardiac output (e.g. aortic valve stenosis)
  - Allergy to local anaesthetics
  - Local infection around the spinal area.

Giving a spinal anaesthetic

Preparation
- Explain to the patient the type of anaesthesia.
- Do not give a pre-operative sedative, as it may reduce the baby’s respiration and conscious level at birth.
Never proceed with the injection if the patient complains of pain on injection.

**Procedure**

- Ensure that there is a large-bore IV cannula (14 or 16G) and IV infusion running.
- Infuse 500–1000 mL of IV fluids (Ringer-lactate or Hartmann’s solution) to preload the mother and avoid hypotension. Also ensure that atropine 0.6 mg and ephedrine 30 or 50 mg diluted to 10 mL with Ringer-lactate or Hartmann’s solution are immediately available.
- Check the patient’s blood pressure.
- Sterility is critical. Use antiseptic skin solution to clean the patient’s back over a wide area. Use sterile gloves and ideally a sterile apron. Do not touch the point or shaft of the spinal needle with your hand. Hold the needle only by its hub.
- Prepare the spinal anaesthetic (heavy bupivacaine 0.5%, 2–2.5 mL).
- Inject 1% lidocaine solution using a fine 25G needle to anaesthetise the skin over the site (L3/4 or L4/5). Do not use a space above L2/3 because the spinal cord ends at around L1/2.
- Introduce the finest spinal needle available (24G) ideally using an introducer needle if available in the midline through the anaesthetised skin, at a right angle to the skin in the vertical plane. Fine spinal needles greatly reduce the risk of post-dural puncture headache.
- If the needle hits bone it may not be in the midline. Withdraw the needle and reinsert it, directing it slightly upwards while aiming in the direction of the umbilicus. It is important to have two correct planes (i.e. midline and also not too near to the spinous processes above or below).
- Advance the spinal needle towards the sub-arachnoid space. A loss of resistance may be felt as the needle pierces the ligamentum flavum.
- Once the needle has passed through the ligamentum flavum, push the needle slowly through the dura. You may feel another slight loss of resistance as the dura is pierced.
- Remove the stylet. Cerebrospinal fluid (CSF) should flow out of the needle.
- If CSF does not come out, reinsert the stylet and rotate the needle gently. Remove the stylet to see if fluid is flowing out. If you continue to fail, try another space.
- Once CSF flows out of the needle, inject 2–2.5 mL of the local anaesthetic solution described above.

**Complications of spinal anaesthesia**

1. **Hypotension.**

2. **Sensory block:** if the bladder is full it will be unnoticed by the patient.

3. **Headache** can occur following a spinal anaesthetic, but is uncommon if small gauge spinal needles are used. Headache occurs because of leakage of CSF, which causes traction on intracranial structures. A typical headache is frontal and/or occipital, and worse on sitting or standing, but better when lying down. It can be immediate or delayed. Management consists of analgesia as per the WHO pain ladder (see Section 1.15) and keeping the patient well hydrated.

4. **If there is bradycardia, tiring or weakness in the hands, or difficulty breathing, the block is likely to be too high.** Give the mother atropine 0.6 mg if she is bradycardic; increase the IV infusion rate and give ephedrine.

5. **Rarely, intracranial spread can also occur.** It produces loss of consciousness and apnoea, and is termed a total spinal block. Resuscitation is required.

**Management of spinal blocks which are too high or total**

**Call for help.**

**Airway:**

- Assess and maintain patency.
- Give oxygen 15 litres/minute via face mask, and measure SpO₂ using a pulse oximeter (which should already be attached).

**Breathing**

- Assess and give chest inflations with a bag-valve-mask if there is apnoea or inadequate breathing.
- Ideally protect the airway by intubation if the patient is unconscious (P or U on the AVPU scale).

**Circulation**

- High or total spinal blocks can cause cardiac arrest.
- Assess pulse and blood pressure.
Give chest compressions if the patient is in cardiac arrest or has an inadequate central pulse (the blood pressure may be unrecordable).

Tilt the patient to the left if this has not already been done.

Treat hypotension with IV Ringer-lactate or Hartmann’s solution and ephedrine.

Treat bradycardia < 50 beats/minute in the mother with atropine 0.6 mg IV, repeated after 3 minutes as necessary.

Keep a chart of pulse, blood pressure, respiratory rate, \( \text{SaO}_2 \), fetal heart rate and treatments given.

For management of anaphylaxis, see Section 2.7.C.

**General anaesthesia**

If spinal anaesthesia is contraindicated, rapid sequence induction and intubation is the recommended anaesthetic if expertise and equipment are available. See in Paediatric anaesthesia section of this section for the ‘10 golden rules of anaesthesia’, essential monitoring, essential drugs, essential equipment, and how to intubate steps 1–6.

General anaesthesia is indicated

1. If spinal fails or is refused by the patient
2. If there is a medical contraindication for spinal anaesthesia:
   - suspected coagulopathy,
   - raised intracranial pressure (impaired consciousness following eclamptic fits),
   - fixed cardiac output (e.g. aortic stenosis)
3. If there is no time for a spinal anaesthetic to be given.

**Conduct of General Anaesthesia**

1. Minimise aspiration risk by the following:
   - restrict oral intake, especially solids for women in labour
   - give H2 receptor antagonist e.g. ranitidine 150 mg orally if time, or 50 mg IV if emergency
   - give sodium citrate 30 mL orally just prior to induction of anaesthesia
   - assess patient, with particular attention to airway.
2. Check drugs available:
   - Induction agents
     - Thiopentone 3–5 mg/kg or
     - Ketamine 1.5–2 mg/kg – causes less hypotension than thiopentone, useful if patient hypovolaemic e.g. if antepartum haemorrhage. Contraindicated if pre-eclampsia or eclampsia or suspected raised intracranial pressure.
   - Muscle relaxant – Suxamethonium 1–2 mg/kg
   - Other drugs – to reduce hypertensive response to intubation, given if the patient has severe pre-eclampsia/eclampsia, magnesium 4 g (2 g if already receiving magnesium) or lidocaine 1.5 mg/kg, and/or rapid onset opioids if available. If opioids are used, the baby may need naloxone after intial resuscitation if not breathing adequately.
3. Check equipment – laryngoscopes, endotracheal tubes and ensure difficult airway equipment, including stylets, bougies, laryngeal mask and cricothyroidotomy kit are available.
4. Lie patient on theatre table with left lateral tilt and ensure suction is on and under pillow. Connect monitoring.
5. Start an IV infusion of Hartmann’s solution via a large gauge (14 or 16G) cannula.
6. Explain to the patient and anaesthetic assistant about cricoid pressure and pre-oxygenate the patient for 3 minutes.
7. Give predetermined dose of induction agent and suxamethonium and support jaw until relaxed, or until fasciculations subside.
8. Intubate patient and inflate cuff. Check position of endotracheal tube before allowing cricoid pressure to be released.
9. Maintain anaesthetic with a volatile agent or intermittent boluses of ketamine.
10. After the baby is delivered, oxytocin is given, as requested by the surgeon, usually 5 units as a bolus, followed by an infusion. Oxytocin may cause tachycardia and hypotension, so care must be given to patients with hypovolaemia or other patients for whom tachycardia would cause cardiovascular compromise e.g. stenotic cardiac valve disease. In these patients, the oxytocin bolus can be drawn up into 20 mL 0.9% saline and given slowly over 5–10 minutes. After delivery the mother can be given opioid analgesia for post-operative pain relief.

**Failed intubation**

This is more likely to occur at emergency Caesarean sections, when it is often unexpected and leads to rapid oxygen desaturation. An early decision should be made to abandon repeated attempts at intubation.

The priority is to OXYGENATE the patient.

1. Maintain cricoid pressure. This should not interfere with bag-valve-mask ventilation if correctly placed, and may need to be adjusted.
2. Inform surgeon and scrub nurse to help.
3. Ventilate the patient with 100% O2, initially with mask.
4. If mask ventilation not successful,
   a. insert oropharyngeal airway
   b. consider using 2 hands to maintain airway with assistant squeezing bag
   c. insert laryngeal mask.
5. If ventilation is still inadequate, a percutaneous cricothyrotomy should be performed.
6. If this is unsuccessful, either surgeon or anaesthetist should perform surgical cricothyrotomy or tracheostomy.

If ventilation and oxygenation is possible at any of the steps before cricothyroidotomy, and the Caesarean section is elective, the patient should be woken up and a spinal or local infiltration should be used.

If the Caesarean section is an emergency, you should consider whether to wake the patient up and give spinal anaesthesia, or proceed with the patient breathing spontaneously and give volatile anaesthesia or intermittent ketamine IV.

If spinal anaesthesia is not possible, intubation fails, or expertise and/or equipment is unavailable, and Caesarean section is urgently needed, the priority is to maintain oxygenation with bag-valve-mask and anaesthetise with either a volatile agent or ketamine depending on the experience of the practitioner.
Ketamine in early pregnancy

Ketamine causes a trance-like state where patients become mentally removed from their surroundings. It causes sleep, analgesia and short-term memory loss (amnesia). The patient is unconscious, pain-free and has no memory of the time under anaesthesia. The airway protective reflexes are usually present but cannot be guaranteed. Therefore it is important that the patient is starved and anaesthetised on a tipping table with suction available. It can only be used as a sole anaesthetic agent in the first trimester and if there is no increased risk of regurgitation. Patients should be fasted for 6 hours prior to ketamine anaesthesia.

Ketamine is contraindicated in patients with high blood pressure (including pregnancy-induced hypertension), eclampsia or heart disease.

Effects of ketamine:

Central nervous system: Ketamine causes sympathetic nervous system stimulation. The additional use of diazepam (after delivery if ketamine is used for a Caesarean section) will reduce the amount of sympathetic stimulation. Ketamine also raises intracranial pressure, which makes it unsuitable for patients with eclampsia.

The effects start 10–15 seconds after IV injection. Ketamine produces a ‘dissociative state’. The eyes may remain open and may make quick side-to-side movements (nystagmus), and the patient may move during surgery if ketamine is the only drug used. The patient can be quite agitated, crying and distressed on waking up. This can be minimised by using diazepam with ketamine and avoiding stimulation while emerging from anaesthesia. This can also be helped by including diazepam (see below) as part of the premedication.

Cardiovascular system: Ketamine causes mild stimulation of the cardiovascular system. The blood pressure rises by about 25% and heart rate increases by about 20%. This increases the workload of the heart.

Respiratory system: If given too quickly, IV ketamine can cause the patient to stop breathing for up to a minute. If this happens, ventilate the patient until the effect wears off. The airway is usually maintained, but still needs to be monitored closely. The oxygen saturation may decrease, so give oxygen.

Ketamine causes bronchodilatation. Laryngeal spasm may occur, and may be partly caused by increased secretions resulting from ketamine use (see below for the importance of an atropine premedication in helping to prevent this). If it occurs, continue positive airways pressure by mask with oxygen or manual ventilation with a bag and mask should relieve this potentially dangerous problem. If it doesn’t relieve the obstruction and oxygen saturations are falling, or the patient is cyanosed, give a short acting muscle relaxant (suxamethonium 1 mg/kg IV) and continue bag valve mask ventilation until adequate breathing returns (usually about 5 minutes later).

Muscle: Ketamine increases muscle tone. This makes it an unsuitable drug for major abdominal surgery where abdominal relaxation is necessary. Some body movements can occur.

Uterus and placenta: Ketamine may increase the tone of the uterus. It readily crosses the placenta, so the fetus receives some of the drug.

Premedication before ketamine

- Atropine 10–20 micrograms/kg (up to a maximum of 600 micrograms) IM 30 minutes before or IV at the time of induction of anaesthetic.
- Diazepam 100 micrograms/kg (up to a maximum of 10 mg in pregnancy) can be given IV at the time of induction to prevent hallucinations. When performing a Caesarean section after ketamine induction, give diazepam only after the baby has been delivered as diazepam can cross through the placenta and prevent the newborn baby from breathing.
- Give oxygen at 6–8 litres/minute by mask or nasal cannulae.

Administration of ketamine in pregnancy

1. Should only be used without intubation in the first trimester.
2. Can be used as an induction agent as part of rapid sequence induction in 2nd and 3rd trimester if there are no contraindications, e.g. pre-eclampsia, eclampsia.

Start an IV infusion of crystalloid and ensure that a reliable IV cannula is in place.

Ketamine may be given by IV injection or by IV infusion. At doses of 250–500 micrograms/kg IV ketamine is a good analgesic. At doses of 1–2 mg/kg IV ketamine is an anaesthetic.

Giving IV diazepam 100 microgram/kg will reduce nightmares and hallucinations, but respiratory depression is more likely than with ketamine alone.

Ketamine injection

- Check vital signs (pulse, blood pressure, respiration and temperature).
- Oxygen should be given to ensure that SaO₂ remains above 94%, ideally near 100%.

Induction of anaesthesia is achieved by slowly administering ketamine 2 mg/kg body weight IV slowly over 2 minutes. For short procedures lasting less than 15 minutes, this will provide adequate anaesthesia.

- Check the adequacy of anaesthesia at the operation site before proceeding with the surgery. Pinch the incision site with forceps. If the pregnant woman feels the pinch, wait 2 minutes and then retest.
- Monitor vital signs (pulse, blood pressure and respiration) every 5 minutes during the procedure.

Give additional IV boluses of ketamine 1 mg/kg body weight as needed.

Ketamine infusion

- For longer procedures, infuse ketamine 200 mg in 100 mL of 5% dextrose at 2 mg/minute (i.e. 20 drops per minute with a standard giving set with a drop factor of 20) and titrate to response. More or less may be needed. Stop the infusion 10 minutes before the end of the operation. If the patient needs a blood transfusion, give it through a different IV line.
- Monitor vital signs (pulse, blood pressure and respiration) every 5 minutes during the procedure.
Post-procedure care
Discontinue ketamine infusion and administer a post-operative analgesic appropriate to the type of surgery performed. The patient takes about 2 hours to wake up, and needs to be in a quiet area. Let her wake up naturally without stimulation. Maintain observations every 30 minutes until the patient is fully awake.

Local anaesthesia for Caesarean section
In extreme situations, Caesarean section can be undertaken under infiltration with local anaesthetic. Although not ideal, this can be necessary in an extremely ill patient (e.g. if unconscious and/or eclamptic), where general anaesthetic/intubation is not available and spinal anaesthetic is inadvisable.

Up to 100 mL of lidocaine 0.5% with adrenaline 1:200 000 is used to infiltrate the layers of the abdominal wall either side of the midline from the symphysis pubis to 5 cm above the umbilicus.

Paediatric anaesthesia
This must only be undertaken by anaesthetic practitioners with adequate experience, preparation and equipment. If these skills and equipment are not available, the child should be referred to a more experienced hospital if at all possible.

Ketamine anaesthesia is commonly used in children and is usually safe, but it must still be undertaken with care.

The ‘10 golden rules of anaesthesia’ (originally defined by Maurice King in his manual Primary Anaesthesia) form the basis of essential safe anaesthetic practice for all cases, and are listed below.

1. Do an adequate pre-operative assessment.
2. Ensure that the patient has been nil by mouth for an appropriate time.
3. Use a tipping table.
4. Check all equipment and drugs.
5. Have suction ready.
6. Keep the airway open.
7. Be prepared to ventilate the patient (with oxygen).
8. Check the pulse, blood pressure and oxygen saturation (SpO₂).
9. Have a vein open with a reliable venous cannula.
10. Have an assistant ready to apply cricoid pressure.

In addition:
- Create a non-frightening environment. If possible and appropriate, the parents should be present up to the time of induction of anaesthesia.
- Be aware of anatomical, physiological and pharmacological concepts relevant to infancy and childhood.
- Know the normal values of the main physiological variables.
- For all emergencies, remember ABC for assessment and treatment, and call for help early.
- Know the hourly fluid and blood requirements for every patient (for children these are based on their weight).
- Ensure that all equipment and drugs are available for the child.

Pre-operative assessment
- Past medical history (including anaesthetic history), in particular any cardiorespiratory illness, and the presence of respiratory tract infection, which increases the risk of adverse respiratory events during anaesthesia.
- Medication and allergies.
- Nil-by-mouth guidelines (if unsure, ensure 6 hours nil by mouth for all oral intake)
  - clear fluids: 2 hours
  - breast milk: 4 hours
  - food: 6 hours.
- Weigh the child.
- Note the physiological status: airway, oxygenation and ventilation, cardiovascular stability, hydration.
- Assess airway and ease of intubation. Burns, facial deformity, small chin and reduced mouth opening are all signs of a potentially difficult airway. If any problems with airway or intubation are anticipated, consider referring the child to a more experienced hospital.
- If the child is sick, consider whether the procedure is really necessary, and if it is, ensure adequate resuscitation prior to any procedure.
- Plan the fluid requirements. Do not give hypotonic solutions such as 0.18% saline in 5% dextrose. Give Ringer’s lactate or Hartmann’s solution, which are best and essential intra-operatively. Neonates, infants and sick children need glucose (dextrose) intra-operatively, and therefore a 5% or 10% solution of glucose in Ringer-lactate or Hartmann’s solution is ideal. Check the blood glucose levels regularly, and give additional glucose (10%) 2 mL/kg as required.
- Basic maintenance fluids in children:
  - Give 4 mL/kg/hour for the first 10 kg of body weight.
  - Then add 2 mL/kg/hour for the next 10 kg of body weight.
  - Then add 1 mL/kg/hour for each kg thereafter.
- Additional fluids: Judge these clinically: cardiovascular status and urine output (> 0.5–1 mL/kg body weight/hour for a child).
- Premedication: give oral paracetamol. Avoid sedative premedications unless you are experienced in their use.
- Explain what is to happen to the child and their family.

Intra-operative considerations
Planning the anaesthetic
- Maintenance of normal physiological status is part of balanced anaesthesia.
- General anaesthesia involves a reduced conscious level (sleep), muscle relaxation and analgesia. Anaesthetic drugs rarely provide all three of these (e.g. ketamine is a poor muscle relaxant, ether is not analgesic, local anaesthetics provide no fall in conscious level). Therefore modern anaesthesia uses combinations of drugs to provide balanced anaesthesia.
- Avoid general anaesthesia wherever possible. Most operations can be performed using one or all of the following: sedation, local anaesthesia and ketamine. These techniques should be the basis of anaesthesia for the non-specialist anaesthetist.
- General anaesthesia is indicated where other methods are precluded due to lack of knowledge, lack of drug, the nature of the surgical procedure (abdominal surgery) or contraindication for ketamine/local anaesthetic drug.
- Inhalation anaesthesia with or without muscle relaxant...
and local anaesthetic/opioid as analgesia is the standard combination.
- Intravenous ketamine is an excellent induction agent unless it is contraindicated. Thiopentone is a useful alternative if inhalational anaesthesia is planned and intravenous induction is required.
- Induction can be achieved by inhalation of anaesthetic gases, provided that there is adequate expertise and equipment. This is not safe for patients with a full stomach, but in those with acute upper airway obstruction it must be used (intravenous induction often leads to apnoea or a worsening of airway obstruction).
- Neonates and infants form a special group. Do not undertake anaesthesia without concern in this age group, and it should be administered only by an experienced practitioner. Sedation and ketamine anaesthesia are more difficult to perform safely. Under general anaesthesia, neonates and infants do not breathe well (due to difficult airway maintenance, unfavourable chest wall/lung mechanics and limited reserve in the face of hypoxaemia). Therefore, in general, ventilation must be controlled. Caution must be exercised with regard to drug doses (opioids and local anaesthetics due to side effects, suxamethonium is required at a higher dose), and post-operative risks are increased. Ketamine or inhalational anaesthesia with controlled ventilation is the technique of choice.

For all anaesthesia:
- Remember the ‘10 golden rules’.
- Give oxygen if it is available (especially at altitude).
- Use all monitoring that is available. The best monitor is the anaesthesia provider closely watching the patient at all times. A pulse oximeter is the most essential basic monitor.
- Maintain normothermia (using warm fluids and high ambient temperature).
- Give fluids for maintenance with additional fluid as indicated clinically.
- The optimal haemoglobin level depends on age, but preferably should always be higher than 8g/dl. Correction of chronic anaemia is not necessary unless major blood loss is expected.
- Analgesia: paracetamol, non-steroidal anti-inflammatory drugs, local anaesthetic infiltrations and blocks, and opioids (morphine and pethazocine).
- Plan to maintain spontaneous ventilation wherever possible. Never use muscle relaxants without knowledge of and experience in how to intubate.

When to intubate
- To protect the airway/lungs: All acutely ill children and pregnant women have poor gastric emptying. If in doubt, or if there is a strong indication of a ‘full stomach’ (acute abdomen) you must protect the lungs with an endotracheal tube. Intravenous induction with the application of cricoid pressure prior to intubation is the technique of choice. Prolong nil by mouth times post trauma to minimise the risk of regurgitation.
- To ensure a safe maintained airway: In the case of a difficult airway or potentially difficult intubation, never give muscle relaxant until the airway is secured with an endotracheal tube (i.e. keep breathing!). Upper airway obstruction is a contraindication to intravenous anaesthesia, including ketamine.
- To provide positive pressure ventilation: Prolonged surgery, where muscle relaxant is essential (abdominal surgery).
- To improve oxygenation in neonates and infants: You can administer 100% oxygen and maintain better lung volumes with positive end-expiratory pressure (PEEP).

Post-operative care
- Basic recovery care: attention to ABC, maintenance of normothermia, continued fluid therapy, and provision of safe and effective analgesia.
- Commence oral fluids as soon as possible.
- If intravenous fluids are required (due to ongoing losses or nil by mouth), give at 70% maintenance with additional fluids matched to losses.
- Regular oral/rectal analgesia (paracetamol, non-steroidal anti-inflammatory drugs) with opioid as rescue analgesia. Consider opioid infusion (see Section 1.6 and Section 1.15).
- Pain assessment scores to titrate analgesia (see Section 1.16).
- Family care and communication.

Techniques

Sedation
In pregnancy and in children should only be administered by experienced health workers; usually an anaesthetist.
- Conscious sedation through to general anaesthesia: based on loss of airway self-maintenance, gradual loss of protective reflexes and decreased responsiveness.
- All drugs can have unpredictable and prolonged effects.
- Cardiorespiratory compromise is the greatest danger.
- Avoid sedation altogether in patients with upper airway obstruction.
- Prepare as for general anaesthesia,
- Drugs: chloral hydrate, midazolam or diazepam.
  - chloral hydrate: 25–50mg/kg orally (infants)
  - midazolam: 200 micrograms/kg intranasally, orally or sublingually
  - diazepam: 200 micrograms/kg IV (500 micrograms/ kg rectally).

Local anaesthetic
- Advantages:
  - It is cheap, and minimal equipment is required.
  - Its use can avoid the need for general anaesthesia.
  - The procedures are simple and brief.
  - It can be used for post-trauma analgesia and post-operative analgesia.
- Disadvantages:
  - Slow onset, and prolonged effect.
  - Each block can have major complications.
  - Toxicity: central nervous system (seizures) and cardiovascular (arrhythmias).
  - All techniques can be lethal.
  - It is not sedative!
- Safety:
  - Always ensure sterility.

Never exceed the maximum doses of local anaesthetics: lignocaine 3 mg/kg (7 mg/kg with adrenaline), and bupivacaine 2 mg/kg (with or without adrenaline).
- Be very cautious with doses in neonates.
- Know the anatomy.
- Use blunted needles (easier to identify layers), ideally 25–29 gauge.
- Always aspirate before any injection (this is not a 100% guarantee of avoiding intravascular injection).
- All injections should be easy (i.e. there should be no resistance to injection; resistance indicates intra-nerve injection).
- Be aware of the possibility of toxicity, and assess for it during and after administration of local anaesthesia (an early symptom of toxicity is tingling of the lips, which are a highly vascular area).

**Applications**

This can be administered topically, by infiltration or by regional blocks.

**Do not combine local anaesthetic with adrenaline in digital or penile blocks.**

- **Topical application:** easy to do and can be very effective (e.g. Ametop or EMLA skin anaesthesia, local anaesthetic soaked dressings, eye drops).
- **Infiltration:** use a small needle, and slow injection.

**Nerve blocks**

For all blocks, first consider whether ketamine anaesthesia would be safer and more tolerable for the child.

- Explain this type of anaesthesia to the patient and carers, and gain their consent.
- Warn the patient about motor blockade and the sensation of sensory blockade.
- Apply the principles of safe use of local anaesthetics.
- The onset of effect can be slow (30–60 minutes).
- The effect can be prolonged (up to 24 hours).
- Be aware of the distribution of analgesia for each block.

**Femoral block/’3 in1’**

- Femoral shaft fractures, burns, grafts from anterior thigh.
- Medial calf only blocked below the knee.
- Lie the patient in a supine position. The femoral nerve lies lateral to the vascular sheath just below the inguinal ligament (the nerve, artery and vein lie laterally to medi-ally, respectively).
- Sterilise the skin and provide skin analgesia.
- Identify the artery. The injection point is 0.5–1 cm lateral to the artery.
- Advance a 21G blunted needle perpendicular to the skin until two ‘pops’ are felt (the fascia lata and fascia iliaca).
- Aspirate, inject lignocaine 1% with adrenaline (1 in 200,000), 0.5–0.7 mL/kg.
- Larger volume blocks obturator and lateral cutaneous nerves in addition, hence ‘3 in 1’.

**Brachial plexus block (axillary approach)**

- This is the easiest and safest approach.
- It blocks the whole arm except for the upper arm and shoulder.
- Lie the patient supine, abduct the arm to 90 degrees, rotate it externally, forearm to 90 degrees.
- Identify the artery, sterilise the skin, and provide skin analgesia.
- Advance 1 inch with a 22 G needle, aiming for the apex of the axilla, over and parallel to the artery.

- After one pop is felt, let go of the needle. It will bounce with arterial pulsation if correctly sited.
- Support the needle, then carefully aspirate and inject 0.5 mL/kg lignocaine 1% with adrenaline 1 in 200,000. Intravascular injection is a significant risk.

**Intercostal block**

- This is useful for fractured ribs and upper abdominal surgery.
- The risk of complications is high, but it is an effective block.
- Identify the postero-medial curve of the rib.
- Sterilise the skin and provide skin analgesia.
- Advance a 22–24G needle perpendicular to the skin until you hit the rib.
- “Walk” the needle just under the rib, aspirate and inject.
- Repeat at each rib.
- Beware of the maximum dose, 0.5 mL/kg of 1% lignocaine with adrenaline 1 in 200,000, as intravascular uptake from this site is high.

**Intravenous regional anaesthetic (IVRA)/Bier’s block**

- This is used for distal limb excisions and fracture manipulations.
- It involves intravenous injection of local anaesthetic into an arm with a tourniquet blocking off the arterial and venous supply. It is therefore dangerous and must only be performed with the appropriate equipment.
- Exsanguinate the arm by elevation.
- Apply the tourniquet (a double one if available).
- Insert two IV cannulae – one in the limb to be blocked as distal as possible, and the other for safety in another limb.
- Inflate the tourniquet (to twice the arterial pressure).
- Inject lignocaine 1% (10 mL at 1 year, 20 mL at 5 years, 30 mL at 10 years) into the cannula in the limb to be blocked (but not with adrenaline and not with bupivacaine).
- There is a 10-minute onset, and it is safe to release the tourniquet after 30 minutes.

**Ilioinguinal/iliohypogastric block (field block)**

- This is used for hernia repair and orchidopexy.
- Lie the patient supine and identify the anterior superior iliac spine.
- This is 1 cm medial and 1 cm caudal.
- Sterilise the skin and provide skin analgesia.
- Advance a 22 G blunted needle perpendicular to the skin until one pop is felt (after the skin). Then aspirate and inject.
- Two pops are acceptable. Three pops or ‘feels too far’ runs the risk of femoral nerve block.
- Infiltrate 0.5 mL/kg 1% lignocaine with 1 in 200,000 adrenaline after aspiration.
- Withdraw to skin and infiltrate.

**Central blocks**

Central neural blockade should only be used by experienced anaesthetic practitioners in older children. It is not appropri-ate to discuss central blocks for children in this textbook. Please refer to a specialist anaesthetic textbook.

**Ketamine**

Ketamine anaesthesia is not always safe, and must only
ever be undertaken with great care. Remember the 10 Golden Rules of anaesthesia and ensure that adequate preparation has taken place.

Ketamine is an analgesic, dissociative anaesthetic that induces a trance-like cataleptic state dissociated from the environment.

**Advantages:**
- airway maintenance
- cardiovascular stability
- useful for short procedures, and limb and extra-cavity surgery.

**Disadvantages:**
- airway is not guaranteed, and interference risks laryngospasm and bronchospasm; cardiovascular stability is no alternative to good resuscitation
- hypoxaemia and apnoea, especially after bolus administration
- hypertensive, especially with prolonged anaesthesia (greater than 1 hour)
- resistance is unpredictable except in developmentally delayed children
- it raises the intracranial and intraocular pressure
- emergence phenomena (e.g., hallucinations), although these are perhaps less common in children, and can be minimised with benzodiazepines.

- Use as low a dose as possible.
- Recovery may be prolonged.
- Use only with great caution in neonates (apnoea is very likely to occur).

**Ketamine doses**

- 1 mg/kg slow IV bolus.
- Repeat half the first dose (500 micrograms/kg) after 15 minutes.
- 7 mg/kg IM induction dose.

For IV infusion:

- Make up a solution of 1 mg/mL by placing 500 mg in a 500-mL bag of 5% glucose or 0.9% saline.
- Maintenance after the initial bolus.
- Aim for 2–4 mg/kg/hour for general anaesthesia.
- Aim for a lower dose, of 500 micrograms to 1 mg/kg/hour, for analgesia.

Marked tachyphylaxis can occur with infusions that last for more than 30–60 minutes.

**Inhalational anaesthesia**

Do not undertake this unless you are trained in anaesthesia.

- Airway maintenance skills and the ability to recognise an appropriately anaesthetised patient are the absolute minimum requirements for safe practice.
- The best simple guide to depth of anaesthesia is the level of sympathetic nervous system arousal.
- The equipment for this type of anaesthesia is generally more specialised.
- Spontaneous ventilation via mask or endotracheal tube and breathing system is the safest application.

**Ether** is a relatively safe drug to use, although it is no longer widely available. It can be given by an open method or by a breathing system and vaporiser, usually of the draw-over type. Induction of anaesthesia is slow and relatively predictable. Respiratory depression is late, and cardiovascular stability is well maintained. Recovery can be prolonged. Ether has no analgesic effect.

**Halothane** is a potent but highly effective inhalational anaesthetic agent. It can only safely be given via a vaporiser. It is easy and dangerous to use too much.

**Trichloroethylene (trilene)** has the advantages of slow onset, high potency and an analgesic effect. Tachyphylaxis and post-operative nausea are seen. It is rarely if ever used alone.

**Essential equipment**

This should follow the World Health Organization (WHO) or World Federation of Societies of Anaesthesiologists (WFSA) standards. The minimum is Level 1 facility.

**Minimum equipment required for ketamine and local anaesthesia provision**

- Equipment to support the airway and ventilation (bag-valve-mask).
- Suction (foot operated or electric).
- Intravenous cannulae.
- Syringes.
- Needles.
- Pulse oximeter.

**Preferred equipment for ketamine, inhalational anaesthesia and resuscitation**

- Oxygen masks: with and without reservoir bags (paediatric and adult sizes).
- Oxygen supply: cylinders with oxygen flow meter or oxygen concentrator.
- Intravenous fluids (isotonic solutions such as Hartmann’s, Ringer’s lactate or 0.9% saline) not dextrose solutions without electrolytes, except in the first 2 days of life.
- Intravenous administration sets (ideally burettes).
- Paediatric anaesthetic face masks (ideally clear masks with inflatable rings that provide an airtight seal and have minimal dead space).
- Oropharyngeal airways (Guedel), sizes 0–4.
- Bag-valve-mask incorporating non-rebreathing valve (paediatric), reservoir tubing/bag and self-inflating bag (preterm neonatal (250 mL) and full term neonatal and child (500 mL) sizes).
- Ayre’s T-piece, with Jackson–Rees modification (open-ended 500-mL bag).
- Endotracheal tubes: 2.0–9.0 mm internal diameter, cuffed and uncuffed, PVC.
- Laryngoscopes: straight-bladed and curved-bladed.
- Magill’s forceps (adult and paediatric sizes).
- Fixation tape.
- Suction apparatus (manual, foot/hand pump).
- Suction catheters.
- Yankauer suckers, paediatric and adult.

A means of administering inhalational anaesthetic agents: continuous-flow (Boyles type) require a continuous oxygen supply; simple draw-over (OMV, EMO based, triservice); or new hybrid machines, such as the Universal Anaesthesia Machine (www.gradianhealth.org) or the Glostavent (www.diamedica.co.uk) (please refer to specialist anaesthetic textbooks).

**Essential monitoring**

- This improves patient safety, reducing morbidity and mortality.
Use in any location and for any technique, including sedation.
Use from induction through to recovery.
Documentation is essential.

The best and only universally available monitor is the presence and vigilance of the person administering the anaesthetic.

Minimum monitoring includes colour, pulse rate and volume, chest wall movements, capillary refill time, respiratory rate and auscultatory findings, and pupil size. This monitoring can and should be performed repeatedly by the anaesthetist.

Always remember to check:
• equipment prior to use
• whether there is enough oxygen
• whether oxygen is flowing into the patient
• the patient’s arterial oxygen saturation (SpO₂), electrocardiogram, non-invasive blood pressure (this is extremely valuable), temperature (ideally core temperature), blood glucose levels, urine output, and capnography (expensive but useful).

Essential drugs
• Oxygen.
• Intravenous fluids.
• Local anaesthetics (lignocaine and bupivacaine).
• Ketamine.
• Atropine.
• Diazepam.
• Midazolam.
• Paracetamol.
• Morphine or another opiate.
• Succinylmethylonium bromide (if no refrigeration facilities are available), (lasts 5 minutes, higher dose is needed in neonates, salivation, hyperkalaemia, masseter spasm, anaphylaxis).
• Pancuronium (or atracurium or vecuronium); neostigmine.
• Adrenaline (resuscitation doses: 1 in 10 000 = 100 micrograms/mL; 1 in 1000 = 1 mg/mL).
• Thiopentone (apnoea, hypotension).
• Intravenous fl uids.
• Oxygen.

Aids to intubation
• Laryngoscope: blade (straight for neonates and infants because of their long, floppy epiglottis; curved for older children and pregnant mothers), bulb and handle.
• Magill’s forceps.
• Introducer (not further than the end of the tube itself).
• Gum elastic bougie (over which the tube can pass).
• Cricoid pressure (can aid visualisation of the larynx).
• Suction apparatus must be available, plus Yankauer and other catheters.
• Syringe (cuffed tube).

Predictors of difficulty
• Difficulty in opening mouth
• Reduced neck mobility
• Laryngeal/pharyngeal lesions
• Congenital: Pierre-Robin syndrome, mucopolysaccharidoses.
• Acquired: burns, trauma.
• Look from the side: a small chin is a predictor of difficulty.

Complications
• Displacement: oesophageal, endo-bronchial, out of larynx.
• Obstruction: kinking, secretions.
• Trauma: from the lips to larynx.
• Hypertensive response.
• Hypoxic response.
• Vagal response.
• Laryngeal or pharyngeal spasm.
• Aspiration of gastric contents.

How to intubate
1 Prepare and check the equipment.
• Choose an appropriate tube size, with one size above and one size below available.
• Get the tape ready to fix the tube.
• Suction must be available.
• Induce anaesthesia and give muscle relaxant unless completely obtunded. Do not attempt this in a semi-conscious patient.

2 Position:
• Children over 3–4 years of age and pregnant mothers: ‘sniffing morning air’ position (head extended on shoulders and flexed at neck).
• Children under 3 years (especially neonates and infants): neutral position (large occiput).
• Keep in a neutral position with in-line immobilisation if there is an unstable cervical spine (e.g. due to trauma or Down’s syndrome).

Choice of tube
• Uncuffed under 25 kg: the larynx is narrowest below the glottis and subglottic area with a small air leak detectable at 20 cmH₂O (i.e. sustained gentle positive pressure).
• Size of uncuffed tubes: measure the tube internal diameter against the diameter of the little finger of the child:
  - preterm neonates: 2.5–3.5 mm internal diameter
  - full-term neonates: 3.0–4.0 mm internal diameter
  - infants under 1 year of age and after the neonatal period: 3.5–4.5 mm internal diameter
  - children over 1 year: internal diameter in mm = age/4 + 4
  - length of tube in cm = age/2 + 12 for oral tube
  - = age/2 + 15 for nasal tube.

Intubation
This is used:
• to secure the airway
• to protect the airway
• for prolonged ventilation
• for intra-operative ventilation
• for tracheo-bronchial toilet
• for the application of high airway pressures and positive end-expiratory pressure (PEEP)
• for cardiopulmonary resuscitation (all of the above)
• in patients with raised intracranial pressure to maintain normal oxygenation and normocapnia.
1.25 Non-invasive respiratory support

Introduction
Respiratory support is needed when the patient fails to sustain an adequate airway, oxygenation or ventilation, despite treatment of the condition leading to respiratory failure. Respiratory failure may result from:

- respiratory illnesses
- severe shock
- coma
- convulsions
- meningoc-encephalitis
- neuromuscular disorders
- raised intracranial pressure (e.g. from trauma).

Infants and young children are more likely to progress to respiratory failure because:

- they are more susceptible to infection
- their airway is smaller
- their thoracic cage is more compliant
- their ribs are (nearer) horizontal
- their respiratory muscles are more prone to fatigue.

Pregnant women and girls are also more susceptible to respiratory failure. They have reduced immune function, an expanding abdominal mass which impairs lung expansion, and are more prone to gastro-oesophageal reflux and aspiration of gastric contents.

As respiratory failure progresses, it will ultimately lead to cardiorespiratory arrest and death. Thus recognition of the severity of the conditions that lead to respiratory failure, followed by appropriate treatment, will reduce morbidity and mortality.

Use of respiratory support
The following clinical signs should be observed when assessing the adequacy or inadequacy of breathing:

- intercostal, sub-costal and supra-sternal recession
- respiratory rate
- inspiratory and expiratory noises
- use of accessory muscles
- adequacy of breath sounds and chest expansion
- heart rate
- skin colour
- mental status.

To help to assess the development of respiratory failure, it is necessary to assess changes in the clinical signs listed above. In the following situations, however, these signs are less useful because there is absent or decreased work of breathing:

- in patients with fatigue or exhaustion (e.g. after prolonged respiratory effort)