BVSC & AH STUDY BOOK 5 OF 7

Veterinary Anaesthesiology and Analgesia

Fourteen chapters on safe anaesthesia and pain relief: assessment, sedation, injectable and inhalation agents, equipment, local blocks, monitoring, special patients, species and field practice, wildlife capture, record keeping and emergencies. Each chapter ends with a 10-question self-test.

14 chapters | **140** practice questions | **No** dose tables

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Start here

Pick a chapter from the list on the left (or the top bar on a phone). The chapters follow the path of an anaesthetic from assessment to recovery: preparation, sedation, induction, maintenance, equipment, local blocks, analgesia, monitoring, special patients and species, field work, safety, and emergencies. Each chapter has six parts: Learn, Concepts, Compare, Species, Quiz and Revise. Your quiz progress is saved on this device only.

CHAPTER 1 OF 14

Principles of anaesthesia and pre-anaesthetic assessment

Anaesthesia is a planned, monitored reversible loss of awareness, sensation and movement, and most anaesthetic deaths trace back to poor assessment or preparation. This chapter covers the stages and planes of anaesthesia, ASA grading, history and examination, fasting by species, consent and the equipment checklist.

After this chapter you can

- Describe the stages and planes of anaesthesia and the signs used to recognise them
- Assign an ASA physical status grade and explain how it guides risk discussion
- List the key points of history and physical examination before anaesthesia
- Explain why fasting advice differs between dogs, cats, ruminants, horses and small mammals
- Prepare an equipment and drug checklist and obtain informed consent

Why assessment comes before the drug

General anaesthesia produces unconsciousness, muscle relaxation and loss of reflex response to pain, but every anaesthetic drug also depresses the heart, the lungs or both. The margin between a useful depth and a dangerous one is narrow. For this reason the safest anaesthetic begins **before** any drug is drawn up.

Surveys of small animal and equine practice repeatedly show that anaesthetic deaths are not mainly due to a single bad drug. They arise from unrecognised disease, poor preparation, inadequate monitoring and delayed response to a problem. A good pre-anaesthetic routine is therefore a patient safety tool, not paperwork.

The aim is to answer four questions: how sick is this animal, which drugs suit its condition, what could go wrong, and are we ready to deal with it.

Stages and planes of anaesthesia

The classical description by Guedel was made with ether, but the idea still helps students recognise depth. Modern injectable and balanced techniques pass through the early stages so quickly that they can be hard to see.

1. **Stage I, analgesia.** The patient is conscious but drowsy, and pain sense is reduced.
2. **Stage II, excitement or delirium.** Consciousness is lost but the brain's inhibitory control is lost first, so the animal may struggle, vocalise, paddle, have irregular breathing and an unpredictable heart rate. This is the stage that smooth

induction and good premedication try to avoid. Vomiting and regurgitation are likely here.

3. **Stage III, surgical anaesthesia.** Divided into light to deep planes. Breathing becomes regular, muscles relax and reflexes fade as the plane deepens.
4. **Stage IV, overdose.** Respiratory and then cardiac failure. This is an emergency: reduce or stop the anaesthetic, ventilate with oxygen and support circulation.

In practice the clinician judges depth by a group of signs, not one. Eye position, jaw tone, palpebral and corneal reflexes, response to surgical stimulus, heart rate, blood pressure and respiratory pattern are read together. A common confusion is to treat a lost palpebral reflex as proof of adequate depth. Signs differ between drugs: ketamine keeps eyes open and reflexes partly present even when the patient is anaesthetised, whereas inhalant agents behave more like the classical scheme.

ASA physical status grading

The American Society of Anesthesiologists (ASA) system, adapted for animals, places each patient in one of five categories before anaesthesia. It describes the animal's health, not the procedure.

- **ASA I**: normal healthy patient, for example a routine elective spay.
- **ASA II**: mild systemic disease without functional limitation, such as a mild, well-controlled condition, an obese animal or a very young or old patient.
- **ASA III**: severe systemic disease with functional limitation, for example anaemia or moderate heart disease.
- **ASA IV**: severe systemic disease that is a constant threat to life, such as decompensated heart failure or severe shock.
- **ASA V**: moribund animal not expected to survive without the procedure.

An **E** is added for emergency surgery. Higher grades carry greater risk, so grading guides drug choice, how much monitoring is needed, whether to stabilise first and what to tell the owner. A frequent mistake is to assume a young animal is automatically ASA I; a puppy with a congenital shunt or a calf with dehydration and acidosis is not. Grading is also a judgement, so two clinicians may differ by one grade.

History and clinical examination

The history should record species, breed, age, weight, current and recent drugs, previous anaesthetic reactions, vaccination and deworming status, exercise tolerance, coughing, fainting, seizures, and any family history of drug problems. Ask specifically about drugs such as ivermectin, steroids, NSAIDs and anything given by the owner or a local practitioner, because these may interact with anaesthetics or affect the kidney and liver.

The physical examination should include demeanour, mucous membrane colour and capillary refill, hydration, heart rate and rhythm, auscultation of heart and lungs, pulse quality, respiratory pattern, temperature and body condition. In ruminants and horses, rumen fill, bloat and colic signs matter. Weigh the animal accurately; drug calculation errors from guessed body weight are a preventable cause of overdose.

Laboratory tests are chosen by the findings and the grade. At minimum, packed cell volume and total protein are cheap and useful; older animals or those with systemic illness benefit from a fuller profile of kidney, liver and electrolytes. Correct dehydration, anaemia, hypovolaemia and electrolyte problems first when the procedure allows it.

Fasting by species

Fasting reduces the volume of stomach contents so that vomiting, regurgitation and aspiration are less likely, and lowers pressure on the diaphragm. But fasting too long causes hypoglycaemia in the very young and small, dehydration and stress. Exact durations vary between textbooks and institutions, so follow your hospital protocol and current guidelines.

- **Dogs and cats**: food is withheld for a limited period, with water allowed until close to premedication. Neonates, toy breeds and diabetics need shorter fasts and glucose awareness.
- **Rabbits, guinea pigs and rodents**: they cannot vomit, so prolonged fasting adds risk without benefit. Rabbits in particular should not be starved long, and food in the mouth should be cleared before induction.
- **Horses**: practices vary. Concentrates are withheld and hay is often reduced; water is usually left available. A full gut presses on the diaphragm and may cause poor ventilation in dorsal recumbency.

- **Cattle, sheep and goats**: the rumen ferments continuously, so complete emptying is not possible. A fasting period lowers rumen volume and bloat, yet regurgitation can still occur. Intubate with a cuffed tube and keep the head lower than the pharynx during recumbency.

Consent, equipment and the final check

Informed consent. The owner should be told in plain language why anaesthesia is needed, the animal's grade, the general risks (including death), the cost of monitoring and the options. Signing a form does not replace the conversation. Record the consent, identification of the animal and the planned procedure. In farm animals, explain the risk for food-producing animals and withdrawal periods for drugs used, and check the current regulations for your region.

Equipment checklist. Before the first drug is given, confirm each item:

1. Oxygen supply with enough reserve, breathing system and anaesthetic machine checked for leaks.
2. Endotracheal tubes in a range of sizes, cuffs tested, laryngoscope working, suction ready.
3. Monitors available: pulse oximeter, blood pressure, ECG, capnograph and thermometer.
4. Intravenous catheter and fluids.
5. Emergency drugs and reversal agents drawn up or labelled and a written emergency plan.
6. Warming equipment, since hypothermia is common and prolongs recovery.

Finally, label every syringe, confirm drugs against the patient record and give a clear start time. Good practice continues after the procedure: recovery needs a trained observer until the animal can protect its airway and hold its own temperature.

Concept cleared

Concept cleared: Planes of anaesthesia

Think of lowering a lift down a building. Each floor is a deeper plane, and the lower you go the quieter the building becomes but the harder it is to get back. The anaesthetist's job is to stop at the floor where surgery is possible and no lower.

Concept cleared: ASA grade

The grade is a weather forecast for the patient, not for the operation. It tells you how rough the journey is likely to be so that you pack the right equipment and warn the owner.

Concept cleared: Excitement stage

When anaesthesia starts, the brain's brakes are switched off before its engine. A struggling, paddling animal is not light, it is disinhibited, and a smooth premedication prevents this.

Concept cleared: Fasting differs by gut

A simple-stomached animal can be emptied, so a short fast helps. A rumen cannot be emptied, so protecting the airway matters more than the length of the fast.

Memory aid: Pre-anaesthetic safety questions

Use SAFE: Status (ASA grade), Animal (history and examination), Fasting and fluids, Equipment and emergency drugs ready. If any letter is missing, pause before inducing.

Compare and contrast

Stages of anaesthesia

Stage	Name	Main features	Clinical aim
I	Analgesia	Conscious, drowsy, reduced pain sense	Starting phase
II	Excitement	Unconscious but disinhibited, struggling, irregular breathing, vomiting possible	Pass through quickly and smoothly
III	Surgical anaesthesia	Regular breathing, relaxation, fading reflexes by plane	Maintain at lightest adequate plane
IV	Overdose	Respiratory then cardiac arrest	Emergency, reverse and support

ASA physical status grades

Grade	Description	Example	Practical meaning
I	Normal healthy	Elective spay	Standard monitoring
II	Mild systemic disease	Obesity, old age	Extra care
III	Severe disease, limits function	Anaemia, moderate heart disease	Stabilise, fuller monitoring
IV	Constant threat to life	Decompensated heart failure	High risk, discuss with owner
V	Moribund	Severe shock	Survival unlikely without procedure

Species notes

Dog

Brachycephalic breeds have narrow airways and are at risk of obstruction and regurgitation during recovery, so keep the tube in until the animal is fully awake. Sighthounds and some herding breeds need drug choice adjusted, covered in later chapters.

Cat

Small body size means rapid heat loss and easy overdose if weight is guessed. Handle gently, since stress raises risk, and take care with the airway because laryngospasm is common.

Horse

Recovery is the dangerous phase: a heavy animal can injure itself standing up. Check footing, padding and assistance, and plan the whole procedure with trained staff.

Cattle, sheep and goat

Regurgitation and bloat are the main risks. Use a cuffed tube, avoid prolonged recumbency and keep the head low. Ruminants can be very sensitive to sedatives.

Rabbit and small mammals

Do not starve them for long, as they cannot vomit. Lose heat fast, and are easily stressed, so keep a quiet warm environment.

Clinical pearls

Self-test: 10 questions

1. Which stage of anaesthesia is characterised by struggling and irregular breathing despite loss of consciousness?

Stage II is excitement or delirium, caused by loss of inhibitory brain control before motor activity is depressed.

2. An animal with decompensated heart failure scheduled for anaesthesia is best graded as:

Severe disease that is a constant threat to life is ASA IV.

3. The letter E added to an ASA grade means:

E denotes emergency procedure, which adds risk.

4. Which statement about fasting is correct?

Rabbits and rodents do not vomit, so long fasting adds risk without benefit; neonates need short fasts.

5. Which is the main airway risk in ruminants under general anaesthesia?

Rumen contents can reach the pharynx; use a cuffed tube and keep the head low.

6. Why is guessing body weight dangerous?

Drug amounts are based on weight, so errors can lead to overdose or underdose.

7. Which sign is unreliable as the only measure of depth during ketamine anaesthesia?

Ketamine often preserves eyelid and eye reflexes, so reflex loss alone is misleading.

8. A young puppy with a congenital shunt is:

Age alone does not define grade; disease status does.

9. Which belongs on the pre-anaesthetic equipment checklist?

Airway equipment, oxygen, monitors, fluids and emergency drugs should be ready before induction.

10. Informed consent for anaesthesia should include:

Owners need to understand benefits, risks and options before agreeing.

Key points to revise

1. Anaesthesia needs assessment, preparation, monitoring and recovery planning.
2. Guedel stages: analgesia, excitement, surgical anaesthesia, overdose.
3. Stage II is avoided by good premedication and smooth induction.
4. ASA grades I to V describe physical status; E means emergency.
5. History should include current drugs, previous reactions and exercise tolerance.
6. Fasting differs by species; follow current protocol and avoid long fasts in small mammals.
7. Informed consent includes the risk of death.
8. Test equipment and have emergency drugs ready before induction.

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- Ch 3. Injectable anaesthetic agents (in this book)
- Veterinary drugs list: classes, uses and cautions
- Veterinary Drug Index
- Veterinary Drug Concepts Clearly Explained

Sources

- Wikipedia: Veterinary anesthesia
- Wikipedia: ASA physical status classification system
- Wikipedia: Guedel's classification

CHAPTER 2 OF 14

Premedication, sedation and tranquillisation

Premedication calms the patient, reduces the dose of induction and maintenance drugs and gives early analgesia. This chapter explains phenothiazines, benzodiazepines, alpha-2 agonists and their reversal, opioid combinations, and why cattle and horses respond so differently to the same drug.

After this chapter you can

- State the aims of premedication and distinguish sedation from tranquillisation

- Explain the actions, advantages and cautions of phenothiazines and benzodiazepines
- Describe the effects of alpha-2 agonists and the logic and risks of reversal
- Explain how opioids are combined with sedatives and what to watch for
- Explain why cattle and horses need special care with sedatives

Aims of premedication

Premedication is the drug given before induction. It is not a luxury. A calm animal needs less induction drug, has a smoother induction and recovery, and is safer to handle. Premedication can also provide analgesia, reduce salivation or vagal reflexes, and prevent the pain that would otherwise make anaesthesia harder to manage.

Two terms are often confused. **Tranquillisation** means the animal is calm and unconcerned but still aware and reactive to its surroundings. **Sedation** means drowsiness and reduced response, with the animal often lying down. Neither guarantees analgesia, so a sedated animal may still react sharply to a painful procedure unless an analgesic is added.

The choice of drugs depends on the patient's grade, temperament, procedure and species. Healthy calm animals need light premedication; sick or shocked animals need little, and the doses are reduced. Always give premedication in a quiet place, allow time to work, and monitor heart rate, breathing and temperature afterwards.

Phenothiazines

Acepromazine is the main phenothiazine tranquilliser. It blocks dopamine receptors in the brain, giving calmness, and blocks alpha-1 receptors in blood vessels, causing vasodilation and a fall in blood pressure. It also lowers body temperature.

Its advantages are low cost, smooth calm and an anti-emetic effect. Its disadvantages matter more. It gives **no analgesia**, it has **no specific reversal agent**, and its action is long, often several hours, so a mistake cannot be undone quickly. Hypotension is the main hazard, so avoid it in dehydrated, hypovolaemic, shocked or bleeding animals.

Other cautions: reduce its use in old or debilitated patients; breeds such as boxers and some giant breeds are reputed to be more sensitive; dogs with the MDR1 (ABCB1) mutation, such as collies, may show prolonged and deeper effect, so lower amounts are advised; and its use in animals with a seizure history is debated. In stallions and geldings it can cause penile relaxation and prolapse, so owners must be warned. A common confusion is to expect the drug to "calm pain". It does not.

Benzodiazepines

Diazepam and midazolam act on the $GABA_A$ receptor, making the chloride channel open more often when GABA is present. The result is anxiety relief, muscle relaxation and anticonvulsant effect, with **very little cardiovascular and respiratory depression**. This makes them useful in sick, old or cardiac patients, and as a partner to ketamine or opioids.

Their weakness is that they are poor sedatives alone in healthy animals. A fit dog or cat may become excited, disinhibited or even aggressive, called paradoxical excitement. They are better when combined with an opioid or used in already depressed patients. They provide no analgesia.

Diazepam is dissolved in propylene glycol, which can irritate veins, and it adsorbs to plastic, so it should not be diluted or stored carelessly. Midazolam is water soluble and can be given by more routes. Oral diazepam has been linked to serious liver failure in cats, so check current advice. Benzodiazepine effect can be reversed with flumazenil, a competitive antagonist, though in practice reversal is seldom needed.

Alpha-2 agonists and reversal

Xylazine, medetomidine, dexmedetomidine and detomidine act on alpha-2 adrenergic receptors, reducing noradrenaline release in the brain and spinal cord. They give reliable sedation, muscle relaxation and some analgesia, and they sharply reduce the amount of other anaesthetic drugs required.

The costs are cardiovascular. Blood vessels constrict, causing a brief rise in pressure, then **bradycardia** follows through baroreceptor reflex and the central effect, and cardiac output falls substantially. Mucous membranes may look pale or bluish, which is expected but should not be confused with hypoxia, so confirm with

a pulse oximeter or by other signs. Other effects include hyperglycaemia, increased urine output, vomiting in dogs and especially cats, muscle tremor, bloat risk in ruminants, and uterine stimulation, notably with xylazine in late pregnancy of ruminants.

These drugs are best used in healthy, young to middle-aged patients. Avoid them in animals with heart disease, shock, severe liver or kidney disease, or in patients with a marked bradycardia.

Reversal uses an alpha-2 antagonist such as atipamezole (or yohimbine and tolazoline in some settings). Reversal is a key advantage, but it carries a warning: it also removes the analgesia given by the alpha-2 agonist, so a patient reversed soon after painful surgery may wake in pain. It can also cause sudden vasodilation, hypotension, agitation and tachycardia if given too quickly. Never use anticholinergics routinely to counter bradycardia from alpha-2 agonists, since this can cause hypertension and arrhythmia, unless a clinician has decided it is justified.

Opioid combinations

Combining an opioid with a tranquilliser or sedative is called **neuroleptanalgesia**. The sedative calms; the opioid adds analgesia and stable cardiovascular effect, and the two together allow lower doses of each. Common combinations pair acepromazine or an alpha-2 agonist with butorphanol, buprenorphine, methadone or morphine. Pure mu agonists give more analgesia than butorphanol, which is mainly useful for mild pain and sedation. Opioid side effects include bradycardia, respiratory depression, panting, nausea and vomiting (morphine), and urinary retention. Opioids are reversible with naloxone, but reversal also removes analgesia.

Before giving any opioid combination, check liver function, breathing and the procedure, and have naloxone and oxygen ready. Sedative and opioid effects add together, so reduce each amount in old, sick or very quiet animals.

Horses, cattle and other species

Horses. Horses given an opioid alone may become excited, restless and walk in circles, so opioids are normally given after a sedative such as an alpha-2 agonist. Sedated horses can look calm yet kick suddenly, so approach carefully and stay at the shoulder, not behind. Their head drops and the upper airway may narrow, so

avoid sedation in animals with airway disease. Detomidine is widely used in horses, but doses differ from small animals.

Cattle. Cattle are far more sensitive to xylazine than horses, so much lower amounts are used, and equine amounts can be dangerous. Sedation causes salivation, bloat, regurgitation, recumbency and a fall in oxygen; lie the animal on the sternum and keep the head lower than the pharynx. Sheep and goats are also sensitive. Pregnant cows risk premature calving. Pigs are comparatively resistant to alpha-2 agonists. Always use label and current references for the species, and never extrapolate from dogs or horses.

For all species, begin with the lowest effective plan, wait for full onset before judging effect, and keep the animal under observation until it is fully recovered.

Concept cleared

Concept cleared: Tranquillisation versus sedation
A tranquillised animal is like a person who has stopped worrying but is still listening. A sedated animal is drowsy and may lie down. Neither feels less pain unless an analgesic is given.

Concept cleared: Alpha-2 bradycardia
Alpha-2 drugs squeeze the vessels, pressure rises, and the brain slows the heart in response. When the pressure falls later the heart stays slow and output drops. It is a drug effect, not a fault of dose alone.

Concept cleared: Reversal removes analgesia
If you reverse an alpha-2 agonist with atipamezole, you take away both the sleep and the pain relief. Think of switching off the whole lamp, not only the colour.

Concept cleared: Neuroleptanalgesia
A tranquilliser is the driver who calms the horse, the opioid is the one who removes pain. Together they work better with lower amounts of each.

Memory aid: Premedication drug cautions

Remember ABCD: Acepromazine = hypotension, no reversal; Benzodiazepine = may excite healthy animals; Cattle = very sensitive to xylazine; Dexmedetomidine and kin = bradycardia and reversal removes analgesia.

Compare and contrast

Main premedication drug groups

Group	Examples	Main benefit	Main caution
Phenothiazine	Acepromazine	Calm, anti-emetic	Hypotension, no analgesia, no reversal, long action
Benzodiazepine	Diazepam, midazolam	Minimal cardiorespiratory effect, muscle relaxation	Excitement in healthy animals, no analgesia
Alpha-2 agonist	Xylazine, medetomidine, dexmedetomidine, detomidine	Deep sedation, some analgesia, reversible	Bradycardia, low output, vomiting, species sensitivity
Opioid	Butorphanol, buprenorphine, methadone, morphine	Analgesia, cardiovascular stability	Respiratory depression, vomiting, horse excitement if alone

Reversal agents

Drug reversed	Antagonist	Effect of reversal	Caution
Alpha-2 agonist	Atipamezole	Wakes patient, removes analgesia	Pain, agitation, hypotension if rapid
Opioid	Naloxone	Reverses respiratory depression and analgesia	Short action, renarcotisation possible
Benzodiazepine	Flumazenil	Reverses sedation	Rarely needed, may unmask seizures
Acepromazine	None	Wait and support	Treat hypotension with fluids

Species notes

Dog

Use lower amounts of acepromazine in boxers, giant breeds and MDR1 mutation breeds. Alpha-2 agonists cause vomiting and bradycardia, so use only in healthy patients.

Cat

Alpha-2 agonists often cause vomiting. Opioids can cause excitement or mydriasis in some cats, so combine with a sedative. Be careful with oral diazepam.

Horse

Alpha-2 agonists and opioids are used together, but horses can still kick. Acepromazine can cause penile prolapse in males. Plan a quiet, safe place.

Cattle, sheep and goat

Very sensitive to xylazine. Expect salivation, bloat and regurgitation. Avoid in late pregnancy and use species-specific references.

Pig

Relatively resistant to alpha-2 agonists. Azaperone and combinations are used, but venous access and airway management are difficult, so plan ahead.

Clinical pearls

Self-test: 10 questions

1. Which drug has no specific reversal agent?

Acepromazine has no antagonist, so effects are managed by supportive care.

2. Benzodiazepines act on which receptor?

They enhance GABA action at the GABA-A chloride channel.

3. A healthy dog given a benzodiazepine alone may show:

Fit animals can become disinhibited without another sedative.

4. The main cardiovascular effect of alpha-2 agonists is:

Vasoconstriction triggers reflex bradycardia, and cardiac output falls.

5. Reversing xylazine with atipamezole also:

The analgesia is mediated by the same receptors, so it is lost.

6. Which statement about acepromazine is correct?

Alpha-1 blockade causes hypotension, so avoid in shock.

7. Why are horses usually given an opioid after a sedative?

Opioids alone can cause excitement and restlessness in horses.

8. Compared with horses, cattle are:

Ruminants respond to far lower amounts, so equine amounts can be dangerous.

9. A common risk of acepromazine in male horses is:

Penile relaxation and prolapse may occur, so owners should be warned.

10. Neuroleptanalgesia means:

The combination calms the animal and gives analgesia, allowing lower amounts of each drug.

Key points to revise

1. Premedication calms, reduces other drug needs and provides early analgesia.
2. Tranquillisation is calm with awareness; sedation is drowsiness.
3. Acepromazine blocks dopamine and alpha-1 receptors, causing hypotension.
4. Benzodiazepines act on GABA-A with little cardiovascular depression.
5. Alpha-2 agonists give sedation and analgesia but reduce heart rate and output.
6. Atipamezole reverses alpha-2 agonists, and naloxone reverses opioids.
7. Opioids plus sedatives give neuroleptanalgesia.
8. Cattle, sheep and goats are far more sensitive to alpha-2 agonists than horses.

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- Veterinary Drug Index
- Veterinary Drug Concepts Clearly Explained

Sources

- Wikipedia: Veterinary anesthesia
- Wikipedia: Alpha-2 adrenergic receptor
- Cornell University College of Veterinary Medicine: Drug sensitivity (MDR1)

CHAPTER 3 OF 14

Injectable anaesthetic agents

Injectable agents induce anaesthesia quickly and can also maintain it as total intravenous anaesthesia. This chapter covers propofol, alfaxalone, ketamine, thiopentone and etomidate, how to give them safely to effect, and the special cautions for sighthounds, cats and ruminants.

After this chapter you can

- Explain how rapid induction occurs and why recovery depends on redistribution and metabolism
- Compare propofol, alfaxalone, ketamine, thiopentone and etomidate by mechanism, advantages and risks
- Describe the principles of induction to effect and of total intravenous anaesthesia
- Explain breed and species cautions in sighthounds, cats and ruminants
- Recognise and respond to common complications of injectable induction

How injectable induction works

After intravenous injection, a lipid-soluble anaesthetic travels with blood to the brain, which receives a large share of cardiac output. Anaesthesia therefore starts within one arm-brain circulation time. Recovery after a single dose is not mainly due to metabolism. It happens because the drug **redistributes** from the brain to muscle and then fat, so brain concentration falls. The drug is later removed by liver metabolism or other routes.

This explains why a repeated dose or a lean, poorly perfused animal behaves differently. When muscle and fat stores fill, or when body fat is low, the drug stays in the blood and brain longer, so recovery is slow.

Safe induction rests on three habits. Give the dose **slowly and to effect**, not as a rapid push, because circulation time is longer in sick or shocked animals. Have the airway equipment, oxygen and a means of ventilation ready, because most induction agents cause apnoea. And pre-oxygenate where possible. Premedication reduces the needed amount, and the calculated dose is only a guide, so always watch the patient. No dose figures are given here; consult current references.

Propofol and alfaxalone

Propofol is a short-acting phenol that enhances $GABA_A$ receptor activity. Induction is rapid and smooth, and recovery is quick because of redistribution and fast

hepatic and extra-hepatic metabolism. This makes it a popular choice for induction and total intravenous anaesthesia.

Its cautions are important. It causes **dose-dependent apnoea**, especially with a fast injection, and vasodilation leading to hypotension. It gives no real analgesia. The lipid emulsion supports bacterial growth, so syringes and opened vials must be handled aseptically and discarded within the time stated by the manufacturer. Pain on injection may occur. In cats, repeated daily use can cause oxidative injury, with Heinz body formation, slower recovery and sometimes appetite loss, so avoid prolonged or repeated infusions in cats unless judged necessary.

Alfaxalone is a neuroactive steroid that also acts on $GABA_A$ receptors. It is now formulated in a cyclodextrin vehicle, which allows a smooth induction with a wide safety margin and little irritation. It can also cause apnoea and some cardiovascular depression, though usually less than propofol at comparable depth. In cats and dogs, recovery without adequate premedication can be rough, with paddling or excitement, so premedicate and recover the animal in a quiet place.

Ketamine

Ketamine is a **dissociative** agent. It blocks the NMDA receptor, which disconnects the cortex from the lower brain, so the animal looks awake with open eyes but is unaware. It gives good somatic analgesia and, unlike most induction agents, tends to **support heart rate and blood pressure** by sympathetic stimulation. Respiration is usually preserved, though the breathing pattern may become irregular.

The same sympathetic drive can be harmful in a heart that is already compromised or an animal that is depleted of catecholamines, since the direct effect of ketamine on the heart is depressant. Other cautions: muscle rigidity and rough recovery if used alone, so it is almost always combined with a benzodiazepine or an alpha-2 agonist; increased salivation; and caution in animals with raised intracranial or intra-ocular pressure, uncontrolled seizures or severe hypertension. In cats, much of the drug leaves unchanged in the urine, so urethral obstruction is a concern. Reflexes such as the palpebral and corneal reflexes stay present, so do not rely on them to judge depth.

Ketamine is widely used in food animals and horses, where combinations with sedatives are standard. Check the current rules on its use and withdrawal in food-

producing species.

Thiopentone and etomidate

Thiopentone is an ultra-short-acting thiobarbiturate acting at the $GABA_A$ receptor. It induces smoothly, but recovery depends on redistribution; in sighthounds and thin animals this is slower and metabolism is also slower, so recovery can be prolonged. Thiopentone depresses breathing and the heart, and it can sensitise the myocardium to catecholamines, producing ventricular arrhythmias. The solution is strongly alkaline, so **perivascular injection causes tissue necrosis**; use a secure catheter. Thiopentone has little analgesia and may cause apnoea. Its availability varies between markets, so check what is available to you.

Etomidate is an imidazole that acts on $GABA_A$. Its main advantage is **cardiovascular stability**, so it is considered in animals with heart disease or shock where little blood pressure fall is tolerated. Its drawbacks: myoclonus and retching on induction, unless premedicated; pain on injection and haemolysis with some solvents; and suppression of adrenal steroid synthesis, even after a single dose. It is therefore avoided for repeated use or infusions and in animals with adrenal disease or critical illness where cortisol response matters. It gives no analgesia.

Induction and TIVA in practice

For induction, premedicate, pre-oxygenate, place an intravenous catheter, give the agent slowly until the jaw relaxes and the animal can be intubated, then connect oxygen. Stop giving the drug once the depth is adequate; the calculated volume may not be needed. In sick animals, a small amount of a benzodiazepine or opioid beforehand lowers the induction requirement and helps stability, sometimes called co-induction.

Total intravenous anaesthesia (TIVA) means maintaining anaesthesia with a continuous infusion or repeated boluses of injectable agents instead of an inhalant. It is useful when inhalant equipment is not available, for short procedures, for field work, and for patients where inhalant side effects should be avoided. The drug must be given by a controlled method, an animal must be intubated and oxygen supplied, and monitoring should be at least equal to inhalant anaesthesia. Agents with short, predictable recovery, such as propofol and alfaxalone, suit TIVA better

than thiopentone or etomidate. Recovery is longer after long infusions in cats, and analgesia must be provided separately.

In large animals, combinations such as guaifenesin, ketamine and an alpha-2 agonist are used to maintain anaesthesia for short procedures, usually after sedation and induction; follow current references.

Sighthounds, cats, ruminants and complications

Sighthounds such as greyhounds and related breeds have little body fat and slower hepatic metabolism of some drugs. Thiobarbiturate recovery can be very prolonged, so propofol or alfaxalone are generally preferred. Give by slow titration, keep warm and observe for longer after recovery.

Cats are sensitive to drug accumulation because of slow glucuronidation. Propofol repeat use, ketamine kidney excretion, and apnoea and laryngospasm at intubation are the main points. Use a small amount of local anaesthetic spray on the larynx and avoid forcing the tube.

Ruminants are at risk of regurgitation, bloat and aspiration. Ketamine combinations are common in cattle, sheep and goats. Intubate quickly with a cuffed tube, position the head low, and avoid long recumbency. Ruminants may also be sensitive to the sedative given alongside, so reduce accordingly.

Complications and responses:

1. Apnoea: provide oxygen and ventilate, and wait for return of breathing.
2. Hypotension: reduce depth, give fluids, and consider supportive drugs.
3. Perivascular injection: stop, aspirate and follow current tissue-protection advice.
4. Excitement or myoclonus: usually temporary; deepen anaesthesia with a safe agent or improve premedication.
5. Prolonged recovery: keep warm, support airway, and observe until the animal can stand and protect itself.

Concept cleared

Concept cleared: Redistribution

Like pouring water from a bucket into a pond, the drug leaves the brain not because it is destroyed but because it spreads into muscle and fat. In a lean animal there is less pond, so waking is slower.

Concept cleared: Dissociative anaesthesia

With ketamine the lights are on, but nobody is home. Eyes are open and reflexes remain, yet the animal is unaware, which is why normal depth signs can mislead.

Concept cleared: Induction to effect

Give a little, wait for circulation time, assess, and give more only if needed. A fixed calculated dose is a guide, not an order.

Concept cleared: TIVA

TIVA is like running a tap at a steady, adjustable flow instead of vapour from a machine. The airway and oxygen are still your responsibility.

Memory aid: Induction agent memory hook

PAKTE: Propofol and Alfaxalone are smooth, Ketamine is dissociative, Thiopentone needs a clean vein, Etomidate protects the heart but suppresses the adrenal.

Compare and contrast

Injectable induction agents

Agent	Mechanism	Main advantage	Main caution
Propofol	GABA-A enhancement	Rapid smooth induction and recovery, suits TIVA	Apnoea, hypotension, no analgesia, contamination, cats on repeated use
Alfaxalone	Neurosteroid at GABA-A	Smooth induction, wide margin	Apnoea, rough recovery if unpremedicated
Ketamine	NMDA antagonist	Analgesia, supports heart rate and pressure	Rigidity, poor in cardiac or raised pressure cases, cat renal excretion
Thiopentone	Barbiturate at GABA-A	Rapid induction	Necrosis if perivascular, arrhythmia, slow recovery in sighthounds
Etomidate	GABA-A modulation	Cardiovascular stability	Myoclonus, adrenal suppression

Species and breed cautions

Group	Main concern	Preferred approach
Sighthounds	Prolonged recovery from thiobarbiturates	Propofol or alfaxalone, warmth, careful monitoring
Cats	Slow drug clearance, laryngospasm, kidney excretion of ketamine	Avoid repeat propofol, protect airway
Ruminants	Regurgitation, bloat, sedative sensitivity	Cuffed tube, head low, reduce sedative
Cardiac or shocked patients	Hypotension	Consider etomidate or co-induction, give slowly

Species notes

Dog

Titrate induction slowly. Brachycephalic breeds need airway readiness. Sighthounds recover slowly from thiobarbiturates.

Cat

Avoid repeated propofol over days. Ketamine is eliminated unchanged in urine, so be cautious in urinary obstruction. Laryngospasm is common.

Horse
Induction usually follows sedation, with ketamine and a benzodiazepine commonly used. Control the fall and plan a safe recovery.

Cattle, sheep and goat
Ketamine combinations are standard. Watch for regurgitation, bloat and aspiration, and use a cuffed tube.

Rabbit and small mammals
Injectable combinations are used, but venous access is hard and hypothermia is quick, so monitor and keep warm.

Clinical pearls

Self-test: 10 questions

1. Recovery after a single induction bolus is mainly due to:

The drug leaves the brain for muscle and fat, so brain concentration falls.

2. Which agent is a dissociative NMDA antagonist?

Ketamine blocks NMDA receptors and causes dissociation.

3. A major concern with perivascular thiopentone is:

The solution is strongly alkaline and irritant.

4. Which agent is most noted for cardiovascular stability but adrenal suppression?

Etomidate causes little cardiovascular change but inhibits adrenal steroid synthesis.

5. Which is generally preferred over thiopentone in sighthounds?

Sighthounds recover slowly from thiobarbiturates, so propofol or alfaxalone are favoured.

6. Why must propofol syringes be handled aseptically?

Contamination can cause infection, so discard within the manufacturer's time.

7. A cat concern with repeated daily propofol is:

Cats have limited ability to conjugate phenols, so oxidative injury may occur.

8. Which step is essential for TIVA?

Injectable maintenance carries the same airway and cardiovascular risks as other anaesthesia.

9. Ketamine in cats needs caution in:

Much of the drug is excreted unchanged in urine, so obstruction prolongs the effect.

10. A main complication of induction in ruminants is:

Rumen contents can reach the pharynx, so a cuffed tube and low head position are needed.

Key points to revise

1. Give injectable agents slowly and to effect.
2. Redistribution ends the effect of a single dose.

3. Propofol is smooth but causes apnoea and hypotension and needs aseptic handling.
4. Alfaxalone is a neurosteroid with a wide margin but needs premedication for smooth recovery.
5. Ketamine is a dissociative NMDA antagonist that supports heart rate but is not used alone.
6. Thiopentone causes tissue damage if given outside the vein.
7. Etomidate is cardiovascularly stable but suppresses the adrenal gland.
8. TIVA requires intubation, oxygen and full monitoring.

Go deeper on this site

- Ch 4. Inhalation anaesthesia (in this book)
- Ch 2. Premedication, sedation and tranquillisation (in this book)
- Veterinary drugs list: classes, uses and cautions
- Veterinary Drug Index
- Veterinary Drug Concepts Clearly Explained

Sources

- Wikipedia: Propofol
- Wikipedia: Alfaxalone
- Wikipedia: Veterinary anesthesia

CHAPTER 4 OF 14

Inhalation anaesthesia

How volatile agents are delivered, why potency is measured as MAC, how isoflurane, sevoflurane and nitrous oxide differ, and how breathing circuits, scavenging and ventilation keep patient and staff safe.

After this chapter you can

- Explain why precision vaporisers are agent-specific and how they work
- Define MAC and list factors that raise or lower it

- Compare isoflurane, sevoflurane and nitrous oxide in terms of solubility, side effects and use
- Describe the purpose of waste gas scavenging and the main sources of pollution
- Explain why ventilation support and monitoring are needed during inhalation anaesthesia

Why inhalation anaesthesia is the preferred maintenance method

In inhalation anaesthesia a volatile liquid is turned into vapour, mixed with oxygen and breathed in. The lung is both the entry and the exit route. The anaesthetist can therefore make the patient deeper or lighter within minutes by changing the dial, and most of the drug leaves through the lungs rather than depending on the liver or kidney.

This control is the main safety advantage over injectable-only anaesthesia, especially in sick, young, old or very small patients. The price is that the patient needs a secured airway, an oxygen supply, a machine that works properly, and a person who watches the patient continuously.

Vaporisers

A **precision vaporiser** delivers a known, safe percentage of vapour into the fresh gas flow. Part of the gas passes through the vaporising chamber and part bypasses it, and the dial sets the splitting ratio. Modern vaporisers are temperature compensated, because evaporation cools the liquid and would otherwise reduce output.

Key points for students:

- Most vaporisers are **agent-specific** and **out of circuit**. A vaporiser built for one agent has different vapour pressure characteristics, so using another agent in it can give a dangerously wrong concentration.
- Keyed filling systems exist to prevent filling with the wrong liquid. Always check the label on the vaporiser before filling.
- Keep the vaporiser upright, avoid tilting it, and have it serviced and calibrated as the maker advises.

- Never use a precision vaporiser for an agent it was not designed for. Simple draw-over or in-circuit vaporisers are different devices and give less predictable output.

Remember that the dial setting is the concentration delivered to the circuit, not the concentration in the patient's brain. The two differ for several minutes at the start of anaesthesia.

MAC and agent solubility

MAC (minimum alveolar concentration) is the alveolar concentration of an agent at which half of patients do not move in response to a standard painful stimulus. It is the standard measure of potency: a low MAC means a potent agent. MAC values are broadly additive, and an animal at about 1.3 times MAC is usually considered adequately anaesthetised for surgery, although this is a guide only.

MAC is *lowered*, so the vaporiser can be turned down, by opioids, alpha-2 agonists, benzodiazepines, other sedatives, older age, hypothermia, hypotension, pregnancy and severe illness. It is *raised* by hyperthermia, and values differ between species. This is why a premedicated animal needs less volatile agent, and why an overdose is easy in a cold, hypotensive neonate.

MAC tells you about potency, not about speed. Speed depends on the **blood:gas partition coefficient**, which describes how soluble an agent is in blood. A poorly soluble agent leaves the blood and reaches the brain quickly, so induction, changes of depth and recovery are fast. A very soluble agent is taken up into blood and tissues for longer, so everything is slower. Do not confuse potency (MAC) with speed (solubility).

Isoflurane, sevoflurane, nitrous oxide and others

Isoflurane is widely used in many species. It causes dose-dependent respiratory depression and vasodilation with fall in blood pressure, and little sensitisation of the heart to catecholamines. Its smell is pungent, so mask induction is less pleasant.

Sevoflurane is less soluble, so induction and recovery are faster. It is less irritant to the airway, and is popular for mask or chamber induction in small animals and exotics. It also depresses breathing and blood pressure. It is more expensive, which matters in practice. Sevoflurane can break down with some carbon dioxide

absorbents, forming compound A; its clinical importance in animals is debated, and the manufacturer's guidance on fresh gas flow should be followed. Dry, exhausted or desiccated absorbent can also generate heat and carbon monoxide with modern agents, so absorbent should be changed on schedule and not left with gas flowing through it overnight.

Halothane is an older agent. It sensitises the myocardium to catecholamines, so arrhythmias are more likely, and it is associated with liver injury in some patients. Availability differs by country, so check what is currently marketed. **Desflurane** is very insoluble but needs a special heated vaporiser and is rarely used in veterinary practice.

Nitrous oxide is a weak anaesthetic with a very high MAC, so it cannot anaesthetise on its own and is used only as an adjunct. Its good points are a mild analgesic effect and the *second gas effect*, which speeds uptake of the volatile agent. Its dangers are important: it diffuses into gas-filled spaces faster than nitrogen leaves them, so it is avoided with pneumothorax, gastric dilatation-volvulus, intestinal obstruction, tympany in ruminants and air embolism. At the end of anaesthesia it rushes out of the blood into the alveoli and dilutes oxygen (**diffusion hypoxia**), so the patient should breathe 100 percent oxygen for a few minutes afterwards. Because of these limits, and because it is a greenhouse gas, many clinics no longer use it.

Breathing circuits and scavenging

The volatile agent reaches the patient through a **breathing circuit**. In a **rebreathing (circle) system** exhaled gas passes through a carbon dioxide absorber and is breathed again, so low fresh gas flows save oxygen and agent. In a **non-rebreathing system** a higher fresh gas flow flushes exhaled gas away. The next chapter covers these in detail. Whichever is used, the circuit size must match the patient so that resistance and dead space are acceptable.

Scavenging removes waste anaesthetic gas from the breathing system. Exhaled gas and gas released through the pop-off valve are led away by tubing, either to an *active* system with a fan or to a *passive* system with a charcoal canister. Charcoal canisters do not absorb nitrous oxide and must be weighed and replaced as advised. Passive systems must never be blocked.

Staff are exposed through leaks, poorly fitting masks, chamber induction, spills during filling, and disconnecting the patient while the vaporiser is still on. Good practice is to use a cuffed tube, check the system for leaks, fill vaporisers carefully, turn off the vaporiser before disconnecting and flush the circuit with oxygen at the end. Pregnant staff should discuss risks with their supervisor and check the current local occupational exposure guidance.

Ventilation, monitoring and complications

Nearly all volatile agents depress the respiratory centre. Under anaesthesia, especially in recumbent large animals or obese and brachycephalic patients, breathing becomes shallow and carbon dioxide rises. **Hypoventilation** is therefore the commonest problem. A rise in end-tidal CO_2 shown by capnography is the early warning. The remedy is manual or mechanical **intermittent positive pressure ventilation** (IPPV), used with care because high airway pressures can damage the lung and reduce venous return. Horses are usually ventilated during volatile anaesthesia.

The other main problem is **hypotension**, caused by vasodilation and falling cardiac output. First reduce the vaporiser setting if the plane is too deep; then consider fluids and other supportive measures chosen by the clinician. Monitoring should include heart rate and rhythm, respiration, mucous membrane colour, capnography, pulse oximetry, blood pressure and body temperature. Hypothermia is common and slows recovery.

Remember that a patient that looks "light" may simply be hypoxic or hypercapnic. Check oxygen flow, airway and circuit before deepening anaesthesia. Malignant hyperthermia, a rare inherited trigger condition linked to volatile agents, is described mainly in pigs and also reported in some other species, and needs urgent recognition by rising CO_2, temperature and rigidity.

Concept cleared

Concept cleared: MAC

Think of MAC as the 'price' of anaesthesia in vapour. A potent agent has a low price in concentration terms. Sedatives and opioids are like a discount, so you need less vapour. Cold and low blood pressure also lower the price, which is why a cold, sick animal can be overdosed on a setting that suits a healthy one.

Concept cleared: Solubility and speed

A sponge that soaks up a lot of water takes longer to fill and longer to dry. A very soluble agent is like that sponge, with slow induction and slow recovery. A poorly soluble agent like sevoflurane is like a waxed surface, which fills and empties quickly.

Concept cleared: Diffusion hypoxia

At the end of nitrous oxide use, a large volume of gas pours from blood into the lung. This dilutes the oxygen in the alveoli, like pouring a jug of water into a glass of squash. Breathing 100 percent oxygen for a few minutes replaces the diluted mix.

Concept cleared: Vaporiser setting versus patient

The dial is the concentration in the pipe, not in the brain. Brain concentration rises slowly, like a bath filling from a tap, so a patient that is still light a few minutes after starting is normal and not a reason to open the dial fully.

Memory aid: Low solubility, low delay

Remember: Low blood solubility means Quick control. Low MAC means a Potent agent. Potency and speed are two separate questions.

Compare and contrast

Common volatile agents

Agent	Solubility	Induction and recovery	Main cautions
Isoflurane	Moderate	Moderate	Hypotension, respiratory depression, pungent smell
Sevoflurane	Low	Fast	Respiratory and blood pressure depression; compound A and cost
Halothane	Higher	Slower	Arrhythmias with catecholamines; liver injury; availability
Nitrous oxide	Very low	Very fast uptake	Weak; fills gas spaces; diffusion hypoxia

Potency versus speed

Property	Measured by	Meaning	Affected by
Potency	MAC	How much vapour is needed	Drugs, age, temperature, pregnancy, species
Speed	Blood:gas partition coefficient	How fast depth changes	Solubility, ventilation, cardiac output

Species notes

Dog

Brachycephalic breeds have airway obstruction and are prone to hypoventilation, so secure the airway early, preoxygenate and monitor recovery closely.

Cat

Small body size means rapid heat loss and a greater risk of circuit dead space and resistance, so use a suitable circuit and warm the patient.

Horse

Recumbent horses develop ventilation-perfusion mismatch and hypotension under volatile agents, so ventilation and blood pressure support are usually needed.

Pig

Pigs are the species most associated with malignant hyperthermia; watch for rising CO2, temperature and muscle rigidity.

Ruminants

Nitrous oxide is avoided because of rumen gas, and regurgitation risk means the cuffed tube is essential.

Clinical pearls

Self-test: 10 questions

1. MAC is best defined as the alveolar concentration that

MAC is the alveolar concentration at which half of patients do not move in response to a standard surgical stimulus.

2. Which of the following lowers MAC?

Opioids and other sedatives are additive with volatile agents, so less agent is needed.

3. A low blood:gas partition coefficient means

A poorly soluble agent equilibrates quickly between blood and brain, so depth changes fast.

4. A precision vaporiser for isoflurane should

Vaporisers are calibrated for one agent. Another agent gives an unpredictable concentration.

5. Nitrous oxide should be avoided in

It diffuses into gas-filled spaces and increases their volume.

6. Diffusion hypoxia is prevented by

Oxygen replaces the nitrous oxide that rushes into the alveoli.

7. The commonest respiratory problem under volatile anaesthesia is

Volatile agents depress the respiratory centre, so carbon dioxide rises unless the patient is ventilated.

8. Which agent is associated with myocardial sensitisation to catecholamines?

Halothane makes arrhythmias more likely, especially with adrenaline.

9. The best step if a patient seems light but oxygen supply has not been checked is to

Hypoxia and hypercapnia can mimic light anaesthesia, so deepening without checking may cause harm.

10. A passive charcoal scavenging canister

Canisters become saturated, do not absorb nitrous oxide, and must never be obstructed.

Key points to revise

1. Inhalation anaesthesia gives fine control of depth because the lungs deliver and remove the drug.
2. Precision vaporisers are agent-specific, out of circuit and temperature compensated.
3. MAC is the alveolar concentration that prevents movement in half of patients.
4. Opioids, alpha-2 agonists, sedatives, old age, cold and hypotension lower MAC.

5. Low solubility gives rapid induction and recovery.
6. Sevoflurane is faster and less irritant than isoflurane, and both cause dose-dependent depression of breathing and blood pressure.
7. Nitrous oxide is a weak adjunct that expands gas-filled spaces and causes diffusion hypoxia on withdrawal.
8. Scavenging, leak checks and careful filling protect staff from waste gas.

Go deeper on this site

- Ch 5. Anaesthetic equipment and breathing circuits (in this book)
- Ch 3. Injectable anaesthetic agents (in this book)
- Veterinary drugs list: classes, uses and cautions
- Veterinary Drug Index
- Veterinary Drug Concepts Clearly Explained

Sources

- WSAVA Global Pain Council Guidelines
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- PubMed search: veterinary anesthesia breathing circuits

CHAPTER 5 OF 14

Anaesthetic equipment and breathing circuits

The parts of an anaesthetic machine, how rebreathing and non-rebreathing circuits differ, how to test for leaks before every case, and how to place and check an endotracheal tube in different species.

After this chapter you can

- Name the main parts of an anaesthetic machine and their functions
- Distinguish rebreathing from non-rebreathing circuits and choose between them
- Perform and interpret a pre-use leak test
- Describe the role and limits of the carbon dioxide absorbent

- Explain endotracheal intubation and tube checks in dogs, cats, horses, ruminants and pigs

Why equipment knowledge is a safety skill

Many anaesthetic accidents are not caused by the drug but by equipment: an empty oxygen cylinder, a disconnected hose, a stuck valve or an exhausted absorbent. The machine delivers oxygen and anaesthetic gas, and the circuit carries them to the patient and removes carbon dioxide. A student who understands the path of the gas can find a fault quickly.

The golden rule is to check the whole system *before* the patient is premedicated, not after the animal is already asleep.

Parts of the anaesthetic machine

Follow the gas from source to patient.

1. **Gas supply.** Oxygen comes from a cylinder or a pipeline. Cylinders are fitted through yoke connections designed so that the wrong gas cannot be attached, and the cylinder pressure gauge shows how much oxygen is left, so a falling gauge means the supply is running out.
2. **Pressure regulator.** It reduces the very high cylinder pressure to a low, steady working pressure.
3. **Flowmeter.** It sets the fresh gas flow of oxygen. Read it at the correct point on the float, with the machine upright.
4. **Vaporiser.** Adds a controlled amount of volatile agent to the oxygen, as described in the previous chapter.
5. **Common gas outlet.** Fresh gas leaves here to the breathing circuit.
6. **Oxygen flush valve.** It delivers a high flow of pure oxygen that bypasses the vaporiser. It is used to fill the circuit quickly and to flush out agent at the end of anaesthesia. Use it with caution while connected to a patient, because the sudden pressure can harm the lungs and it dilutes the anaesthetic.
7. **Breathing circuit** with reservoir bag, pressure manometer, adjustable pressure-limiting (APL or pop-off) valve and a link to the scavenging system.

Rebreathing and non-rebreathing circuits

The purpose of any circuit is to bring fresh gas to the patient and prevent the animal from rebreathing its own carbon dioxide.

A **rebreathing system**, usually the **circle system**, directs exhaled gas through a **carbon dioxide absorber** (soda lime or similar) and returns it to the patient with fresh gas added. One-way valves keep the flow in one direction. The advantages are saving of oxygen and volatile agent, retention of heat and moisture, and less pollution. The disadvantages are more parts that can leak or fail, greater resistance, and slower change in anaesthetic depth when flows are low. It is usually chosen for patients above a certain size, which the maker states for each machine.

A **non-rebreathing system** has no absorber and no one-way valves in the same way. A high fresh gas flow washes exhaled gas out through the pop-off valve. Examples are the Bain coaxial system and the T-piece (Jackson-Rees). Their strengths are low resistance, light weight and quick change of depth, so they suit cats, small dogs, birds and other small patients. The weakness is the high gas use and the greater cooling and drying of the patient and pollution risk. If the flow is too low in a non-rebreathing system, carbon dioxide builds up and the patient becomes hypercapnic, so the flow must follow the maker's or textbook recommendation.

Common confusion: students think that "low flow" is always better. In a circle system low flow is a saving only if the absorber, leaks and monitoring are all in good condition.

The carbon dioxide absorbent

The absorbent chemically binds carbon dioxide and releases heat and water. It has a limited life. Signs of exhaustion include a colour change of the indicator, a warm canister, and rising inspired CO_2 on the capnograph. The indicator may revert to its original colour after a rest, so a pale colour on the next morning does not prove that the granules are fresh, and capnography is the better guide.

Do not leave gas flowing through the absorber overnight, because dry granules can produce heat and unwanted by-products with some volatile agents. Keep the lid closed, store spare absorbent sealed, and replace it on a routine schedule noted in a log. Channeling, where gas runs through a small path in loosely packed granules, reduces absorption, so do not overfill the canister or leave gaps.

Leak and function tests

A **leak test** should be done on every circuit, every day of use, and again after any change of circuit parts.

1. Check oxygen supply, flowmeter and vaporiser level; make sure the scavenging line is connected.
2. Close the APL valve and block the patient end of the circuit (the Y-piece or the open end of the tubing).
3. Fill the system with oxygen by the flush valve until the reservoir bag or manometer shows a moderate pressure, as advised for your machine.
4. Stop the flow and watch. The pressure should hold. A steady fall means a leak, so check tubing, connections, the absorber canister, the bag and the valves.
5. Open the APL valve and confirm that the pressure is released and the gas passes to scavenging.

Test the one-way valves by watching them move on a breath. For a Bain system a separate test checks that the inner fresh gas tube is intact and not disconnected, since a break turns the whole outer tube into dead space and causes rebreathing.

Remember to open the APL valve before connecting to the patient. Leaving it closed is a classic cause of dangerous pressure build-up in the lungs.

Endotracheal intubation by species

The **endotracheal tube** secures the airway, allows delivery of oxygen and volatile agent, permits ventilation and protects the lungs against regurgitated material or blood. A cuff seals the airway, but an overinflated cuff can injure the trachea. Inflate it just until no leak is heard under gentle bag pressure.

General steps: the patient is adequately unconscious, the head and neck are extended in line, the tongue is drawn forward, the larynx is seen with a laryngoscope where needed, and the tube is passed through the open arytenoids. Confirm placement by observing chest movement, listening for breath sounds, feeling breath at the tube, and above all by seeing a normal capnograph trace. Tie the tube in place and check it does not reach beyond the thoracic inlet, since a tube that goes too far enters one bronchus and ventilates only one lung.

- **Dog:** usually straightforward. Brachycephalic breeds have a long soft palate, narrow trachea and swollen tissues, so a smaller tube size is often needed and extubation must be delayed until the animal is fully swallowing.
- **Cat:** prone to laryngospasm, and the trachea is delicate and can rupture if a tube is oversize, forced or the cuff overinflated. Topical laryngeal local anaesthetic may be used by the clinician, and the neck should not be over-flexed or twisted with the tube in place.
- **Horse:** a long cuffed tube is passed through the mouth with a mouth gag to protect the tube from being bitten, often guided by hand. Check the tube is not kinked, and the cuff must be tested before use.
- **Cattle, sheep and goats:** intubation is done to protect the airway because of the real risk of regurgitation. The head is held extended, a gag is used, and it is passed with the larynx located by hand or laryngoscope. Ruminants often need the head positioned lower than the pharynx during recumbency so that saliva drains away.
- **Pig:** the long snout, small mouth opening and laryngeal anatomy make intubation difficult, and laryngospasm is common. A laryngoscope with a long blade and small tubes is needed.

Concept cleared

Concept cleared: Rebreathing
A circle system is like a recycling plant: the used gas is cleaned (CO_2 removed) and returned. If the cleaner is spent, the same dirty gas goes round again and the patient slowly builds up carbon dioxide. A non-rebreathing system is like opening a window: a strong draught of fresh gas pushes the old air out.

Concept cleared: Leak testing
Blowing up a tyre and watching the gauge is the same idea. A tight system holds pressure. If it falls, something leaks, and the patient will lose agent to the room or oxygen to the air.

Concept cleared: Dead space

Dead space is the part of the airway or circuit where gas moves back and forth without exchange. A broken inner tube in a Bain system, or a long connector on a cat, adds dead space and makes the patient rebreathe CO2.

Concept cleared: Tube depth

Putting the tube in too far is like pushing a drinking straw into one branch of a Y. Only one lung gets gas, so oxygen levels fall. The tube tip should stay at or before the chest entrance.

Memory aid: Gas path: GRF-VOC-B

Gas source, Regulator, Flowmeter, Vaporiser, Outlet, Circuit, Breathing patient. Test the machine in that order, and always open the APL valve before connecting the patient.

Compare and contrast

Rebreathing versus non-rebreathing circuits

Feature	Circle (rebreathing)	Bain or T-piece (non-rebreathing)	Practical meaning
CO2 removal	Absorbent	High fresh gas flow	Absorber must be fresh; flow must be adequate
Gas use	Low flows possible	High flows needed	Cost and pollution
Resistance	Higher	Low	Small patients favour non-rebreathing
Heat and humidity	Retained	Lost	Hypothermia risk in non-rebreathing

Intubation concerns by species

Species	Main difficulty	Main risk	Precaution
Dog	Brachycephalic airway	Obstruction after extubation	Smaller tube; delayed extubation
Cat	Laryngospasm	Tracheal injury	Small tube; gentle cuff inflation
Horse	Size and mouth	Tube bitten or kinked	Gag and cuff check
Ruminant	Regurgitation	Aspiration	Cuffed tube; head position
Pig	Long snout, small larynx	Laryngospasm	Long blade and small tubes

Species notes

Dog

Brachycephalic breeds should be kept intubated until they swallow and have a clear airway, and should be recovered with close observation.

Cat

A cat trachea is easily damaged by an oversize tube or an overinflated cuff, so use gentle technique and check the cuff pressure.

Horse

A mouth gag prevents the horse from biting through the tube, and a long, cuffed tube is needed with a stout connector.

Cattle and small ruminants

A cuffed tube is essential to protect against aspiration of rumen fluid and saliva, and the head is kept low during recumbency.

Pig

Laryngospasm is common, and intubation needs a long-bladed laryngoscope and several small tube sizes.

Clinical pearls

Self-test: 10 questions

1. The oxygen flush valve

It bypasses the vaporiser, so it dilutes the anaesthetic and can cause high pressure if used on a connected patient.

2. A main advantage of a circle system is

Exhaled gas is cleaned of CO2 and re-used.

3. Which circuit is usually preferred for a kitten?

Low resistance and low dead space suit very small patients.

4. During a leak test with the APL valve closed and the Y-piece blocked, the manometer pressure steadily falls. This means

A tight system holds pressure.

5. One of the safest ways to confirm tracheal intubation is

A normal capnograph trace shows that exhaled CO2 comes from the lungs and not the oesophagus.

6. Overinflation of the cuff in a cat can cause

The cat trachea is thin, and high cuff pressure or oversize tubes can tear it.

7. Which is a sign of exhausted soda lime?

If CO_2 is not absorbed, the patient inspires CO_2.

8. Why is a cuffed tube essential in ruminants?

Ruminants regurgitate readily when recumbent and sedated.

9. A tube advanced too far in a dog is likely to

Endobronchial intubation gives uneven ventilation and hypoxia.

10. What must be done before connecting a patient to a circle system?

A closed APL valve allows pressure to build up in the lungs.

Key points to revise

1. Gas flows from source to regulator, flowmeter, vaporiser, outlet and circuit.
2. The oxygen flush valve bypasses the vaporiser and should be used with care on a connected patient.
3. Circle systems recycle gas through an absorber, saving oxygen and agent.
4. Non-rebreathing circuits need high fresh gas flow and suit small patients.
5. Absorbent has a limited life and exhaustion shows as rising inspired CO_2.
6. A pressure leak test is done before each day's use.
7. The endotracheal tube cuff should seal without overinflation.
8. Tube position is confirmed by capnography and chest movement.

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- Ch 6. Local and regional anaesthesia (in this book)
- Ch 4. Inhalation anaesthesia (in this book)
- Veterinary drugs list: classes, uses and cautions
- Veterinary Drug Index
- Veterinary Drug Concepts Clearly Explained

Sources

- WSAVA Global Pain Council Guidelines
- PubMed search: veterinary anesthesia breathing circuits
- University of Minnesota Libraries: Principles of Pharmacology study guide

CHAPTER 6 OF 14

Local and regional anaesthesia

How local anaesthetic drugs block nerve conduction, why they can be toxic, and how nerve blocks, epidurals, cattle paravertebral and line blocks and ring blocks are chosen and used safely.

After this chapter you can

- Explain how local anaesthetics block sodium channels and why pH and tissue infection matter
- Compare amide and ester agents and name the main toxicity signs
- Describe the purpose and cautions of epidural anaesthesia
- Explain the paravertebral, line, inverted L and ring blocks used in cattle
- State patient safety rules for any regional technique

Why local and regional techniques matter

Local anaesthetics stop pain signals from reaching the brain by blocking nerve conduction at the site of injection. In veterinary practice, especially in cattle, sheep and goats and in equine standing procedures, they allow surgery with a conscious patient and avoid the risks of general anaesthesia. In small animals they are added to general anaesthesia to reduce the dose of other drugs and to improve pain relief after surgery.

A local block does not provide restraint or calm the animal. A frightened or fractious animal may still need sedation. Sedation and a block together are safer than a deeper general anaesthetic in many field cases.

How local anaesthetics work

Local anaesthetics block **voltage-gated sodium channels** inside the nerve membrane. Without sodium entry the nerve cannot generate an action potential, so the signal is not carried. Small, thin fibres carrying pain and sympathetic signals are usually blocked first, then touch and pressure, and motor fibres last in a lower concentration. This is why an animal may feel less pain but can still move.

These drugs are weak bases. The **non-ionised** form crosses the nerve membrane; the **ionised** form binds the channel inside. In inflamed or infected tissue the pH is acidic, so more drug is ionised outside the nerve, less enters, and the block is weak or fails. This is the reason for the old advice not to inject into an abscess.

Two groups are described. **Amides** such as lidocaine, mepivacaine, bupivacaine and ropivacaine are broken down in the liver and are the common agents. **Esters** such as procaine are broken down by plasma esterases and are used less. Lidocaine acts quickly with moderate duration, and bupivacaine is slower to start and longer lasting. Adrenaline added to some preparations narrows blood vessels, slows absorption, prolongs action and reduces toxicity, but it should **not** be used where the blood supply depends on end arteries, such as ear tips, tail, penis, teats and digits, because it can cause tissue loss.

Toxicity and its management

Toxicity occurs when too much drug reaches the blood, usually by accidental intravascular injection, overdose in a small animal, or rapid absorption from a vascular site. Because many cases are small animals, the dose must be calculated from the body weight, and the total allowed amount should not be exceeded when several blocks are done in one patient.

Signs usually progress from the nervous system to the heart. Early signs are muscle twitching, restlessness, ataxia and then seizures, followed by depression and coma. Cardiovascular signs are arrhythmias, hypotension and collapse. **Bupivacaine** is especially cardiotoxic, and it must never be given intravenously or used for intravenous regional techniques. Cats are generally considered more sensitive to systemic effects of lidocaine, so smaller total amounts are used, and topical benzocaine preparations are avoided in cats because of the risk of methaemoglobinaemia.

Prevention rules: aspirate before each injection and inject slowly in small increments, use the lowest effective volume, avoid injecting into the vein or artery, and keep oxygen, airway equipment and emergency drugs ready. Treatment is supportive: stop injecting, secure the airway, give oxygen, control seizures and treat arrhythmias and low pressure. Intravenous lipid emulsion has been reported as a rescue treatment for severe local anaesthetic toxicity, and the clinician decides on its use. In food-producing animals, a withdrawal period applies to local anaesthetics, so check the current regulatory notification and label advice.

Nerve blocks and epidural anaesthesia

A **nerve block** places local anaesthetic near a named nerve to desensitise the area it supplies. Examples are dental blocks (infraorbital, mental, maxillary and inferior alveolar nerves) in dogs and cats, the brachial plexus block for forelimb surgery, intercostal blocks for thoracic pain, and testicular and spermatic cord infiltration in castration. Block success depends on accurate anatomy, a clean technique, enough waiting time and avoiding vessels.

Epidural anaesthesia places drug in the space outside the dura of the spinal canal. In dogs and cats it is usually given at the lumbosacral space; in cattle and horses the caudal (sacrococcygeal or first intercoccygeal) site is common. Epidural local anaesthetic blocks the nerves of the tail, perineum, rectum, vagina and, with larger volume, hindlimbs. Epidural opioids and alpha-2 agonists can add pain relief with less motor loss; their selection is a clinical decision.

Concerns: spread of drug forward can paralyse the hindlimbs and cause recumbency, a serious problem in standing cattle, or can block the chest nerves and sympathetic fibres, causing hypotension and breathing difficulty. Epidurals are avoided in infection at the site, bleeding disorders, severe hypovolaemia and unstable spinal disease. Strict asepsis is needed because infection of the epidural space can be devastating. The patient must be supported and not allowed to walk until the block has gone.

Cattle paravertebral block

Many cattle operations are done standing under local techniques. For flank laparotomy (caesarean section, rumenotomy), the usual choices are the **paravertebral block** and the **line (infiltration) block**.

A **paravertebral block** deposits local anaesthetic near the spinal nerves emerging between vertebrae (the last thoracic nerve and the first and second lumbar nerves) before they spread into the flank. The skin, muscle and peritoneum of the flank are desensitised, the abdominal wall relaxes, and a warm, pain-free area is created by blood vessel dilation. Various approaches are named after their authors, and which one is used is a matter of training and preference. Advantages are small drug volume and good muscle relaxation; disadvantages are skill needed, possible failure, and temporary curvature of the spine toward the blocked side. The block can be falsely judged successful or unsuccessful if tested too early.

Line, inverted L, ring and cornual blocks

A **line block** is a row of infiltration along the line of the planned incision, and an **inverted L** block places the row along two sides of the area. It is simple and needs little skill, but it needs more drug volume, it blocks only the layers infiltrated, distorts tissue layers, and may delay wound healing if used excessively. Muscle relaxation is less complete than with a paravertebral block.

A **ring block** is a circle of subcutaneous infiltration around a limb, teat, tail or digit to block all nerves entering the area below. It is used for amputation of digits, teat surgery and tail docking. Adrenaline-containing products must not be used for ring blocks. Do not inject too tightly around the structure because the volume can compress its blood supply. Intravenous regional anaesthesia (Bier block) below a tourniquet is a related technique used for digit surgery in cattle, and tourniquet time should be limited.

Also in cattle, a **cornual block** of the cornual nerve is used for dehorning. Animal welfare rules in many countries require pain relief for dehorning and castration, so check the current guidance for your area.

Concept cleared

Concept cleared: Ion trapping at the nerve

Think of the drug as a key that must first pass through a door (non-ionised) and then turn in a lock inside (ionised). In acidic infected tissue most keys arrive in the wrong form to pass the door, so the nerve is not blocked.

Concept cleared: Order of nerve block

Pain fibres are thin and blocked first, like narrow pipes that clog fastest. Large motor fibres need more drug. That is why a block can remove pain and temperature sensation while the animal can still move the limb.

Concept cleared: Why adrenaline is avoided at extremities

Adrenaline narrows vessels to keep the drug in place. At a digit or teat the blood supply is a single thin vessel, so tightening it can starve the tissue and cause death of the tip.

Concept cleared: Line block versus paravertebral block

A line block is like painting each room of the house after the damage is done, with a lot of paint and many layers. A paravertebral block is like switching off the power at the main box before it reaches the rooms, using little drug.

Memory aid: Before every local injection: ASPIRATE

Aspirate for blood, Slow injection, Pause and watch the patient, Inject in small increments, Respect total allowed amount, Avoid adrenaline at extremities, Treat toxicity early, Equipment ready for emergencies.

Compare and contrast

Amide and ester local anaesthetics

Feature	Amides	Esters	Practical meaning
Examples	Lidocaine, bupivacaine, ropivacaine, mepivacaine	Procaine, tetracaine	Amides are the common choices
Metabolism	Liver	Plasma esterases	Liver disease prolongs amides
Allergy	Rare	More common (PABA metabolite)	Esters need more caution in sensitive patients
Use	Most blocks	Limited, topical or older products	Check availability

Cattle flank techniques

Technique	Site	Strength	Limitation
Paravertebral	Spinal nerves near vertebrae	Small volume, good relaxation	Skill needed; spinal curvature
Line block	Along incision	Simple	Large volume; incomplete relaxation; tissue distortion
Inverted L	Two sides of the field	Simple, covers more area	Large volume; same drawbacks
Ring block	Around limb, teat or tail	Quick for distal parts	No adrenaline; avoid compression

Species notes

Cattle

Standing flank surgery under paravertebral or line block is routine, but cranial spread of an epidural can cause recumbency, so be careful with volume and the choice of drug.

Cat

Cats are sensitive to systemic local anaesthetic effects and to methaemoglobinaemia from benzocaine, so calculate the total carefully and avoid benzocaine products.

Dog

Dental and limb blocks reduce the need for general anaesthetic and give postoperative comfort, but bupivacaine must never go into a vein.

Horse

Standing procedures need sedation plus local block, with attention to the safety of the people near the hindlimbs during caudal epidural anaesthesia.

Sheep and goats

Small body size makes overdose easy, so the total dose by weight must be calculated before blocks,

especially when several sites are infiltrated.

Clinical pearls

Self-test: 10 questions

1. Local anaesthetics act mainly by blocking

Blocking sodium entry prevents the action potential.

2. Why does a block fail in an abscess?

Ionised drug does not cross the nerve membrane.

3. Which agent is particularly cardiotoxic if given intravenously?

Bupivacaine binds tightly in the heart and can cause refractory arrhythmias.

4. Early signs of local anaesthetic toxicity are

CNS excitation usually appears first and may progress to seizures.

5. Adrenaline-containing preparations should NOT be used for

Vasoconstriction at an end-artery site can cause tissue necrosis.

6. Which of these is an advantage of paravertebral block over line block?

It blocks nerves proximally, using less drug and relaxing the wall.

7. A risk of cranial spread of an epidural in a standing cow is

Motor nerves to the hindlimbs may be blocked.

8. Before injecting local anaesthetic, you should

Aspiration detects intravascular needle placement, a main cause of toxicity.

9. A topical agent to avoid in cats because of methaemoglobinaemia is

Cats are particularly sensitive to benzocaine-induced methaemoglobinaemia.

10. A cornual block is used for

It desensitises the cornual nerve supplying the horn base.

Key points to revise

1. Local anaesthetics block voltage-gated sodium channels.
2. Pain fibres are blocked before motor fibres.
3. Amides are metabolised by the liver, esters by plasma esterases.
4. Acidic infected tissue reduces effect.
5. Toxicity progresses from CNS excitation to cardiovascular collapse.
6. Epidural anaesthesia carries a risk of hindlimb weakness and hypotension.
7. Paravertebral block gives flank anaesthesia with a small volume of drug.
8. Ring blocks must avoid adrenaline and tight circumferential injection.

Go deeper on this site

- Ch 7. Analgesia and pain management (in this book)
- Ch 5. Anaesthetic equipment and breathing circuits (in this book)
- Veterinary drugs list: classes, uses and cautions
- Veterinary Drug Index
- Veterinary Drug Concepts Clearly Explained

Sources

- WSAVA Global Pain Council Guidelines
- PubMed search: local anesthetic systemic toxicity and lipid emulsion
- University of Minnesota Libraries: Principles of Pharmacology study guide

CHAPTER 7 OF 14

Analgesia and pain management

How pain signals travel from tissue to brain, why combining drug classes works better than one drug, and how opioids, NSAIDs, ketamine and gabapentinoids fit into a plan. Includes pain scoring in dogs, cats, horses and farm animals, with species cautions.

> **After this chapter you can**
>
> - Trace the nociceptive pathway through transduction, transmission, modulation and perception
> - Explain peripheral and central sensitisation and why pre-emptive analgesia matters
> - Justify multimodal analgesia by matching each drug class to a point on the pathway
> - Describe the actions, benefits and cautions of opioids, NSAIDs, ketamine and gabapentinoids
> - Choose a suitable pain scale for a species and interpret behaviour changes

Why pain control is a patient safety issue

Pain is not only a welfare problem. Untreated pain raises catecholamines, increases heart rate and blood pressure, slows wound healing, suppresses appetite and delays recovery. In the anaesthetised patient, nociception that is not blocked causes autonomic responses that can be mistaken for light anaesthesia, and the usual reaction is to give more inhalant. This deepens anaesthesia and lowers blood pressure. Good analgesia therefore allows a lighter, safer plane of anaesthesia.

Animals cannot report pain, so the clinician must assume that any procedure painful to a human is painful to the animal. Prey species such as sheep, goats and cattle

often hide pain, and cats show it in subtle ways. Absence of crying is never proof of comfort.

The pain pathway and where drugs act

Nociception has four steps, and each is a drug target.

1. **Transduction.** Tissue damage releases prostaglandins, bradykinin and other mediators that excite nociceptors. NSAIDs act here by blocking cyclo-oxygenase. Local anaesthetics also prevent the nerve ending from firing.
2. **Transmission.** The signal travels along A-delta fibres (sharp, fast) and C fibres (dull, slow) to the dorsal horn of the spinal cord. Local anaesthetics block conduction in these fibres.
3. **Modulation.** In the dorsal horn, signals can be amplified or dampened. Opioids, alpha-2 agonists and gabapentinoids act here. The NMDA receptor, blocked by ketamine, drives amplification.
4. **Perception.** The brain interprets the signal as pain. Opioids, alpha-2 agonists and general anaesthetics act at this level.

Because no single drug acts on all four steps, combining drugs gives broader control.

Sensitisation and pre-emptive analgesia

Repeated or intense nociception changes the system. In **peripheral sensitisation**, inflamed tissue lowers the threshold of nociceptors, so normal touch becomes painful. In **central sensitisation**, sustained C-fibre input activates NMDA receptors in the dorsal horn and the spinal neurons become hyperexcitable. This is called wind-up. The result is hyperalgesia (exaggerated response to a painful stimulus) and allodynia (pain from a normally painless stimulus).

Once sensitisation is established it is harder to treat and may become chronic pain. This is the reason for **pre-emptive analgesia**: giving analgesics before the surgical insult so that the spinal cord never becomes sensitised. A common confusion is to think pre-emptive means a bigger drug amount. It means earlier timing and continued cover afterwards, not a larger exposure.

Multimodal analgesia

Multimodal analgesia combines drugs from different classes, often with local or regional blocks, so that each acts at a different site. The benefit is better pain relief with less of each drug, so the side effects of any one drug are reduced. A typical plan might pair an opioid, an NSAID where safe, a local anaesthetic block and, for selected cases, ketamine or a gabapentinoid.

Two cautions apply. First, combining drugs also combines their risks, so patient selection still matters; an NSAID is not suitable for a hypovolaemic or hypotensive patient. Second, drugs from the same class should not be stacked. Two NSAIDs together do not add analgesia but do add gastric and renal injury.

Local and regional anaesthesia deserve special mention in this plan. A nerve block or a local infiltration stops transmission before the signal reaches the cord, so it also reduces the amount of inhalant and opioid needed. Always check the maximum safe exposure for the species and body weight, because cats and small patients are easily overdosed with local anaesthetics. Signs of toxicity include tremors, seizures and arrhythmias, and the response is to stop, support ventilation and call for senior help.

Opioids, NSAIDs, ketamine and gabapentinoids

Opioids act on mu, kappa and delta receptors, which are G-protein-coupled and reduce neurotransmitter release and neuronal firing. Full mu agonists give the strongest analgesia. Partial agonists and agonist-antagonists such as buprenorphine and butorphanol are milder; butorphanol is short acting and better for visceral than for severe somatic pain. Common effects are sedation, bradycardia, respiratory depression, vomiting and defecation in dogs, and constipation or urine retention with prolonged use. Respiratory depression is usually modest in conscious animals but is additive with anaesthetics, so ventilation must be watched. Opioids are controlled substances; follow the current Indian narcotic rules, which should be checked in the latest notification.

NSAIDs block cyclo-oxygenase and reduce prostaglandins at the site of injury and in the cord. They are excellent for inflammatory and post-operative pain. The risks are gastric ulceration, renal injury (especially with hypotension or dehydration) and effects on platelets. COX-1 protects stomach and kidney; COX-2 is induced in inflammation, so COX-2 preferential drugs are considered safer. Never give an

NSAID together with a corticosteroid, and allow a washout between different NSAIDs.

Ketamine is an NMDA receptor antagonist. At low sub-anaesthetic exposure it dampens wind-up and reduces opioid need, which is useful in severe or chronic pain. It does not replace an opioid. Watch for tachycardia and, in some patients, dysphoria.

Gabapentinoids (gabapentin, pregabalin) bind the alpha-2-delta subunit of voltage-gated calcium channels and reduce release of excitatory transmitters. They are used for neuropathic and chronic pain, and gabapentin is also valued for calming cats before handling. The main effect is sedation and ataxia. They are cleared by the kidney, so reduced function needs caution. Gabapentin is not a quick rescue drug for acute severe pain.

Pain scoring and reassessment

Pain must be measured repeatedly, because analgesia is adjusted to the score and not to a fixed routine. Scales combine behaviour, posture and response to touch.

- **Dogs:** the Glasgow Composite Measure Pain Scale (short form) uses behaviour, response to gentle touch and posture, and gives a score at which rescue analgesia is advised.
- **Cats:** the Feline Grimace Scale scores ear position, orbital tightening, muzzle tension, whisker position and head position. Hiding, reduced grooming and loss of appetite are common signs.
- **Horses:** the Horse Grimace Scale and composite scores look at ears, eyes, nostrils and facial muscle tension, along with posture, weight shifting and reluctance to move.
- **Cattle, sheep and goats:** scoring is less standardised; look at facial expression, head carriage, rumination, feeding and willingness to move.

A common error is to score only when the animal is disturbed. Observe quietly first, then approach, then palpate. A sedated animal can still be in pain, and sedation should not be read as analgesia. Always follow a dysphoric, whining, hypotensive or vomiting patient back to the cause: pain, drug effect, or both.

Concept cleared

Concept cleared: Wind-up

Think of a crowded stairwell alarm. A single press of the button rings once. If the button is pressed again and again, the alarm becomes louder and starts to ring even when lightly touched. Repeated C-fibre input makes spinal neurons overreact in the same way, which is why early analgesia keeps the alarm calm.

Concept cleared: Multimodal analgesia

To stop water flowing through a pipe, closing one tap works but needs great force. Closing several taps along the line, each a little, works easily. Different drug classes close different taps on the pain pathway, so each is needed in a smaller amount.

Concept cleared: Sedation is not analgesia

A quiet animal is not always a comfortable animal. Alpha-2 agonists and acepromazine produce calm, but acepromazine gives no pain relief at all. Score pain separately from sedation.

Concept cleared: Rescue analgesia

Every pain plan needs a pre-agreed score above which extra analgesia is given. This turns pain control into a measured loop: score, treat, rescore.

Memory aid: TTMP

Transduction, Transmission, Modulation, Perception: the four steps of nociception. Match a drug to each one when planning multimodal analgesia.

Compare and contrast

Analgesic classes at a glance

Class	Main site of action	Best for	Key caution
Opioid	Spinal cord and brain receptors	Moderate to severe acute pain	Respiratory depression, bradycardia, vomiting
NSAID	Peripheral COX at injury site	Inflammatory and post-operative pain	Gastric and renal injury, hypovolaemia
Ketamine (low level)	NMDA receptor in dorsal horn	Severe, chronic or wind-up pain	Tachycardia, dysphoria; adjunct only
Gabapentinoid	Calcium channel alpha-2-delta	Neuropathic and chronic pain	Sedation, ataxia, renal clearance
Local anaesthetic	Sodium channel on nerve	Block of transmission	Systemic toxicity, especially cats

Pain pathway steps and drugs

Step	What happens	Drug that acts here
Transduction	Tissue injury excites nociceptor	NSAIDs, local anaesthetics
Transmission	Signal along A-delta and C fibres	Local anaesthetics
Modulation	Dorsal horn amplifies or dampens	Opioids, alpha-2 agonists, ketamine, gabapentinoids
Perception	Brain interprets pain	Opioids, general anaesthetics

Species notes

Dog

Opioids commonly cause vomiting and slowed heart rate. Herding breeds with the ABCB1 (MDR1) variant may be more sensitive to some opioids such as butorphanol, so check breed history. Dogs are prone to NSAID gastric injury; avoid

Cat

Cats clear many NSAIDs slowly because of limited glucuronidation, so only drugs licensed or well documented for cats should be used, with great care over repeat exposure. Pain signs are subtle; use a facial scale. Opioids may cause

combining NSAIDs and corticosteroids.

excitement in some cats, so selection and monitoring matter.

Horse

Opioids may cause excitement or reduced gut motility, so colic and post-operative patients need careful monitoring. NSAIDs are the mainstay for musculoskeletal pain, but gastric and right dorsal colon ulceration and renal injury remain risks.

Cattle, sheep and goats

Ruminants hide pain and are often under-treated. Drugs used in food animals must respect withdrawal times, and there are Indian rules for residues, so check the current notification before choosing any analgesic in a milk or meat animal.

Pig

Pigs show pain by vocalisation, isolation and reluctance to move. Procedures such as castration should include analgesia and local anaesthesia; also confirm local legal requirements for food animals.

Clinical pearls

Self-test: 10 questions

1. Which step of nociception is mainly blocked by NSAIDs?

NSAIDs reduce prostaglandin formation at the injury site, which lowers the excitation of nociceptors (transduction).

2. Wind-up in the dorsal horn is mainly driven by which receptor?

Sustained C-fibre input activates NMDA receptors and makes spinal neurons hyperexcitable. Ketamine blocks this receptor.

3. Pre-emptive analgesia means:

The aim is to stop sensitisation by timing, not by larger exposure.

4. A dog under anaesthesia has rising heart rate and blood pressure during incision. The best first thought is:

Autonomic response to surgery often signals inadequate analgesia, and simply deepening the inhalant adds hypotension.

5. Which pairing is unsafe?

Two NSAIDs add gastric and renal risk without extra analgesia.

6. Gabapentin is mainly useful for:

It acts on calcium channel alpha-2-delta and is slow; it is not a rescue drug.

7. Which statement about acepromazine is correct?

Acepromazine is a phenothiazine tranquilliser without analgesic action.

8. Common sign of pain in a cat is:

Cats show pain subtly; facial scales and behaviour change are more reliable than vocalisation.

9. Which patient is the least suitable for an NSAID?

Prostaglandins maintain renal blood flow in low-perfusion states; NSAIDs may cause kidney injury.

10. Opioids act through which receptor type?

Mu, kappa and delta opioid receptors are G-protein-coupled and reduce transmitter release.

Key points to revise

1. Nociception has four steps: transduction, transmission, modulation, perception.
2. Central sensitisation (wind-up) involves NMDA receptors and makes pain harder to treat.
3. Pre-emptive analgesia protects the spinal cord from sensitisation.
4. Multimodal analgesia uses drugs from different classes at different sites.
5. Opioids act on mu, kappa and delta receptors; side effects are respiratory depression, bradycardia and vomiting.
6. NSAIDs reduce prostaglandins; risks are gastric, renal and platelet effects.
7. Ketamine blocks NMDA receptors; gabapentinoids act on calcium channel alpha-2-delta.
8. Use a species-appropriate pain scale and reassess repeatedly.

Go deeper on this site

- Ch 8. Monitoring and neuromuscular blockade (in this book)
- Ch 6. Local and regional anaesthesia (in this book)
- Veterinary drugs list: classes, uses and cautions
- Veterinary Drug Index
- Veterinary Drug Concepts Clearly Explained

Sources

- WSAVA Global Pain Council Guidelines
- University of Minnesota Libraries: Pharmacology, G protein-coupled receptors
- Cornell University College of Veterinary Medicine: Drug sensitivity (MDR1)

CHAPTER 8 OF 14

Monitoring and neuromuscular blockade

The core monitors of anaesthesia, what each one measures and where it misleads, and how to read them together. Also covers neuromuscular blocking drugs, how their action is monitored and reversed, and the rule that a relaxed patient must always be ventilated and kept unconscious.

After this chapter you can

- Explain what pulse oximetry, capnography, blood pressure, ECG and temperature each measure and their limits
- Interpret abnormal capnograph findings and decide on a first response
- Distinguish oxygenation from ventilation and perfusion
- Compare non-depolarising and depolarising neuromuscular blockers by mechanism
- Describe how block is monitored and reversed, and the safety rules that apply

Why we monitor

Anaesthetic drugs depress the cardiovascular and respiratory systems, so the safe depth is a balance between enough anaesthesia and too much. Monitoring detects drift before it becomes an emergency. The most important monitor is a trained person who stays with the patient. Machines add information but do not replace observation of colour, pulse quality, chest movement, jaw tone and eye position.

Monitoring should begin before induction, continue through recovery, and be recorded on a chart at regular intervals so that trends are visible. A single normal value matters less than a changing one.

Before starting, check the equipment as well as the patient: oxygen supply, vaporiser level, absorber, breathing circuit leak test, suction and a working emergency drug and intubation kit. Many serious events trace back to a missed circuit fault or an unreadied rescue tool. Set alarm limits for the species and size, and treat an alarm as information to investigate, never as noise to silence. Hand-over between staff during a case should be explicit, so that the person watching the patient always knows the drugs given and the plan for recovery.

Oxygenation: pulse oximetry

A pulse oximeter shines two wavelengths of light through tissue and compares absorption by oxygenated and deoxygenated haemoglobin. It reports SpO_2 and pulse rate. It measures **oxygenation**, not ventilation.

Important limits: it reads poorly with poor perfusion, vasoconstriction (for example after alpha-2 agonists), movement, pigmented or thick tissue, and a cold probe site. It can read falsely normal with carbon monoxide poisoning, and methaemoglobin pushes the reading towards a fixed value. Also, an animal breathing high oxygen can have a normal SpO_2 even while hypoventilating badly, because the extra inspired oxygen masks the problem. This is why SpO_2 cannot replace capnography. A falling SpO_2 is a late sign, so act early: check the airway, circuit and oxygen supply first, then the patient.

Ventilation: capnography

A capnograph measures carbon dioxide in exhaled gas. The end-tidal value ($ETCO_2$) approximates alveolar and arterial CO_2 in a healthy lung and shows **ventilation**. The waveform also tells a story.

- **High $ETCO_2$** means hypoventilation, increased CO_2 production (malignant hyperthermia, fever), or rebreathing from an exhausted absorber or faulty valve.
- **Low $ETCO_2$** means hyperventilation, falling cardiac output or poor lung perfusion, or a leak or sampling problem.
- **Sudden loss of the trace** may mean disconnection, oesophageal intubation, tube obstruction or cardiac arrest. Check the patient first, then the machine.
- **A baseline that does not return to zero** suggests rebreathing.

Capnography also confirms correct tracheal intubation, because a regular waveform appears only when gas comes from the lungs. A common confusion is to think a normal $ETCO_2$ proves a good circulation. It does not; a patient in shock can have a low value for that reason alone.

Perfusion: blood pressure and ECG

Blood pressure reflects perfusion of vital organs. Mean arterial pressure matters most because organs, especially the kidney and brain, are perfused according to it.

Anaesthetic drugs usually lower it through vasodilation and reduced cardiac output. Hypotension is common and dangerous, particularly in sick, young, old or hypovolaemic patients. Non-invasive methods (Doppler and oscillometric) are common; direct arterial measurement is the most accurate and is used in high-risk cases. Cuff size must suit the limb, because a cuff that is too small reads falsely high and one too large reads falsely low.

The **ECG** shows rhythm and rate but not whether the heart is pumping blood. A patient in pulseless electrical activity has an ECG trace and no output, so always feel the pulse. It is used to detect bradycardia, tachyarrhythmia, ventricular premature complexes and conduction block. Check the cause before treating a rhythm change: pain, hypoxia, hypercapnia, light anaesthesia, electrolyte problems and drug effects are common reasons.

Do not attribute hypotension to anaesthetic depth alone. Reduce inhalant if appropriate, give fluids if hypovolaemic, and use supportive drugs on indication. Alpha-2 agonist effect, bradycardia and vasodilation need different responses.

Temperature

Anaesthesia inhibits thermoregulation, and a patient in a cold theatre with exposed skin and clipped hair loses heat quickly. Small patients, neonates and the old are most at risk. Hypothermia lengthens recovery, reduces drug clearance, prolongs the effect of agents, impairs clotting and increases infection. Measure core temperature, usually oesophageal or rectal, and begin warming early with warm air blankets, insulation, warmed fluids and a warm room. Avoid direct contact with heating pads that can burn skin. Hyperthermia is less common but can follow some drugs in cats, or a very warm environment, and malignant hyperthermia, though rare, must be remembered.

Neuromuscular blockers and reversal

Neuromuscular blocking drugs paralyse skeletal muscle at the nicotinic receptor of the motor end plate. They have **no sedative or analgesic effect**. A paralysed animal that is not adequately anaesthetised can be fully aware and in pain while unable to move, so the plane of anaesthesia must be secured first, and the patient must be ventilated because the diaphragm is also paralysed.

Non-depolarising agents (atracurium, cisatracurium, rocuronium, vecuronium) compete with acetylcholine at the receptor. They are used to give relaxation for eye, thoracic and orthopaedic surgery and to allow controlled ventilation. Their effect is reversed by increasing acetylcholine at the junction with an **anticholinesterase** such as neostigmine or edrophonium, usually given with an antimuscarinic (atropine or glycopyrrolate) to prevent bradycardia and excess secretions. Rocuronium and vecuronium can also be reversed with sugammadex, a binding agent, where it is available. Atracurium and cisatracurium break down spontaneously in plasma (Hofmann elimination), which is helpful in patients with kidney or liver disease.

Depolarising agents (suxamethonium) act like acetylcholine, causing initial fasciculations then a persistent depolarisation. They cannot be reversed with anticholinesterases, which would worsen the block. Their use in veterinary practice is limited, with risks including hyperkalaemia, muscle pain and raised intraocular pressure.

Block is monitored with a **peripheral nerve stimulator**, usually the train-of-four pattern. Fade, meaning progressively weaker twitches, indicates a non-depolarising block. Reversal should not be given until at least some twitches return, or it may fail. Before extubation, confirm recovery by return of spontaneous breathing, strong twitches and normal muscle tone. Residual block leads to hypoventilation, regurgitation and airway obstruction, so keep ventilating until recovery is certain. Hypothermia, acidosis, low potassium and some antibiotics prolong block.

Concept cleared

Concept cleared: Oxygenation versus ventilation

Oxygenation is how much oxygen sits on the haemoglobin; ventilation is how well air moves in and out and removes CO2. A patient breathing 100 per cent oxygen can have a normal pulse oximeter reading while CO2 climbs dangerously. Use the pulse oximeter for oxygenation and the capnograph for ventilation.

Concept cleared: Monitor the patient, not the machine

A trace can look normal when the animal is in trouble, and look alarming when a probe has slipped. Always confirm an abnormal reading by examining the patient, then correct the cause rather than the number.

Concept cleared: Paralysis is not anaesthesia

Neuromuscular blockers stop movement only. They do not affect consciousness or pain. Think of a locked door: the person inside is still awake. Never give a blocker without adequate anaesthesia and ventilation.

Concept cleared: Why reversal works

A competitive blocker occupies receptors, and acetylcholine cannot reach them. An anticholinesterase stops acetylcholine breakdown, so its level rises until it outcompetes the blocker. Because it also raises acetylcholine elsewhere, an antimuscarinic is given with it.

Memory aid: VOP-T

Ventilation (capnograph), Oxygenation (oximeter), Perfusion (blood pressure and ECG), Temperature. Check all four before blaming one.

Compare and contrast

What each monitor tells you

Monitor	Measures	Shows	Main limitation
Pulse oximeter	Haemoglobin saturation	Oxygenation	Late sign; poor in low perfusion; masks hypoventilation
Capnograph	Exhaled CO2	Ventilation, circuit problems, perfusion trend	Low value can reflect poor circulation
Blood pressure	Arterial pressure	Perfusion	Wrong cuff size gives false values
ECG	Electrical activity	Rhythm and rate	Does not show pumping or output
Temperature	Core heat	Heat loss or gain	Probe site affects reading

Neuromuscular blockers

Feature	Non-depolarising	Depolarising
Example	Atracurium, rocuronium	Suxamethonium
Mechanism	Competes with acetylcholine	Mimics acetylcholine, persistent depolarisation
Fasciculations	No	Yes
Reversal	Anticholinesterase or sugammadex	Not reversed by anticholinesterase
Train-of-four	Fade present	No fade (phase I block)

Species notes

Dog

Brachycephalic and obese dogs hypoventilate easily, so capnography and readiness to assist ventilation are essential. Small dogs lose heat quickly.

Cat

Cats have small tidal volumes, so capnograph sampling may under-read, and heart rate under anaesthesia can drop substantially. Their small size makes cuff size and probe site important.

Horse

Large horses commonly hypoventilate and develop hypotension and poor muscle perfusion when recumbent, so blood pressure is best measured directly and ventilation assisted. Poor recovery can injure the animal, so recovery must be supervised.

Cattle and small ruminants

Regurgitation and bloat occur in recumbent ruminants, so a cuffed tube and a head-down position protect the airway. Salivation is profuse and should be allowed to drain.

Pig

Pigs are prone to malignant hyperthermia in susceptible lines, so rising ETCO2 and temperature should alert you early. Peripheral vessels are hard to access and probe placement is difficult.

Clinical pearls

Self-test: 10 questions

1. A pulse oximeter measures:

It reports haemoglobin saturation, which reflects oxygenation, not CO2 removal.

2. A rising ETCO2 with a baseline that does not return to zero suggests:

An exhausted absorber or faulty valve returns exhaled CO2 to the patient.

3. Sudden loss of the capnograph trace should first prompt:

Possible causes include disconnection, tube obstruction, oesophageal intubation or arrest.

4. Which is a late sign of hypoventilation?

Oxygen supplementation delays SpO2 changes, so other signs appear earlier.

5. A blood pressure cuff that is too small gives:

A narrow cuff needs extra pressure to occlude the vessel.

6. The ECG alone cannot tell you:

Pulseless electrical activity shows a trace with no output.

7. Which statement on neuromuscular blockers is correct?

They paralyse muscle only, so adequate anaesthesia and ventilation are needed.

8. Neostigmine is usually given with an antimuscarinic because:

Raised acetylcholine acts on muscarinic receptors as well.

9. Train-of-four fade indicates:

Progressive weakening of the four twitches characterises competitive block.

10. Which drug breaks down by Hofmann elimination?

Atracurium breaks down spontaneously in plasma, useful in renal or hepatic disease.

Key points to revise

1. The best monitor is a trained person who stays with the patient.
2. Pulse oximetry measures oxygenation; its readings fail with poor perfusion.
3. Capnography measures ventilation and confirms tracheal intubation.
4. Blood pressure reflects perfusion; use a suitable cuff size.
5. ECG shows rhythm only; always check the pulse.
6. Anaesthesia causes hypothermia, so monitor core temperature and warm early.
7. Non-depolarising blockers compete with acetylcholine and are reversed by anticholinesterases with an antimuscarinic.
8. Suxamethonium is depolarising and is not reversed by anticholinesterases.

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- Ch 9. Anaesthesia of special patients (in this book)
- Ch 7. Analgesia and pain management (in this book)
- Veterinary drugs list: classes, uses and cautions
- Veterinary Drug Index
- Veterinary Drug Concepts Clearly Explained

Sources

- WSAVA Global Guidelines
- University of Minnesota Libraries: Pharmacology, G protein-coupled receptors
- FDA Center for Veterinary Medicine: Animal and Veterinary

CHAPTER 9 OF 14

Anaesthesia of special patients

Why neonates, old animals, caesarean patients and animals with heart, kidney or liver disease or a flat face need a changed approach. The emphasis is on physiology, drug choice reasoning, monitoring and what to do when things go wrong.

> **After this chapter you can**

- Explain why neonatal and paediatric patients respond differently to anaesthetic drugs
- Describe the age-related changes that make geriatric patients more vulnerable
- Outline anaesthetic principles for caesarean section, for the dam and the newborn
- Apply the reasoning for cardiac, renal and hepatic disease to drug and fluid choice
- List the airway risks of brachycephalic breeds and how to manage them from premedication to recovery

A general approach to the high-risk patient

Special patients have less physiological reserve, so the margin between enough anaesthesia and too much is narrow. The same plan works every time: assess the problem, stabilise before induction where possible, choose drugs that are titrated and reversible, use balanced anaesthesia to reduce inhalant needs, monitor more closely, keep the patient warm, and plan the recovery as carefully as the induction.

Always ask three questions. What does this disease do to drug uptake, distribution, metabolism and excretion? What does it do to circulation and breathing? Which drug and technique do the least harm? Prefer drugs with an antagonist or a short action, and take extra care to maintain blood pressure, oxygen delivery and body temperature. Choose the senior person for the case and do not hurry.

Complications are best met early. Falling blood pressure calls for a check of depth, volume and heart rate before any drug is added. Hypoxia calls for airway, oxygen supply and ventilation first. Hypothermia is prevented rather than treated. If cardiac arrest occurs, begin basic life support at once, call for help and follow a current veterinary resuscitation guideline.

Neonates and paediatric patients

Neonates differ from adults in several ways. Their heart rate, not stroke volume, drives cardiac output, so bradycardia reduces output sharply. The liver enzymes that metabolise many drugs are immature, and renal clearance is lower, so drug effects last longer. Plasma protein is low, which leaves more free drug. Body fat is

low and water content high, which changes distribution. Their temperature control is poor and heat is lost quickly because of a high surface area. Glycogen stores are small, so prolonged fasting risks hypoglycaemia. Oxygen consumption is high and the respiratory reserve small, so hypoxia develops fast.

The practical approach is short fasting, active warming, careful fluid and glucose management, a reversible and short-acting drug plan, and attention to airway size and tube choice. Avoid drugs that depend on hepatic metabolism for termination where possible. Monitor closely and expect slower recovery than in an adult. Fluid overload is a risk in small bodies, so measured fluids are needed.

Geriatric patients

Ageing reduces cardiac output, renal and hepatic function, lung elasticity and thermoregulation. Many older animals also have unrecognised disease, such as a heart murmur, early kidney disease, or endocrine disease. Anaesthetic requirement falls with age, so the same drug amount can produce a deeper effect. The response to hypotension is slower, and recovery is longer.

Good practice is a full pre-anaesthetic work-up, correction of dehydration and anaemia, titration of every drug to effect, careful choice of agents with a minimum of cardiovascular depression, and multimodal analgesia. NSAIDs need caution if kidney function is uncertain. Warm the patient and use supported recovery. A frequent mistake is to treat old age as a disease; it is a risk factor that is managed with preparation.

Caesarean section

There are two patients, the dam and the offspring, and the aim is a stable mother and vigorous newborns. Pregnancy increases oxygen demand and reduces lung reserve because the uterus pushes on the diaphragm. Anaesthetic requirement is reduced, gastric emptying is slowed so regurgitation risk is high, and blood volume is raised but the dam can still become hypotensive, especially when lying on her back, because the uterus compresses the vena cava. Drugs cross the placenta readily, so anything that depresses the dam may depress the newborns.

The principles: pre-oxygenate, keep the dam tilted rather than flat on her back, shorten the time from induction to delivery by preparing the surgeon and theatre

first, protect the airway with early intubation, and use agents with rapid onset and short action. Maintain blood pressure with fluids. Use opioid and other drugs with a reversal available for the newborns where appropriate, and local anaesthesia (line or epidural block) may reduce the general anaesthetic need. Prepare warmed towels, suction and resuscitation help for neonates, with drying and stimulation the first step. In cattle and small ruminants, caesarean is often done standing with local or regional blocks, which avoids recumbency risks.

Cardiac, renal and hepatic disease

Cardiac disease. The aim is to maintain cardiac output and avoid sudden changes in heart rate, preload and afterload. Stabilise heart failure and arrhythmia first. Avoid drugs that cause marked bradycardia or vasodilation, or raise heart rate and myocardial oxygen demand sharply. Alpha-2 agonists are usually avoided in significant disease because they cause bradycardia and a rise in afterload. Fluids are given cautiously, because volume overload causes pulmonary oedema. Use an ECG and direct blood pressure, and keep hypoxia and pain from adding stress. A short, steady induction technique is better than a rapid large bolus.

Renal disease. The kidney is vulnerable to hypotension. Correct dehydration, electrolyte and acid-base disturbances before anaesthesia. Maintain blood pressure and perfusion, and keep urine production under watch. Avoid NSAIDs while hydration or function is uncertain. Drugs that depend on renal excretion last longer, so choose agents with other routes of elimination.

Hepatic disease. The liver metabolises many anaesthetics and makes albumin and clotting factors. Low albumin raises free drug levels, and clotting problems increase bleeding risk with blocks and surgery. Watch for hypoglycaemia. Prefer drugs that depend less on liver metabolism or that have an antagonist, and titrate to effect. In portosystemic shunt patients, sedatives and hepatically metabolised drugs may have prolonged effects.

Brachycephalic patients

Brachycephalic breeds (bulldogs, pugs, Pekingese, Persian cats and others) have shortened skulls with stenotic nares, an elongated soft palate, narrow trachea in some, and often everted laryngeal saccules. Together they are called

brachycephalic obstructive airway syndrome. They are prone to airway obstruction, regurgitation, and hypoventilation, and they also have high vagal tone.

Management starts before induction. Avoid excess stress and heat. Give oxygen before induction, and keep it ready afterwards. Use light sedation that is titrated, because heavy sedation can cause obstruction. Pre-oxygenate, induce with a drug that allows rapid intubation, and have several tube sizes, including smaller ones, ready. Keep a laryngoscope and suction available. Monitor with capnography and oximetry.

The greatest danger is at recovery. Extubate late, only when the animal is awake with a strong swallow and can hold its head up, and keep it in sternal position with oxygen and observation. Be ready to re-intubate. Obstruction on recovery, with noisy breathing and respiratory effort, is an emergency: restore the airway, give oxygen, and call for help.

Concept cleared

Concept cleared: Reduced reserve
A healthy patient is like a car with a large fuel tank and spare tyre. A special patient has less in both. A small problem such as a drop in blood pressure or oxygen quickly becomes serious, so the plan needs earlier detection and correction.

Concept cleared: Two patients in caesarean
A drug that reaches the dam reaches the fetus through the placenta. The ideal plan therefore keeps the dam stable and uses agents that are short acting or can be antagonised, so the newborns are born breathing.

Concept cleared: Why neonates are slow to clear drugs
The enzymes and kidney function that clear drugs in adults are still maturing, so drug effect lasts longer. Short-acting, reversible drugs are favoured to make up for that.

Concept cleared: Recovery is the dangerous phase for flat-faced breeds

The airway is narrowest and sedation is wearing off at the same time. A breed that cannot hold its airway open needs the tube kept in place until it is fully awake, and oxygen and close observation until it breathes easily.

Memory aid: SPECIAL: titrate and prepare

Stabilise first, Plan the recovery, Evaluate the organs, Choose reversible drugs, Intubate and oxygenate, Always warm, Look closely (monitor). Use it as a checklist for any special patient.

Compare and contrast

Special patients: main problem and main response

Patient	Main problem	Core response
Neonate	Immature clearance, poor temperature control, low glucose reserve	Short fasting, warmth, reversible drugs, careful fluids
Geriatric	Reduced organ reserve, hidden disease	Work-up, titrate, support blood pressure, supported recovery
Caesarean	Placental drug transfer, regurgitation, vena cava compression	Pre-oxygenate, tilt, rapid delivery, protect airway
Cardiac	Limited output	Avoid sudden rate and afterload changes; careful fluids
Renal	Hypotension injury, delayed excretion	Correct dehydration, maintain pressure, avoid NSAIDs
Hepatic	Reduced metabolism, low albumin, clotting	Titrate, choose less liver-dependent drugs, watch glucose
Brachycephalic	Airway obstruction, regurgitation	Pre-oxygenate, tubes ready, late extubation

Why each system matters for drug effect

Factor	Neonate	Geriatric	Liver disease	Renal disease
Metabolism	Immature	Reduced	Reduced	Normal
Excretion	Reduced	Reduced	Normal	Reduced
Protein binding	Low	Often lower	Low	Variable
Heat control	Poor	Reduced	Variable	Variable

Species notes

Dog

Brachycephalic breeds need airway-first planning, and sighthounds are often sensitive to some drugs because of low body fat and slow metabolism of some induction agents; titrate carefully. Herding breeds with the MDR1 variant may react strongly to some sedatives and opioids, so check breed history.

Cat

Cats have limited hepatic glucuronidation, so many drugs act longer. Cardiomyopathy is often silent in cats, so a murmur or gallop calls for assessment. Persian and similar breeds are brachycephalic and need airway planning.

Horse

Foals and geriatric horses need warmth, glucose and blood pressure support. Pregnant mares can be hypotensive when recumbent; plan for careful recovery in a padded area.

Cattle, sheep and goats

Caesarean often uses local or regional blocks, which avoids regurgitation and recumbency. Check withdrawal times and the current Indian rules for residues before choosing drugs in food animals.

Pig

Obese or pregnant pigs have limited respiratory reserve and are slow to recover. Temperature and ventilation

need attention, and difficult airways make intubation harder.

Clinical pearls

Self-test: 10 questions

1. Why is bradycardia especially harmful in neonates?

Neonatal stroke volume is limited, so a slow rate reduces output sharply.

2. Which statement about neonatal anaesthesia is correct?

Immature enzymes and kidney function slow clearance; short fasting and warmth are needed.

3. In a caesarean patient, lying on the back may cause hypotension because:

The gravid uterus reduces venous return when the patient is supine.

4. A key principle for caesarean is to:

Because drugs cross the placenta, a short induction-to-delivery interval protects the newborns.

5. Which drug class is generally avoided in significant cardiac disease?

They cause bradycardia and increase afterload, reducing output.

6. In renal disease the most important protective step is to:

Kidney injury from hypotension is the main risk during anaesthesia.

7. Hepatic disease may lead to:

Reduced metabolism and protein synthesis raise free drug levels and cause bleeding risk.

8. The most dangerous period for brachycephalic breeds is:

Airway narrowing and fading sedation coincide, so obstruction can follow extubation.

9. For a brachycephalic dog, extubation should be:

The tube protects the airway until the animal can maintain it.

10. A geriatric patient should be managed by:

Reduced reserve and hidden disease call for assessment and slow titration.

Key points to revise

1. Special patients have less physiological reserve and need careful titration and monitoring.
2. Neonates clear drugs slowly, lose heat quickly and have small glucose reserves.
3. Geriatric patients need a work-up and often have hidden disease.
4. Caesarean section: pre-oxygenate, avoid back-lying, protect the airway, and prepare for newborn resuscitation.
5. Cardiac disease: maintain output and avoid abrupt rate or afterload changes.
6. Renal disease: correct dehydration and avoid hypotension and NSAIDs.
7. Hepatic disease: lower drug metabolism, low albumin and clotting problems.
8. Brachycephalic patients: airway kit ready, late extubation, oxygen and observation in recovery.

Go deeper on this site

- Ch 10. Species-specific anaesthesia (in this book)
- Ch 8. Monitoring and neuromuscular blockade (in this book)
- Veterinary drugs list: classes, uses and cautions
- Veterinary Drug Index
- Veterinary Drug Concepts Clearly Explained

Sources

- WSAVA Global Pain Council Guidelines
- Cornell University College of Veterinary Medicine: Drug sensitivity (MDR1)
- WSAVA Global Guidelines

CHAPTER 10 OF 14

Species-specific anaesthesia

Why one anaesthetic plan cannot be copied from species to species. The chapter covers the main anatomical, physiological and metabolic differences in dogs, cats, horses, cattle and buffalo, small ruminants, pigs, birds and exotic pets, and the complications each difference invites.

After this chapter you can

- Explain why species and breed change drug choice, monitoring and recovery planning
- Describe the main anaesthetic risks of dogs (including sighthounds, brachycephalic and herding breeds) and of cats
- Explain why horses and ruminants need special attention to recumbency, recovery and regurgitation
- Identify the pig-specific risks: difficult intubation, malignant hyperthermia and vascular access
- Describe how avian and reptile respiratory anatomy and body temperature alter anaesthetic management

Why species matter

An anaesthetic drug is only as safe as the animal it is given to. Species differ in body size, airway shape, stomach design, liver enzymes, temperature control and temperament. A plan that is routine in a Labrador can be hazardous in a cat, a buffalo or a parrot.

Three questions help in every species. What is the **main threat to life** in this animal (airway, regurgitation, hypotension, hypothermia, recumbency injury)? Which **drug properties** suit it (reversible, short acting, little metabolism needed)? How will I **monitor and recover** it safely? This chapter answers these questions species by species. Only concepts are given; doses must always be taken from a current formulary or the product label.

Remember also that breed within species matters, and that the individual patient (age, hydration, pregnancy, liver or kidney disease) can outweigh the species rule.

Dog and cat

Dogs show the widest breed variation of any domestic species.

- **Brachycephalic breeds** (Pug, Bulldog, Boxer) have narrow nostrils, a long soft palate and often a small trachea. Heavy sedation can cause airway obstruction. Give oxygen before induction, keep the airway under watch until the animal is fully awake, and extubate late.
- **Sighthounds** (Greyhound and similar) have little body fat and slower recovery from ultra-short barbiturates, so propofol or other redistribution-independent choices are favoured. Their normal laboratory values also differ from other dogs.
- **Herding breeds** with the MDR1 (ABCB1) mutation can show exaggerated, prolonged sedation from some drugs such as acepromazine and butorphanol; use cautious titration.

Cats are not small dogs. Their small body mass means rapid heat loss and easy overdose from small measurement errors. The larynx is prone to **laryngospasm** on intubation; topical local anaesthetic on the larynx and gentle technique reduce this. Cats are slow at glucuronidation, so some drugs (paracetamol is toxic; many NSAIDs need a cat-specific label) accumulate. Ketamine is largely cleared unchanged through the kidney in cats, so it is a poor choice in a cat with urinary obstruction. Alpha-2 agonists commonly cause vomiting in cats, which matters if the airway is unprotected.

Horse

The horse is a large, flighty animal with an unusual recovery risk. Most serious injuries (fractures, head trauma, spinal damage) happen not at induction but in **recovery**, when a heavy, uncoordinated animal tries to stand.

Key concepts:

- **Planned induction**: a quiet area, adequate sedation first (usually an alpha-2 agonist), then an induction agent, and a padded, well-lit box with an assistant controlling the head.
- **Recumbency effects**: a lying horse has a large V/Q mismatch because lung under its own body weight collapses; hypoxaemia is common and oxygen supplementation is standard in prolonged cases.
- **Hypotension and myopathy**: low arterial pressure and prolonged recumbency cause poor muscle perfusion and postanaesthetic myopathy or neuropathy. Good padding, positioning and blood pressure support reduce the risk.
- **Colic risk**: alpha-2 agonists and opioids slow gut motility. Pre-existing colic patients are high-risk.

A common confusion: horses are not fasted in the same way as ruminants. Fasting is usually brief and tailored, and clinic policy and case type decide it.

Cattle and buffalo

The ruminant stomach explains most anaesthetic hazards. Under sedation or general anaesthesia, rumen fermentation continues, gas cannot be belched, and the animal may **bloat** and **regurgitate** rumen fluid. Fluid in the pharynx is easily aspirated, and aspiration pneumonia can follow days later.

Practical consequences:

- Withhold feed (and sometimes water) before elective procedures, following local practice, to reduce rumen load.
- Use a **cuffed endotracheal tube** for general anaesthesia and keep the head and neck lower than the rumen so fluid drains out of the mouth.
- Cattle are very **sensitive to xylazine** and need much lower doses per kilogram than horses. A heavily sedated cow often lies down, which is itself a risk.

- Xylazine can stimulate uterine contraction, so it must be used carefully in late pregnancy.

Buffalo are generally managed like cattle, but they are often more nervous when handled by strangers and can overheat easily in hot weather, so avoid the afternoon sun and keep water available. Because published guidance is mostly for cattle, apply it cautiously and monitor closely. Both species are food animals, so check drug approval and withdrawal times under current Indian rules.

Small ruminants and pigs

Sheep and goats share the ruminant risks of bloat and regurgitation. Some additional points:

- Sheep can develop hypoxaemia and pulmonary changes after alpha-2 agonist sedation, so many clinicians use low-dose, reversible protocols with oxygen available.
- Goats are more sensitive to the toxic effects of local anaesthetics than many species, so total volume must be calculated carefully, especially in kids and thin animals.
- Small ruminants are easily handled, which tempts people to skip monitoring. Do not.

Pigs are a different problem. The IV route is difficult (the ear vein is the usual site), the larynx is long and prone to spasm, and the neck is short. Fat adds a thick layer through which intramuscular injections may not reach muscle. Some pigs, particularly stress-susceptible lines, are prone to **malignant hyperthermia** triggered by halogenated volatile agents and succinylcholine; the signs are rapidly rising temperature, muscle rigidity and tachycardia. Prevention is to avoid triggers in at-risk animals and to have cooling, oxygen and specific treatment ready. Pigs also squeal and struggle when restrained, so a calm approach with sedation first is better than forcing.

Birds and exotics

Birds do not have a diaphragm. They breathe by moving the sternum, and gas flows in one direction through the lungs, with air sacs acting as bellows. So anything that **restrains the sternum** (a tight hand, a heavy drape, dorsal positioning) can stop

ventilation. Birds under anaesthesia often need **assisted ventilation**, as their breathing can slow fast. Small birds lose heat and glucose quickly, so fasting must be short and warmth is vital. Isoflurane or sevoflurane delivered by mask or tube is a common choice, as these allow quick changes in depth. Tracheal rings in birds are complete, so overinflated cuffs can injure the trachea.

Reptiles are ectotherms: drug metabolism and recovery depend on body temperature, so the animal must be kept within its preferred range. They can hold their breath and have intracardiac shunts, which changes the speed of gas induction.

Rabbits and small mammals are prone to stress-related deaths. Rabbits are obligate nasal breathers, have a small mouth opening that makes intubation hard, and their long hind legs and light skeleton may fracture the spine during struggling. Rabbits cannot vomit, so prolonged fasting is not needed and may do harm. Always handle exotics gently, warm them, and record every sign. If unsure about a species, consult an exotic-animal specialist.

Concept cleared

Concept cleared: Why ruminants regurgitate
Think of a large fermentation tank that never stops bubbling. When the animal is lying down and sedated, the gas cannot be released and the liquid can flow back up. A cuffed tube and a head-down position let the liquid run out instead of into the lungs.

Concept cleared: Brachycephalic airway
Imagine breathing through a narrow straw with a floppy flap at the end. Sedation relaxes the flap further. The breed was bred for a short face, but the soft tissue stayed long, so airway control comes first.

Concept cleared: Avian ventilation
A bird breathes like a bellows pumped by its breastbone. If you press on the keel, you take away the pump. That is why birds need to be held loosely and often need assisted ventilation under anaesthesia.

Concept cleared: Recovery risk in horses

Anaesthesia is like landing an aeroplane: the take-off is easy, but the landing is where accidents happen. A padded box, a calm assistant and a patient plan protect the horse as it relearns to stand.

Memory aid: Species risk shortcuts

Dog = Dental and Direction of the airway (brachycephalic). Cat = Cold. Horse = Hit on recovery. Ruminant = Regurgitate and bloat. Pig = Pyrexia (malignant hyperthermia). Bird = Breastbone must move.

Compare and contrast

Main anaesthetic hazard by species

Species	Main hazard	Key precaution
Dog (brachycephalic)	Airway obstruction	Oxygen, late extubation, careful sedation
Cat	Hypothermia, laryngospasm, drug accumulation	Warmth, topical laryngeal local anaesthetic, cat-specific drugs
Horse	Injury in recovery, hypotension, myopathy	Padded recovery, blood pressure support, assisted recovery
Cattle and buffalo	Bloat, regurgitation, aspiration	Cuffed tube, head low, reduced alpha-2 sensitivity
Pig	Malignant hyperthermia, difficult intubation	Avoid triggers, cooling ready
Bird	Ventilation failure, heat loss	Free sternum, assisted ventilation, warmth

Breed and species sensitivities

Group	Sensitivity	Practical meaning
Sighthound	Slow recovery from some barbiturates	Prefer propofol-type drugs
MDR1 herding breeds	Prolonged sedation with some drugs	Titrate carefully
Cat	Slow glucuronidation	Avoid paracetamol; NSAID only per cat label
Cattle	Very sensitive to xylazine	Use much lower doses than horses
Goat	Sensitive to local anaesthetic toxicity	Calculate total volume carefully

Species notes

Dog

Check breed: brachycephalic, sighthound and MDR1 herding breeds all change drug choice and recovery watching.

Cat

Keep warm, use topical local anaesthetic on the larynx, and avoid ketamine if the urinary tract is blocked.

Horse and ruminants

Horses need a safe recovery; ruminants need a cuffed tube, head position and fasting plan to prevent aspiration.

Sheep, goat and pig

Small ruminants may be sensitive to alpha-2 agonists and to local anaesthetic toxicity; pigs risk malignant hyperthermia.

Birds and exotics

Free the sternum, support ventilation, and warm the patient. Rabbits are stress-prone and cannot vomit.

Clinical pearls

Self-test: 10 questions

1. Which complication is most closely linked to ruminant general anaesthesia?

Rumen contents can flow back and enter the airway when the animal is recumbent and sedated, so a cuffed tube and head-down position are used.

2. Why do brachycephalic dogs need special airway care?

Their airway anatomy predisposes them to obstruction, worsened by sedation.

3. Which drug choice is generally favoured in sighthounds for induction?

Sighthounds have little fat and recover slowly from barbiturates that depend on redistribution.

4. In which phase do many horse fractures occur?

The heavy horse tries to stand before it is coordinated, so recovery needs planning.

5. Why can birds stop breathing if held tightly across the chest?

Birds lack a diaphragm, so restraining the sternum stops the bellows action.

6. Malignant hyperthermia in pigs is typically triggered by:

Susceptible pigs react to these triggers with rigidity, heat and tachycardia.

7. Goats are particularly sensitive to which drug class?

Total dose and volume of local anaesthetic must be calculated carefully in goats.

8. Which statement about rabbits is correct?

Because they cannot vomit, long fasting is not needed, and intubation is technically difficult.

9. Why is ketamine a poor choice in a cat with urethral obstruction?

Reduced urine flow prolongs the effect and may lead to a longer recovery.

10. Compared with horses, cattle are:

Cattle need much lower doses per kilogram of xylazine and may lie down when sedated.

Key points to revise

1. Species, breed and individual condition all change anaesthetic risk.
2. Brachycephalic dogs need airway control and oxygen.
3. Sighthounds are slow with some barbiturates; propofol is often preferred.
4. Cats lose heat fast and are prone to laryngospasm.
5. Horses are most at risk in recovery and from hypotension and myopathy.
6. Ruminants bloat and regurgitate, so use a cuffed tube and head-down position.
7. Pigs may develop malignant hyperthermia with some triggers.
8. Birds lack a diaphragm, so sternal restraint stops ventilation.

Go deeper on this site

- Ch 11. Field anaesthesia and standing sedation in livestock (in this book)
- Ch 9. Anaesthesia of special patients (in this book)
- Veterinary drugs list: classes, uses and cautions
- Veterinary Drug Index
- Veterinary Drug Concepts Clearly Explained

Sources

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- University of Wisconsin-Madison RARC: Species Guidelines on Anesthesia and Analgesia
- Merck Veterinary Manual: Exertional Myopathies in Horses

CHAPTER 11 OF 14

Field anaesthesia and standing sedation in livestock

How to plan safe sedation and pain control for cattle, buffalo, small ruminants and horses when the clinic is a cowshed or a village lane. The chapter covers restraint, standing sedation with regional blocks, handler and animal safety, recovery, and the mistakes that most often cause field accidents.

> **After this chapter you can**
>
> - Explain why standing sedation with local or regional analgesia is preferred for many livestock procedures
> - Describe safe restraint and handler positioning for large animals
> - List the monitoring and emergency items needed even in a basic field kit
> - Explain how to manage recovery and avoid bloat, aspiration and injury
> - Identify common field mistakes and how to avoid them

Why standing sedation is often better in the field

In rural practice there is usually no operating table, no oxygen cylinder, no ventilator and no assistant trained in anaesthesia. The patient may be a milch cow, a working bullock, a buffalo or a pony. In such conditions general anaesthesia of a large animal is risky. A heavy animal lying on a hard floor can suffer nerve and muscle damage, and a ruminant can bloat or aspirate.

The safer approach for many procedures is **standing sedation plus local or regional analgesia**. Sedation controls behaviour and fear. Local analgesia blocks pain at the site. Together they permit procedures such as wound repair, teat surgery, rumenotomy through the flank, caesarean section in cattle, and many dehorning or castration cases, with the animal on its feet.

The aim is not to make the animal unconscious but to make it **calm, pain-free and safe**. Choose the lightest plan that works and be ready to change it.

Planning, restraint and handler safety

Assess before drugs: species, temperament, body condition, hydration, pregnancy, heart and respiratory disease, and the procedure planned. A shocked, dehydrated or very thin animal needs a lighter plan, and perhaps fluids first.

Choose a **safe place**: a non-slip floor, shade, space to work, and a way to get out. Use a crush or a stout post and secure the head with a halter or rope. Tie the animal short enough to control it, but with a quick-release knot so a falling animal does not choke.

Know where animals kick. Horses kick backward but can strike forward; cattle kick forward and sideways with a hind leg in a wide arc; buffalo may be quick and unpredictable. Stand close to the body rather than at full leg-length, with a hand on the animal so you can feel movement, and never kneel or stand directly behind. Keep onlookers and children well away. Wear sturdy footwear and avoid working alone.

Sedation does not remove danger. A sedated animal can wake at a sudden noise or pain, so treat it as unpredictable until recovery is complete.

Sedation and local or regional analgesia

The usual sedative class in field practice is the **alpha-2 agonists** (xylazine and related drugs). They give sedation, muscle relaxation and some analgesia, are cheap and reversible with an alpha-2 antagonist. Side effects include bradycardia, an initial rise then fall in blood pressure, reduced gut motility, salivation, drooling, and in ruminants a tendency to lie down and bloat. Cattle are far more sensitive than horses, so horse protocols must never be copied.

Where available, a benzodiazepine or other adjunct can reduce the alpha-2 requirement, and an opioid can add analgesia, but choice depends on law, access and species. Dose and route must come from a current formulary or the product label.

Local and regional techniques include:

- **Line and inverted-L blocks** for flank surgery.
- **Paravertebral blocks** for the flank in cattle, which give wider desensitisation but need anatomical skill.
- **Cornual nerve block** for horn procedures.
- **Caudal epidural** for tail, perineal, vaginal or rectal procedures and for obstetrics. A high-volume epidural can spread forward and cause hind-limb weakness and collapse, so keep the standing animal supported.

Local anaesthetics are limited by total dose, especially in small ruminants and thin animals, so calculate before drawing up. Always aspirate before injecting to avoid intravascular injection.

Monitoring and emergencies in a basic kit

Monitoring in the field relies on the senses and a few simple tools. Watch **breathing rate and pattern**, **mucous membrane colour**, **heart rate** (stethoscope or femoral/facial pulse), **eye position and reflexes**, **jaw tone** and **body temperature**. In hot weather, sedated cattle and buffalo can overheat, so keep them shaded and cool.

A basic emergency kit should contain: the **reversal agent** for the sedative used, an anticholinergic if bradycardia is dangerous, fluids, a cuffed endotracheal tube or a way to secure the airway where possible, a rope for emergency positioning, and a plan for calling help. If the animal goes down unintentionally, lift the head, check the airway, position it in **sternal recumbency** with the head and neck extended, and treat bloat or regurgitation at once.

Record the drug name, time given and animal weight estimate. These records help if you must repeat treatment or if the animal develops late problems.

Recovery and withdrawal

Recovery is part of the procedure. Keep the animal in a quiet, shaded, non-slip place until it is fully steady. Do not let it walk or return to herd, road or water until the sedation has worn off or been reversed and the gait is normal.

Watch for **bloat**, which can develop within hours after alpha-2 agonist use because the animal cannot belch while sedated. Left unchecked, bloat compresses the lungs

and heart. Ensure the animal is upright and offer no feed until it is alert and the gut is working.

If an animal is down, keep it in sternal position, propped with bales or sacks if needed. Avoid lateral recumbency with the head level with the body, as this encourages regurgitation.

Livestock are food animals. Many sedatives, analgesics and anaesthetics have **withdrawal periods** for milk and meat, and some are not permitted for use in food animals. Check the current product label and the latest Indian regulations or notifications before using any drug, and advise the owner clearly on when milk and meat can be used.

Common field mistakes

Most field accidents come from a short list of errors.

- **Guessing weight and copying horse protocols.** Overdosing causes collapse, bloat and respiratory depression. Estimate weight with a tape or chart, and use species-specific references.
- **Relying on sedation alone for painful work.** Without local analgesia, the animal will kick, and the surgeon will be tempted to give more sedative.
- **Not waiting for onset.** Starting early leads to repeat dosing and overdose. Allow time for the drug to act.
- **Ignoring pregnancy, dehydration and heat.** Late-pregnant, shocked or overheated animals are less tolerant.
- **No reversal agent and no plan for a downed animal.**
- **Too much epidural volume**, causing hind-limb collapse.
- **Poor casting practice.** Casting on hard ground, or leaving the animal on one side too long, causes nerve and muscle injury.
- **Forgetting withdrawal times** and failing to tell the owner.
- **Working alone or allowing crowds.**

A short checklist before every case (weight, health, drug, reversal, restraint, helpers, escape route, recovery area, withdrawal advice) prevents most of these.

Concept cleared

Concept cleared: Sedation versus analgesia

Sedation is like turning down the animal's volume and fear; analgesia is like cutting the wire that carries pain. A calm animal can still feel a knife, so painful work needs a block as well.

Concept cleared: Why cattle lie down

Cattle are very sensitive to alpha-2 agonists. Think of an adjustable dimmer switch that is already close to the maximum in a cow, whereas the same turn gives only half the effect in a horse.

Concept cleared: Bloat after sedation

A cow belches thousands of times a day to release rumen gas. Sedation switches off this reflex, so the gas builds up like a balloon pressing on the chest.

Concept cleared: Standing is safer

An animal on its feet keeps its airway, rumen and muscle circulation working as nature designed. Lying down a heavy animal removes these advantages, so only do it when needed.

Memory aid: Field checklist: WHERE-SAFE

Weight, Health, Equipment, Reversal, Escape route, Sedation level, Analgesia block, Food withdrawal, Environment (shade and floor). Run through it before every case.

Compare and contrast

Standing sedation versus field general anaesthesia

Feature	Standing sedation with block	Field general anaesthesia
Airway control	Animal protects its own	Needs tube and assistance
Risk of bloat and aspiration	Lower	Higher
Muscle and nerve injury	Low	Higher on hard ground
Equipment needed	Simple	Oxygen, tube, monitoring
Best for	Flank surgery, teat, wound, obstetrics	Short lying procedures when unavoidable

Common regional blocks

Block	Area desensitised	Caution
Line or inverted-L	Flank incision line	Uneven depth; large volume
Paravertebral	Flank wall	Needs skill; scoliosis and hypotension if misplaced
Cornual	Horn base	Check withdrawal and species
Caudal epidural	Tail, perineum, vagina	Too much volume may cause collapse

Species notes

Cattle
Very sensitive to xylazine, so use cattle-specific references. Watch for bloat and regurgitation; keep head and neck extended.

Buffalo
Handle quietly, avoid heat and prolonged restraint, and plan for stress. Apply cattle guidance cautiously.

Sheep and goat
Easy to restrain but small margin for local anaesthetic overdose and

Horse and donkey
Less sensitive than cattle but may kick or strike; donkeys and mules

alpha-2 effects on breathing. Keep monitoring.

can be stoic, hiding pain and sedative depth.

Pig
Seldom handled standing; use calm approach and sedation before restraint. Beware malignant hyperthermia in susceptible lines.

Clinical pearls

Self-test: 10 questions

1. Why is standing sedation preferred in many field procedures?

A standing animal avoids many dangers of recumbency such as bloat, aspiration and muscle damage.

2. A calm sedated cow is still kicking during a flank incision. The main reason is:

Sedation does not guarantee analgesia; a block is needed for painful work.

3. Which hazard is especially linked to alpha-2 agonist sedation in ruminants?

The animal cannot belch when sedated and recumbent.

4. A too large caudal epidural volume may cause:

Spread forward blocks nerves to the hind limbs.

5. If a sedated cow goes down, the best position is:

Sternal position allows eructation and reduces aspiration risk.

6. Which should be in every field emergency kit?

Reversal allows rapid correction of overdose, such as respiratory depression or collapse.

7. Why should horse protocols not be copied for cattle?

Cattle need much lower doses per kilogram; overdose causes recumbency and bloat.

8. Which animal handling error is most hazardous?

This is the range of the kick.

9. Before treating a dairy cow, which extra step is essential?

Residues in food are a public health concern and rules apply.

10. Which is a common cause of late recovery injury?

A partly sedated animal may fall or wander onto hazards.

Key points to revise

1. Standing sedation with local or regional analgesia is often safer than general anaesthesia in the field.
2. Assess the animal before choosing a plan.
3. Handler position and escape routes prevent kick injuries.
4. Alpha-2 agonists cause sedation but also bradycardia, salivation and bloat risk.
5. Calculate local anaesthetic totals, especially in small ruminants.
6. Caudal epidural overdose can cause collapse of the hind limbs.

7. Recovery needs a quiet place, upright posture and bloat watch.
8. Withdrawal times must be checked and explained to the owner.

Go deeper on this site

- Ch 12. Chemical restraint and capture of wildlife (in this book)
- Ch 10. Species-specific anaesthesia (in this book)
- Veterinary drugs list: classes, uses and cautions
- Veterinary Drug Index
- Veterinary Drug Concepts Clearly Explained

Sources

- Merck Veterinary Manual: Tranquilizers, Sedatives, and Analgesics for Treatment of Animals
- University of Wisconsin-Madison RARC: Species Guidelines on Anesthesia and Analgesia
- WSAVA: World Small Animal Veterinary Association

CHAPTER 12 OF 14

Chemical restraint and capture of wildlife

The concepts behind immobilising free-ranging and zoo animals with drugs: the main drug classes and why potent opioids are used, darting principles, handler safety, and the two great killers, hyperthermia and capture myopathy. It also outlines how zoo and Forest Department work is organised, with legal points hedged.

After this chapter you can

- Describe the main classes of immobilising agents and the reason for combining them
- Explain the principles of darting and the main factors that decide success or failure
- List the hazards to handlers and how to reduce them, including opioid exposure

- Explain the causes, signs and prevention of hyperthermia and capture myopathy
- Outline how zoo and Forest Department practice is organised and regulated in India

Why wildlife is different

Wild and zoo animals cannot be handled like pets or livestock. They are fearful, strong, often dangerous, and they cannot be examined or moved without restraint. **Chemical restraint** uses drugs to immobilise or sedate an animal for examination, treatment, translocation, sampling or rescue.

Two facts define this field. First, the margin of safety is small: the animal's weight is estimated, its health is unknown, and stress alters the drug response. Second, the animal's own struggle and the capture process can kill it even if the drugs are perfect. Good practice therefore means as little chase, noise and handling time as possible, a plan for every foreseeable emergency, and a team in which each person has a role. All doses and combinations must be taken from current wildlife formularies and experienced colleagues; this chapter gives only concepts.

Immobilising agents: the concepts

Wildlife drugs must work in a small volume, act fast, be safe in different species, and ideally be reversible. This explains the main groups.

- **Potent opioids** (etorphine, carfentanil) are extremely potent, so a tiny volume fits in a dart. They produce deep immobilisation in many large hoofed animals and elephants but cause respiratory depression, hypoxaemia and often hypertension and a rise in body temperature. They are reversible with opioid antagonists. They are **dangerous to humans**; a tiny exposure can be life-threatening, and an antagonist and a second trained person must be present.
- **Alpha-2 agonists** (xylazine, medetomidine and related drugs) give sedation and muscle relaxation and are reversible. They are used alone or with other drugs.
- **Dissociative anaesthetics** (ketamine, tiletamine) with a benzodiazepine-like partner are widely used in carnivores and primates. They are not fully reversible, so recovery may be slow and rough.

- **Neuroleptics** (azaperone and similar long-acting tranquillisers) calm animals for transport and are used to reduce stress.
- **Benzodiazepines** add muscle relaxation and a calmer recovery.

Drugs are **combined** to reduce each dose, shorten the time to immobilisation, and lower side effects. The price is more complicated monitoring.

Species matter: a drug that is safe in one family may be dangerous in another. Always follow a species-specific reference.

Darting principles

Delivery is usually by dart fired from a projector (gas, powder or blowpipe for short range). The key principles are:

- **Weight estimate and drug volume**: the dart volume is limited, so concentrated drugs are used. An underestimate means incomplete immobilisation and a long, stressful chase; an overestimate risks overdose.
- **Site**: aim for a large muscle mass such as the hindquarter or shoulder. Avoid the chest, abdomen, spine, head and joints, where the dart can cause serious injury.
- **Distance and angle**: stay within the effective range of the projector; a dart striking at too high a speed or at an angle can bruise or penetrate too deeply.
- **Environment**: choose cool hours of the day, clear ground, away from water, cliffs, dense bush and roads. Many animals have drowned when they entered a pond or river as they went down.
- **Tracking**: note the direction of flight, keep the animal in sight, and know the expected time of effect. A lost darted animal can be in danger and dangerous.
- **Minimise excitement**: no crowds, no noise, no pursuit on vehicles if avoidable.

Every dart should be accounted for, because a lost or misfired dart is a risk to humans and animals.

Handler safety

Wildlife work endangers people in three ways: from the animal, from the drugs, and from the environment.

- **Opioid exposure**: potent opioids can be absorbed through broken skin, mucous membranes, needle-stick or splash. Wear gloves and eye protection, handle

darts with care, never recap needles, and keep the antagonist and medical support ready. Never work alone with these drugs, and ensure the local hospital knows of the risk.

- **Approach to the animal**: do not assume it is fully immobilised. Approach from behind after the expected time, check for a response to a gentle touch of a long stick, and protect the head and eyes. Many animals recover suddenly.
- **Team roles**: one person leads, one handles drugs, one monitors the animal, one controls the crowd and others deal with transport. Practise before the real event.
- **Environment**: heat, terrain, darkness and conflict situations with a crowd or village increase risk. Police or forest staff should control the site.

Never allow untrained persons to hold, photograph or crowd an immobilised animal.

Hyperthermia, capture myopathy and monitoring

Hyperthermia is the commonest killer after capture. Heat comes from muscle activity during the chase or struggle, from the drug (potent opioids and some combinations raise body temperature), from a hot day, and from restricted heat loss when the animal lies on hot ground. Signs include fast, shallow breathing, high rectal temperature, a rapid pulse and weakness. Action: move to shade, wet the animal with cool water, fan it, and reverse the drug if needed. Never cool so fast that you cause shock.

Capture myopathy is a non-infectious muscle disease caused by exertion, struggling and stress during capture, restraint or transport. It is often fatal. Muscle breaks down, the blood becomes acidic, and the kidneys can be damaged by muscle pigment. Signs may appear during capture or hours to days afterwards: stiffness, weakness, an abnormal gait, collapse, dark urine and sudden death. Treatment is mainly supportive and results are often poor, so **prevention** is the key: short pursuit, short handling time, cool conditions, minimal noise, adequate sedation and a quiet recovery.

During immobilisation, monitor breathing, heart rate, temperature and oxygen saturation, and supply oxygen if the animal is hypoxic. Keep the animal in sternal position if possible, with the head and neck extended and the eyes protected.

Zoo and Forest Department practice in India

In India, immobilisation of wild animals is usually done by veterinarians working with the Forest Department, zoo authorities, rescue centres or research bodies. Most species are protected under wildlife law, so capture, treatment, translocation and release generally need formal permission from the competent authority, and the rules and procedures are updated from time to time. **Check the current Wildlife (Protection) Act provisions, rules, guidelines and orders** for the exact process in your state.

Potent opioids and several other immobilising drugs are controlled substances. Their purchase, storage, record keeping and use are regulated under narcotic and drug laws; **check the current notifications and local authority requirements** before holding or using them.

Common practice includes a written plan with the team roles, a risk assessment, notification of the local officers, a veterinary kit with antidotes, a transport vehicle and a destination or release plan. Post-event reports record the drug, time, response, complications and outcome. Human-wildlife conflict captures (for example of leopards or tigers near villages) add crowd control and public safety issues, and good communication with local people is part of the job.

Release should be at a suitable site and time of day, after full recovery. If an animal is not fit, it should go to a rescue centre or receive veterinary care.

Concept cleared

Concept cleared: Why use potent opioids
A dart can only carry a small volume, like a thimble. A very potent drug fits a full dose into the thimble, whereas a weaker drug would need a bucket. The cost is that a tiny splash on a human is also a full dose.

Concept cleared: Capture myopathy
Imagine running a sprint until your muscles burn, and then continuing for hours. The muscle cells break down and leak into the blood, which can damage the kidneys. A wild animal's chase does the same, but it cannot stop or ask for help.

Concept cleared: Heat from struggle

Muscle work turns fuel into heat. A darted animal that runs 20 minutes on a hot day is already close to its limit before the drug even acts. That is why cool hours and a short chase matter.

Concept cleared: Reversibility

A reversible drug has an undo button. When an animal is in trouble, the antagonist can bring it back quickly. Drugs without an antagonist demand more careful planning and longer monitoring.

Memory aid: DART safety

Distance and site, Antidote ready, Rehearsed team roles, Temperature watch. Before every capture, check each letter.

Compare and contrast

Immobilising drug groups

Group	Main advantage	Main concern	Reversal
Potent opioids	Tiny volume, deep effect in large hoofed animals	Respiratory depression, heat, human danger	Opioid antagonist
Alpha-2 agonists	Sedation and relaxation	Bradycardia, hypotension, respiratory effects	Alpha-2 antagonist
Dissociatives (with partner drug)	Wide use in carnivores and primates	Rough recovery, seizure risk	No specific antagonist
Neuroleptics	Calming for transport	Hypotension, slow onset	No specific antagonist
Benzodiazepines	Muscle relaxation, smoother recovery	Weak alone	Specific antagonist exists

Hyperthermia versus capture myopathy

Feature	Hyperthermia	Capture myopathy
Main cause	Heat from exertion, drug and weather	Muscle damage from exertion and stress
Timing	During or soon after capture	During capture to days or weeks later
Signs	Fast breathing, high temperature	Stiffness, weakness, dark urine, collapse
Key action	Cool, reverse, oxygen	Prevent; supportive care
Prevention	Cool hours, short chase	Short chase, calm, quick handling

Species notes

Elephant

Large size and potent opioids are common; protect the airway and avoid long lateral recumbency, as heavy weight compresses the lungs.

Big cats (tiger, leopard)

Often immobilised for rescue or conflict. Protect the eyes, monitor breathing and temperature, and keep the crowd away.

Deer and antelope

Highly prone to capture myopathy and stress. Reduce chase time and keep recovery quiet.

Rhinoceros and other large hoofed animals

Opioid-induced hypoxaemia and hyperthermia are common; oxygen and cooling should be ready.

Primates and bears

Dissociative combinations are common; handle carefully, as recovery may be rough and the animal may suddenly rouse.

Clinical pearls

Self-test: 10 questions

1. Why are very potent opioids used in dart drugs for large animals?

Darts hold limited volume, so high-potency drugs make immobilisation possible.

2. Which is the preferred dart site?

Muscle absorbs the drug and avoids injury to vital organs.

3. What must be ready when potent opioids are used?

Human exposure can be life-threatening and rapid treatment is needed.

4. Which feature best describes capture myopathy?

It is a non-infectious muscle disease and signs can appear after capture.

5. A darted animal runs toward a pond. The main risk is:

Drugged animals may collapse in water; choose sites away from water.

6. Which action helps a hyperthermic immobilised animal?

Cooling reduces temperature and prevents organ damage.

7. Why are drugs combined in wildlife immobilisation?

Combinations give effect with a smaller volume and fewer effects.

8. Which statement about legal rules is best?

Rules change and state processes vary.

9. Which group of drugs is typically not fully reversible?

Dissociatives have no specific antagonist, so recovery may be slow and rough.

10. When is the best time for most captures?

Cool conditions reduce hyperthermia and capture myopathy risk.

Key points to revise

1. Chemical restraint carries risk to the animal and to people.
2. Drug combinations reduce volume and side effects.
3. Potent opioids need antagonists and extreme care.
4. Dart site, distance and environment affect safety.
5. Hyperthermia needs rapid cooling and reversal where possible.
6. Capture myopathy is best prevented by reducing stress and exertion.
7. Monitor breathing, heart rate, temperature and oxygen.
8. Legal permission and drug control rules must be checked in current notifications.

Go deeper on this site

- Ch 13. Anaesthesia safety, records and controlled drugs (in this book)
- Ch 11. Field anaesthesia and standing sedation in livestock (in this book)
- Veterinary drugs list: classes, uses and cautions
- Veterinary Drug Index
- Veterinary Drug Concepts Clearly Explained

Sources

- Pennsylvania Game Commission: Capture Myopathy
- Merck Veterinary Manual: Tranquilizers, Sedatives, and Analgesics for Treatment of Animals

- WOAH: Animal welfare

CHAPTER 13 OF 14

Anaesthesia safety, records and controlled drugs

Safe anaesthesia depends on systems as much as on drugs: checklists before use, a continuous anaesthetic record, honest risk assessment, secure handling of controlled drugs, and a culture that reports near-misses. This chapter explains why each habit exists and how it protects the patient and the team.

After this chapter you can

- Describe the purpose and content of pre-anaesthetic and pre-use equipment checklists
- Explain why a continuous anaesthetic record is both a safety tool and a legal document
- Outline how patient risk is assessed and reduced before induction
- State the principles of secure storage, issue and logging of controlled drugs, with Indian rules hedged
- Explain why near-misses should be reported and how a no-blame culture improves safety

Why systems matter more than single drugs

Most anaesthetic deaths in animals are not caused by a rare drug reaction. They follow ordinary, preventable events: a flat oxygen cylinder, a disconnected breathing circuit, an undetected fall in blood pressure, a mislabelled syringe, or a patient left unwatched. Safety therefore rests on **habits and systems** that catch errors before they reach the animal.

Three tools do most of this work: **checklists** (before the case), the **anaesthetic record** (during the case) and **reporting** (after the case). Controlled-drug procedures add a fourth layer that protects the public and the clinic from misuse.

Checklists before the animal is touched

A checklist is a short, fixed list checked item by item, every time. Its value is that it does not depend on memory on a busy day. Aviation uses the same idea. There are

two linked checks.

1. **Equipment check.** Confirm oxygen supply and reserve, vaporiser fill and secure fitting, correct breathing system for the species and size, leak test of the circuit and bag, working valves, soda lime that is not exhausted (for rebreathing circuits), scavenging connected, suction working, a range of endotracheal tubes with cuffs tested, a laryngoscope that lights, and monitors switched on and probes available.
2. **Patient and plan check.** Confirm identity, procedure, weight, fasting status, pre-anaesthetic examination and any tests, existing disease, current medicines, allergies, owner consent, and the drugs planned with the reasoning for each.

Also prepare the **emergency kit** before induction: reversal agents, emergency drugs drawn up or ready to draw, an airway kit and a clear plan for who does what. Many emergencies are survivable only because the equipment was already within reach.

A common confusion is to treat the checklist as paperwork. It is a thinking tool: the pause makes the team ask whether the plan really fits this animal.

Assessing and reducing risk

Risk is the chance that anaesthesia harms this particular patient. It depends on the animal, the procedure, the drugs and the people. Many practices use a simple physical-status grading (such as the ASA system, from healthy to moribund) to summarise the animal's condition and to communicate it. The grade guides how much preparation and monitoring are needed. It does not replace clinical judgement.

Patient factors that raise risk include extremes of age (neonates and geriatrics), obesity, dehydration, anaemia, cardiac, respiratory, renal or hepatic disease, emergency surgery, and breed features. Brachycephalic dogs and cats have airway obstruction risk; sighthounds respond differently to some drugs because of low body fat and different metabolism; some herding-breed dogs carry the MDR1 mutation and may be sensitive to certain sedatives and opioids; horses and ruminants carry special risks of positioning injury, myopathy and regurgitation.

Risk is reduced by **stabilising before anaesthetising** (correct dehydration, treat pain, delay non-urgent cases), choosing drugs for the patient rather than by habit,

using the lowest-risk plan that still gives safe conditions, securing the airway, and monitoring continuously. Owners should be told honestly that anaesthesia always carries some risk, higher in sick animals, and consent should reflect this.

The anaesthetic record

The anaesthetic record is a written or electronic chart made **during** the case, not reconstructed afterwards. It serves three purposes. It shows **trends**, because a single heart rate means little but a steady downward drift is a warning. It forces the person monitoring to look at the patient and the monitors at regular intervals. It is also a **medical and legal record** of what was given and what happened.

A good record contains: patient identification and weight; physical status; pre-anaesthetic findings; every drug given with route and time (premedication, induction, maintenance, analgesics, fluids, reversal); airway details; and then regularly timed entries of heart rate and rhythm, respiratory rate, oxygenation, end-tidal carbon dioxide where available, blood pressure, temperature, depth of anaesthesia and vaporiser or infusion settings. Events (start of surgery, position changes, complications, treatments) and recovery details are also noted.

Two cautions. First, record values you actually observed; do not fill in the chart to look normal. Second, the monitor shows numbers but the **trained person** interprets them. A designated person whose only job is the patient should be present until the animal is fully recovered.

Controlled drugs: storage, logs and responsibility

Several drugs used in anaesthesia and analgesia, especially opioids and some sedatives and dissociatives, can be abused or diverted. Rules in most countries therefore require secure storage and traceable records. The details in India depend on the drug and change over time: opioids and some psychotropic substances fall under narcotic and psychotropic legislation, while other drugs are controlled under drug and prescription rules. **Check the current notifications and your State licensing requirements** for which drugs are covered and what is required.

The principles are the same everywhere.

- **Locked, limited-access storage**, with named key holders. Keys are not left in the lock.

- **A running register** for each drug: date, patient, amount used, amount wasted, the person who gave it, and the balance remaining. Entries are made at the time and corrected by a visible, signed amendment, never by erasing.
- **Regular stock reconciliation**, comparing the physical stock with the register, with any discrepancy investigated and documented promptly.
- **Witnessed wastage** of any unused drug, and safe disposal.
- **Authorised prescribers only**, and drugs are used only for patients under the veterinarian's care.

These steps also protect staff. Needle-sharing, diversion and accidental self-injection are real hazards, and a clear audit trail protects honest staff from suspicion.

Near-misses, reporting and a learning culture

A **near-miss** is an error or unsafe condition that was caught before it harmed the patient: a syringe drawn from the wrong vial and noticed, an empty cylinder found at induction, a circuit connected wrongly. A **critical incident** reached the patient and caused or could have caused harm. Both teach the same lessons, and near-misses are far more common than harm.

Units that learn from near-misses write them down in a simple, brief form: what happened, what helped catch it, and what could change. The review looks for **system causes** (poor labelling, similar-looking vials, crowded drug trays, rushed turnover, missing checklist) rather than a person to blame. A no-blame, just culture makes staff more willing to report, and unreported errors repeat.

Practical measures include clear drug labelling, colour-coded or syringe labels, separating look-alike drugs, double-checking high-risk drugs, a standard drug concentration policy, and regular review meetings. For students, the habit to build is simple: say what you see, ask when unsure, and record what happened honestly.

Concept cleared

Checklists catch errors that memory misses

A fixed pre-use checklist for equipment and for the patient removes reliance on memory and is repeated for every case, however routine.

The record shows trends

A continuously charted anaesthetic record turns isolated numbers into trends, prompts regular observation and serves as a medical and legal document.

Risk is assessed and then reduced

Physical-status grading and patient factors guide the plan. Stabilise first, choose drugs for the individual animal and monitor continuously.

Controlled drugs need an audit trail

Locked storage, a contemporaneous register, reconciliation and witnessed wastage prevent diversion and protect staff. Indian specifics must be checked against current notifications.

Memory aid: Before every induction: ARMS

Airway kit and tubes, Reversal and emergency drugs, Monitors on and working, Supply of oxygen and suction. Then confirm the patient and plan.

Compare and contrast

Near-miss versus critical incident

Feature	Near-miss	Critical incident
Reached the patient	No, caught in time	Yes
Harm	None	Harm or potential for harm
Value for learning	High and more frequent	High but costly
Action	Report, find system cause	Treat, report, review and inform owner

Equipment check versus patient check

Feature	Equipment check	Patient and plan check
Focus	Oxygen, circuit, vaporiser, suction, monitors	Identity, weight, fasting, disease, consent
When	Start of the day and before each case	Before premedication and again before induction
Typical failure caught	Leak, empty cylinder, exhausted soda lime	Wrong patient, missed disease, wrong drug plan

Species notes

Dogs
Check breed cautions in the plan: brachycephalic airways, sighthound drug handling and the MDR1 mutation in some herding breeds.

Cats
Small size makes dead space, circuit choice and heat loss important to check. Record temperature carefully.

Horses
Plan padding, positioning and a safe recovery area. Large body mass makes equipment and personnel checks essential.

Ruminants
Record fasting status and plan for regurgitation and bloat. Cuffed tubes and positioning are part of the checklist.

Pigs and exotics
Heat loss, difficult airways and species-specific risks need pre-planned equipment and a named person to monitor.

Clinical pearls

Self-test: 10 questions

1. What is the main purpose of a pre-use checklist?

A fixed list ensures essential checks are done every time, whatever the workload.

2. When should the anaesthetic record be filled?

Contemporaneous charting shows trends and keeps the observer engaged.

3. Which finding is best caught by a circuit leak test?

Leak testing is part of the equipment check and is done before the animal is connected.

4. What does physical-status grading do?

It communicates risk, but clinical judgement still decides the plan.

5. How should an error in a controlled-drug register be corrected?

Register integrity requires that the original entry remains legible.

6. What is a near-miss?

Near-misses show system weaknesses without patient harm.

7. Which approach best encourages reporting of errors?

People report more when review aims at fixing systems.

8. Which is a patient factor that raises anaesthetic risk?

Dehydration and anaemia reduce reserve, so stabilise them first when possible.

9. Why is reconciliation of controlled-drug stock done regularly?

Comparing physical stock with the register shows losses promptly.

10. Who should monitor an anaesthetised animal?

Monitors give numbers, but a trained person interprets them and acts.

Key points to revise

1. Most anaesthetic harm follows preventable system failures rather than rare drug reactions.
2. Use a fixed checklist for equipment and another for the patient and plan.
3. Prepare emergency drugs, reversal agents and airway equipment before induction.
4. Physical-status grading summarises risk and guides preparation, but does not replace judgement.
5. Stabilise the patient before anaesthesia whenever the procedure is not an emergency.
6. A continuous anaesthetic record shows trends and is a legal document.
7. Controlled drugs need locked storage, a contemporaneous register, reconciliation and witnessed wastage; check current Indian notifications.
8. Report near-misses in a no-blame way and fix the system cause.

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- Ch 14. Anaesthetic complications and CPR (in this book)
- Ch 12. Chemical restraint and capture of wildlife (in this book)
- Veterinary drugs list: classes, uses and cautions
- Veterinary Drug Concepts
- Veterinary Drug Concepts Clearly Explained

Sources

- WSAVA Global Pain Council guidelines
- Merck Veterinary Manual
- FDA Center for Veterinary Medicine, Animal and Veterinary

CHAPTER 14 OF 14

Anaesthetic complications and CPR

Anaesthesia can cause hypotension, hypoventilation, hypothermia, regurgitation, malignant hyperthermia and cardiac arrest. This chapter explains how each arises, how it is recognised early, the logical first response, and the basic sequence of cardiopulmonary resuscitation and safe recovery.

After this chapter you can

- Explain the causes, early signs and first responses to hypotension and hypoventilation
- Describe why hypothermia occurs and why it matters in recovery
- Explain how regurgitation occurs and how it is prevented and managed
- Recognise malignant hyperthermia and outline its emergency management
- Outline the steps of cardiopulmonary resuscitation and the principles of a safe recovery

Think in terms of oxygen delivery

Most anaesthetic complications reduce the delivery of oxygen to tissues. Delivery depends on **ventilation** (oxygen reaching the blood), **circulation** (cardiac output and blood pressure), and **haemoglobin** (oxygen carrying capacity). Any complication can be understood by asking which of these has failed.

The best rule is to **respond to trends, not crises**. Monitoring and the anaesthetic record let you see a problem developing. The first step is almost always the same: check the patient, check the equipment, make sure of the airway, give 100% oxygen, and consider reducing anaesthetic depth. Only then look for the specific cause.

Hypotension and hypoventilation

Hypotension is low arterial blood pressure. It reduces perfusion of the brain, heart and kidneys. Common causes are anaesthetic overdose or excessive depth (most inhalants and injectable agents lower blood pressure by vasodilation and reduced cardiac output), hypovolaemia, bleeding, bradycardia, arrhythmias, sepsis and drug effects. It is often present before it is obvious, so measure blood pressure rather than guess from pulse quality.

The logical response is to treat the cause: reduce anaesthetic depth if it is too deep, use balanced anaesthesia with analgesics so less inhalant is needed, correct volume deficits and bleeding with fluids or blood products when indicated, treat bradycardia or arrhythmia, and use drugs that support the heart or vessels where needed. Avoid treating a number without looking for the reason behind it.

Hypoventilation means too little breathing to remove carbon dioxide. Most anaesthetics and opioids depress the respiratory centre, and chest or abdominal pressure, position, obesity and airway obstruction add to this. The signs are a rising carbon dioxide level (end-tidal measurement, if available) and eventually falling oxygen saturation. Pulse oximetry can look normal on high oxygen while ventilation is poor, so oxygen saturation alone does not exclude hypoventilation.

The response is to confirm that the airway is open and the tube is correctly placed, reduce depth, and assist or control ventilation by manual or mechanical means. Keep the technique gentle, because over-inflation damages lungs and impairs venous return.

Hypothermia

Anaesthesia blunts the temperature-regulating response and causes vasodilation, so heat is lost to cold theatres, wet skin, clipped areas, cold fluids and open body cavities. Small patients such as cats, small dogs, neonates and exotics lose heat fastest. Large animals lose less quickly but take long to rewarm.

Hypothermia is not harmless. It slows drug metabolism so that animals sleep longer, reduces anaesthetic requirement (so a given setting is relatively deeper), slows the heart, impairs clotting, increases infection risk and delays healing. During recovery, **shivering sharply increases oxygen demand** when the animal may have little spare capacity.

Prevention is easier than treatment: measure temperature, keep the animal off cold surfaces, use warm air or insulating covers, limit wetting and warm fluids. Warm gradually. Direct hot-water bottles or heating pads can burn anaesthetised skin, so use insulation between the animal and any heat source.

Regurgitation and aspiration

Regurgitation is the passive backflow of stomach or oesophageal contents into the pharynx, because the muscle tone of the lower oesophageal sphincter falls under anaesthesia. It differs from **vomiting**, which is active. Gastric content reaching the airway causes **aspiration pneumonia**, a serious complication. Stomach acid is damaging to lung tissue.

Risk is higher with a full stomach, emergency cases, obesity, brachycephalic breeds, hiatal hernia, oesophageal disease, certain drugs, and in ruminants, whose rumen produces large volumes of fluid and gas. Fasting protocols differ by species and age, and very young animals should not be fasted for long because of hypoglycaemia.

Prevention: appropriate fasting, a rapid and secure airway with a **cuffed endotracheal tube inflated** as soon as it is placed, positioning with the head slightly higher than the stomach in small animals (in ruminants, keep the head lower than the pharynx so that fluid drains out), and cautious recovery with the tube left in until the swallowing reflex returns. If regurgitation occurs, lower the head to drain, suction the pharynx, protect the airway with the cuff, and monitor for coughing, hypoxia or later pneumonia.

Malignant hyperthermia

Malignant hyperthermia is a rare, inherited, life-threatening reaction in which skeletal muscle goes into uncontrolled hypermetabolism after exposure to **volatile inhalant anaesthetics** or the depolarising relaxant **succinylcholine**. It is best described in pigs and also reported in dogs, horses and people. A defect in calcium handling in muscle allows calcium to flood the cell, so muscle burns energy and produces heat and carbon dioxide.

Early signs: rapid rise in end-tidal carbon dioxide despite adequate ventilation, fast heart rate and breathing, muscle rigidity, and then rapidly rising temperature. Later:

acidosis, high potassium, arrhythmias, and muscle breakdown.

Management is an emergency: **stop the triggering agent**, move to a clean oxygen supply and a circuit free of inhalant, ventilate with 100% oxygen, actively cool the animal, treat acidosis and arrhythmias, and give **dantrolene**, the specific drug that blocks the release of calcium in muscle. Prepare in advance in susceptible patients by avoiding triggers. A common confusion is that fever after surgery is not malignant hyperthermia; the pattern of early carbon dioxide rise and rigidity points to it.

Cardiac arrest, CPR and recovery

Cardiac arrest is the loss of effective circulation. Under anaesthesia, it most often follows unrecognised hypoxia, deep anaesthesia, severe hypotension, arrhythmia or electrolyte disturbance, so prevention depends on monitoring. If it happens, act immediately. The principles of current veterinary guidelines (such as the RECOVER initiative) are:

1. **Recognise** arrest: no palpable pulse, no heartbeat, loss of monitored waveform and no breathing. Call for help and note the time.
2. **Stop anaesthetic delivery** and give 100% oxygen. Check the airway and secure it with a tube if not in place.
3. **Start chest compressions at once**, hard and fast, allowing full chest recoil. Minimise interruptions. Position the hands according to species and chest shape. Rotate the person compressing regularly because fatigue reduces quality.
4. **Ventilate** in coordination with compressions without over-inflating.
5. **Attach the ECG** to identify the rhythm. This guides the use of drugs and, if a shockable rhythm, defibrillation.
6. **Give drugs through IV or intraosseous access** according to the current guideline and reverse any reversible agents.
7. **Look for the cause** (for example hypoxia, hypovolaemia, overdose, tension pneumothorax) and treat it, and reassess regularly.

Outcomes from arrest under anaesthesia are better than from arrest in sick animals, but survival is still limited, which is another reason to prevent it.

Recovery is a high-risk period. Keep monitoring until the animal is awake, breathing normally, warm and able to hold its head up. Maintain analgesia, keep the airway

protected until swallowing returns, avoid stimulation, and place large animals in a padded, quiet area with trained staff.

Concept cleared

Oxygen delivery framework
Ask whether ventilation, circulation or oxygen carrying capacity has failed. Give oxygen and secure the airway first, then find the cause.

Treat causes of hypotension
Hypotension usually reflects depth, volume, rate or drug effects. Treat the underlying reason, not just the number.

Passive regurgitation is prevented by airway protection
A cuffed tube, correct positioning and appropriate fasting are the main defences against aspiration.

Malignant hyperthermia is a muscle calcium disorder
Triggered by inhalants and succinylcholine, it causes a rapid rise in carbon dioxide and temperature, and is treated by stopping triggers, cooling and dantrolene.

Memory aid: Complication check: AVOID
Airway open, Ventilation adequate, Oxygen supply and depth reduced, Intravenous fluids and circulation, Depth and drugs reviewed. Do this before looking for rare causes.

Compare and contrast

Regurgitation versus vomiting

Feature	Regurgitation	Vomiting
Mechanism	Passive backflow	Active reflex with abdominal effort
Under anaesthesia	Common, silent	Rare because reflexes are depressed
Warning	May be unnoticed until fluid at the mouth	Retching and salivation
Main risk	Aspiration pneumonia and oesophagitis	Aspiration if airway unprotected

Hypoventilation versus hypoxaemia

Feature	Hypoventilation	Hypoxaemia
Problem	Too little carbon dioxide removed	Too little oxygen in blood
Best monitor	End-tidal or arterial carbon dioxide	Pulse oximetry or blood gas
Effect of 100% oxygen	May hide it on pulse oximetry	Often improves it
Response	Assist or control ventilation	Find the cause and improve oxygenation

Species notes

Dogs
Brachycephalic breeds regurgitate and obstruct easily. Barrel-chested breeds may need different compression positioning in CPR.

Cats
Lose heat quickly and hypoventilate easily. Compression is often done with one hand or around the chest.

Horses
Hypotension and poor ventilation are common under general anaesthesia and recovery injuries are a major

Ruminants
Regurgitation and bloat are major risks. Use a cuffed tube and keep the

risk, so plan padded, supervised recovery.

head lower than the pharynx so fluid drains outward.

Pigs
Some lines are susceptible to malignant hyperthermia. Avoid triggers and be ready to cool and treat.

Clinical pearls

Self-test: 10 questions

1. What is the first general response to an anaesthetic complication?

Securing oxygenation and reducing depth treat the commonest underlying problems.

2. Why can pulse oximetry mislead during hypoventilation?

Animals breathing high oxygen may keep normal saturation while carbon dioxide rises.

3. A common cause of hypotension under anaesthesia is:

Most anaesthetics cause vasodilation and reduce cardiac output.

4. Why does shivering during recovery matter?

Shivering consumes oxygen when reserves may be limited.

5. Regurgitation differs from vomiting because it is:

Regurgitation is passive backflow due to reduced sphincter tone.

6. Which measure best protects against aspiration?

A cuffed tube seals the airway while positioning helps drainage.

7. Malignant hyperthermia can be triggered by:

These agents release calcium in susceptible muscle.

8. Which drug is the specific treatment for malignant hyperthermia?

Dantrolene blocks calcium release in skeletal muscle.

9. In CPR, what should be started immediately after recognising arrest?

Early, high-quality compressions maintain some circulation.

10. Why should heating pads be insulated from the animal?

Anaesthetised animals cannot move away from heat or signal pain.

Key points to revise

1. Most complications reduce oxygen delivery through ventilation, circulation or haemoglobin.
2. Respond to trends. First check the patient and equipment, give oxygen and reduce depth.
3. Treat the cause of hypotension rather than the number.
4. Hypoventilation raises carbon dioxide and may be hidden by pulse oximetry on oxygen.
5. Prevent hypothermia with measurement, insulation and warming, avoiding direct hot surfaces.
6. Regurgitation is passive; a cuffed tube and positioning protect against aspiration.

7. Malignant hyperthermia: stop triggers, cool, ventilate with oxygen and use dantrolene.
8. CPR needs early, high-quality compressions, ventilation, ECG, drugs per current guidelines and a search for the cause.

Go deeper on this site

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How to use Book 5: a short discussion

Anaesthesia is the part of veterinary practice where drug knowledge, physiology and careful observation meet in a single hour. A good anaesthetic is not the one with the cleverest drug combination; it is the one in which the animal is assessed beforehand, monitored throughout, and recovered safely. This book follows that path in fourteen chapters, from the first examination of the patient to the management of an emergency.

Preparation comes first

The opening chapter covers pre-anaesthetic assessment, fasting, physical status grading and equipment checks. Most anaesthetic accidents trace back to poor preparation and inadequate monitoring rather than to one dangerous drug, so this chapter is worth reading twice. The chapters on sedation and injectable agents then

explain why premedication lowers the dose of everything that follows and how each drug class suits or harms different species and breeds.

Maintenance, equipment and monitoring

Inhalation anaesthesia, breathing circuits and monitoring are treated as a connected system. You will meet minimum alveolar concentration, vaporisers, absorbers, pulse oximetry, capnography and blood pressure, and you will learn what each number tells you about the patient and what it cannot tell you. The monitoring chapter also covers neuromuscular blocking drugs and their reversal.

Pain relief and regional techniques

Analgesia is part of anaesthesia, not an optional extra. The chapters on pain management and on local and regional anaesthesia explain how pain pathways work, why combining drugs from different classes gives better relief with fewer side effects, and how nerve blocks and epidurals are used in dogs, cats and livestock. They also explain the signs of local anaesthetic toxicity, which every student should be able to recognise.

Species, field practice and wildlife

Dogs, cats, horses, cattle, buffalo, small ruminants, pigs and birds each respond differently, and the species chapter collects those differences. The field chapter deals with the real conditions of Indian rural practice, where equipment is limited and standing sedation with local blocks is often the safest choice. The wildlife chapter covers the principles of chemical restraint and capture, including handler safety and capture myopathy, and it points out that permissions and controlled-drug rules must be checked before any work begins.

Safety, records and emergencies

The last two chapters cover checklists, anaesthetic records, controlled-drug storage and logs, and the management of complications and cardiac arrest. Reading about hypotension, hypoventilation, regurgitation and malignant hyperthermia in advance is far better than meeting them for the first time on the table.

Recovery and the hours after surgery

Many students stop thinking about the patient once the vaporiser is turned off, yet recovery is when airway obstruction, hypothermia, pain and violent emergence are most likely. Throughout the book you will find reminders to keep the airway protected until the animal swallows, to keep it warm, to keep monitoring, and to continue analgesia into the recovery period. Brachycephalic dogs, cats, horses and ruminants each have their own recovery risks, and the chapters point them out so that you can plan for them in advance.

A note on doses

As in the other books, there are no dose tables or infusion rates. Doses depend on the product, the patient and the situation, and they must come from the label, a current formulary or an experienced anaesthetist. The book gives you the reasoning behind a plan so that you can judge a protocol and ask the right questions. Use the self-tests after each chapter, read the Species notes before an examination, and treat this material as education that does not replace the judgement of a registered veterinarian.