Anaesthesiology

MBBS Recap: high-yield notes for revision

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Fast revision notes for the MD/MS entrance, one section per topic of the practice questions; open the section a wrong answer points to.

Preoperative assessment

ASA physical status

Class	Meaning	Example
I	Healthy, non-smoking, little or no alcohol	Fit adult for hernia repair
II	**Mild** systemic disease, no functional limit	Controlled hypertension, smoker, BMI 30–40
III	**Severe** systemic disease that limits activity	Poorly controlled diabetes, COPD, old MI
IV	Severe disease that is a **constant threat to life**	Recent MI with ischaemia, sepsis with organ failure
V	**Moribund**, not expected to survive 24 h without the operation	Ruptured aneurysm
VI	Brain-dead patient, organs being retrieved	

Add **E** for an emergency. ASA class predicts risk but does not describe the operation or the airway.

Fasting (adults and children, elective surgery)

Exam answer (ASA 2017, kept in its 2023 update), the "2-4-6-8" rule:

- **Clear liquids 2 h** (water, black tea or coffee without milk, clear juice without pulp, carbohydrate drinks).
- **Breast milk 4 h.**
- **Infant formula, non-human milk and a light meal 6 h** (milk curdles in the stomach and empties like a light meal).
- **Fried, fatty or meat meal 8 h** or more.
- ASA 2023 update: **carbohydrate-containing clear drinks are allowed up to 2 h** in healthy adults (about 400 mL); **chewing gum does not delay** an elective case (remove it before induction); children: clear liquids as close to 2 h as possible.

Current practice in children (ESAIC 2022 paediatric guideline, the "6-4-3-1" rule): **clear fluids up to 1 h, breast milk 3 h, formula 4 h, light meal 6 h**. In adults 2 h remains standard. Answer 2 h unless the question names the European paediatric guideline.

GLP-1 agonists (semaglutide, liraglutide, tirzepatide) slow gastric emptying, and residual gastric contents have been found despite normal fasting. ASA consensus 2023: hold the weekly drug 1 week and the daily drug on the day. Multisociety guidance 2024 (AGA, ASMBS, SAGES, endorsed by ASA): **most patients continue**; a 24-h clear-liquid diet for those at high risk (escalation phase, high dose, GI symptoms), gastric ultrasound when unsure, and treat as a full stomach (RSI) if contents are found. Guidance still differs between bodies.

Full stomach and aspiration

- Risk groups: intestinal obstruction, emergency surgery, pregnancy (from the second trimester, and in labour), obesity with reflux, hiatus hernia, diabetic gastroparesis, raised intra-abdominal pressure, recent trauma or opioid.
- In pregnancy three things add up: raised abdominal pressure, slowed gastric emptying and a lax lower oesophageal sphincter. Bag-mask ventilation and the laryngeal mask are relatively unsafe for this reason.
- **Rapid sequence induction (RSI):** preoxygenate for 3 min (or 8 vital-capacity breaths), give a pre-measured induction dose and a rapid relaxant together, apply cricoid pressure (**10 N awake, 30 N once unconscious**), avoid mask ventilation, intubate with a cuffed tube, release pressure only after cuff inflation and confirmation. Relaxant: succinylcholine 1–1.5 mg/kg or rocuronium 1–1.2 mg/kg (reversible with sugammadex). Cricoid pressure (Sellick) is now debated, because it may worsen the laryngeal view; it remains the classical exam answer.
- Prophylaxis: **sodium citrate 0.3 M, 30 mL** (neutralises existing acid at once), H2 blocker or proton-pump inhibitor (works on acid made later), metoclopramide (empties the stomach). **Mendelson syndrome** (1946, obstetric) is chemical pneumonitis from acid aspiration; the classic risk values are **pH below 2.5 and volume above 25 mL (0.4 mL/kg)**. Supine, aspirate goes to the **posterior segment of the right upper lobe and superior segment of the right lower lobe**; upright, to the right lower lobe basal segments.

Drugs around surgery

Drug	Advice
Beta-blocker, statin	**Continue**; never stop a beta-blocker abruptly
Antihypertensives	Continue; **ACE inhibitor or ARB** is commonly omitted for 24 h before (refractory induction hypotension); ACC/AHA 2024: continuing is reasonable in heart failure with reduced ejection fraction
Aspirin	Usually **continue** (POISE-2); stop (about 7 days) only for intracranial, spinal canal, posterior eye chamber or transurethral prostate surgery
P2Y12 inhibitors (surgery, ACC/AHA 2024 and ESC 2022)	**Clopidogrel 5 days, ticagrelor 3–5 days, prasugrel 7 days**; the exam answer for clopidogrel is often 7 days

Drug	Advice
Coronary stent (ACC/AHA 2016 and 2024, ESC 2022)	Delay elective surgery **14 days after balloon angioplasty, 30 days after a bare-metal stent**, and after a **drug-eluting stent ideally 6 months** for stable disease (ESC 2022: 12 months if placed for an acute coronary syndrome); at least 3 months if surgery is time-sensitive; **keep aspirin** throughout. (Older ACC/AHA 2007–2014 teaching: 12 months after a DES)
Warfarin	Stop **5 days** before, aiming at INR below 1.5 (normal INR for neuraxial block); if INR is still above 1.5 the day before, **oral vitamin K 1–2 mg**; bridging heparin only for high thrombotic risk (mechanical mitral valve, recent stroke or VTE), since BRIDGE (2015) showed more bleeding and no fewer clots in atrial fibrillation
DOACs, surgery (ACCP 2022, PAUSE trial)	Apixaban, rivaroxaban, edoxaban: **1 day** off for low or moderate bleeding risk, **2 days** for high; dabigatran 1–2 days, **longer (2–4 days) if creatinine clearance is below 50 mL/min**; no bridging
Neuraxial block timings	See the table under Spinal and epidural
Metformin	Withhold on the day; **SGLT2 inhibitors 3 days** before (ertugliflozin 4), for euglycaemic ketoacidosis (FDA 2020, ACC/AHA 2024)
GLP-1 agonists	See fasting, above
Insulin	About 75–80 % of the usual long-acting dose the night before; glucose 140–180 mg/dL (7.8–10 mmol/L) around surgery; variable-rate insulin infusion for major surgery
Steroids	Continue and add a perioperative supplement if on long-term treatment
Lithium	Stop 24–72 h before major surgery; restart when eating and renal function is normal
MAO inhibitors	Exam answer: stop **2 weeks** before (irreversible agents). Current practice: continue, and **avoid pethidine and indirect sympathomimetics (ephedrine)**
Antidepressants, antiepileptics, antipsychotics, antiparkinson drugs	Continue
Combined oral contraceptive, HRT	Stop **4 weeks** before major surgery or surgery with immobilisation of a leg

Risk assessment

- Functional capacity: **4 METs** (climbing a flight of stairs, walking up a hill) is the usual threshold; ACC/AHA 2024 also uses the Duke Activity Status Index (DASI above 34 is adequate). Below it, further testing only if the result would change management; BNP or NT-proBNP and troponin help stratify (ESC 2022, ACC/AHA 2024).
- **Revised Cardiac Risk Index (Lee, 1999)**, six items: ischaemic heart disease, heart failure, cerebrovascular disease, insulin-treated diabetes, **creatinine above 2 mg/dL**, high-risk (intraperitoneal, intrathoracic or suprainguinal vascular) surgery.
- Wait at least **60 days** after a myocardial infarction for elective non-cardiac surgery (ACC/AHA); classic teaching: re-infarction risk about 30 % within 3 months, 15 % at 3–6 months, 5 % after 6 months, so older books say 6 months.
- Smoking cessation: benefit grows with time, at least 4 weeks and ideally 8; carboxyhaemoglobin clears in 12–24 h. **STOP-BANG** (score 3 or more: high risk) screens for obstructive sleep apnoea.
- **Surgery after COVID-19** (answer with the version the question names):
  - Earlier ASA/APSF statements (December 2020 and March 2021, the figures still often quoted): **4 weeks** if asymptomatic or mild non-respiratory symptoms; **6 weeks** if symptomatic (cough, dyspnoea) without admission; **8–10 weeks** if symptomatic and diabetic, immunocompromised or admitted; **12 weeks** after ICU care. UK consensus 2021 (after COVIDSurg 2021, which found raised mortality up to 6 weeks): no elective surgery within **7 weeks** unless delay is riskier.
  - **Current**: **ASA/APSF (February 2022, revised June 2023)**: **no elective surgery within 2 weeks** of infection; between **2 and 7 weeks** only a low-risk patient for a low-risk procedure, after a risk assessment; consider waiting beyond 7 weeks if symptoms persist. **UK multisociety 2023** (Association of Anaesthetists, Royal Colleges; Anaesthesia 2023): avoid surgery for 2 weeks after a positive test; for recovered, low-risk patients or low-risk surgery **most elective surgery can proceed after 2 weeks**; 2–7 weeks, an individual risk assessment; no benefit in waiting beyond 7 weeks after recovery from mild infection.

Premedication

Aims: anxiolysis (midazolam), amnesia, antisialogogue (glycopyrrolate, atropine), aspiration prophylaxis, analgesia. In children, **oral midazolam 0.5 mg/kg** (maximum about 15–20 mg) 20–30 min before is a common choice; intranasal dexmedetomidine is a modern alternative.

Airway

Assessment

- **Mallampati** (modified by Samsoon and Young, 1987; sitting, mouth fully open, tongue out, no phonation): **I** soft palate, fauces, uvula and pillars; **II** soft palate, fauces and uvula (pillars hidden); **III soft palate and base of the uvula only**; **IV soft palate not seen, hard palate only**. Mallampati's original 1985 scale had three classes. Classes III and IV predict difficulty; Ezri's class 0 (epiglottis visible) predicts easy laryngoscopy.
- Other predictors: mouth opening below 3 cm (less than three fingers), **thyromental distance below 6 cm** (Patil; some use 6.5 cm), sternomental distance below 12.5 cm, short thick neck, limited neck extension, prominent upper incisors, receding mandible, poor jaw protrusion. LEMON is a common checklist (Look, Evaluate 3-3-2, Mallampati, Obstruction, Neck mobility).

Laryngoscopic view: Cormack–Lehane

Grade	View
I	Full glottis
II	Posterior glottis only (IIa partial cords, IIb arytenoids only)
III	**Epiglottis only**, no glottis
IV	No glottic structure, not even epiglottis

Grade III and IV are difficult laryngoscopy. Percentage of glottic opening (POGO) and the BURP manoeuvre are refinements.

Positioning

- **Sniffing position**: flexion of the lower cervical spine with extension at the atlanto-occipital joint, which lines up the oral, pharyngeal and laryngeal axes.
- The **ramped (HELP) position** places the ear level with the sternal notch in the obese. The Rose position (extension at both) is used for tonsillectomy.
- Head elevation of about 7–10 cm in adults, with no pillow in infants (large occiput).

Tubes and devices

- Adult tube internal diameter: **8–9 mm men, 7–8 mm women**; depth at the incisors about **23 cm in men, 21 cm in women**.
- Children: **uncuffed tube = age/4 + 4 mm; cuffed tube = age/4 + 3.5 mm** (a 4-year-old takes 5.0 uncuffed, 4.5 cuffed); term neonate 3.0–3.5 mm. Cuffed tubes are now preferred in children too (lower cuff pressures, fewer tube changes). Oral depth about **age/2 + 12 cm**, nasal age/2 + 15 cm.
- Cuff pressure **20–30 cm H2O**; high-pressure low-volume cuffs cause tracheal ischaemia and stenosis, low-pressure high-volume cuffs cause more aspiration.
- Murphy eye gives an alternative path for gas if the bevel is blocked.
- **Laryngeal mask (LMA)** sits in the hypopharynx outside the larynx, so it does **not** protect against aspiration. Sizes by weight: 1 below 5 kg; 1.5 for 5–10; 2 for 10–20; 2.5 for 20–30; 3 for 30–50; 4 for 50–70; 5 for 70–100; 6 above 100. Second-generation devices (ProSeal, i-gel) have a gastric channel.
- Confirmation: **sustained waveform capnography** is the surest sign; bronchoscopy gives exact position. Ultrasound of the trachea helps in low-flow states.

Complications

- Most commonly injured structure: **upper central incisors**.
- Laryngospasm: 100 % oxygen, CPAP, jaw thrust (pressure at Larson's point), deepen with propofol (about 0.5 mg/kg), then **succinylcholine** if persistent (0.1–0.5 mg/kg IV can break it; 1 mg/kg IV, or 4 mg/kg IM without a line, for full relaxation and intubation), with atropine in a child.
- Oesophageal intubation, endobronchial intubation (right side), sore throat, vocal-cord injury, arytenoid dislocation.

Difficult airway

- **Difficult Airway Society** (2015, updated 2025) for unanticipated difficulty: **plan A** face-mask ventilation and tracheal intubation (no more than 3 attempts, plus one by a more experienced person), **plan B** supraglottic airway (second-generation, up to 3 attempts), **plan C** final attempt at face-mask ventilation and **wake the patient**, **plan D front-of-neck access** in "can't intubate, can't oxygenate" (**scalpel–bougie–tube cricothyroidotomy** through the cricothyroid membrane, 6.0 cuffed tube). DAS 2025 keeps plans A–D, makes **video laryngoscopy the default for plan A** where available, and stresses continuous oxygen delivery, first-attempt success and confirmation by waveform capnography.
- **Airway fire** (diathermy or laser near an oxygen-rich airway): **stop all gas flow, disconnect the circuit and remove the tube at once**, flood with saline, then re-establish ventilation (air first) and examine by bronchoscopy; never increase oxygen.
- **Awake fibreoptic (or videolaryngoscopic) intubation** is the choice when difficulty is predicted (ASA 2022 difficult airway guideline; DAS awake tracheal intubation 2020).

Paediatric airway

Large head and tongue, high anterior larynx (C3–C4 in infants, C5–C6 in adults), obligate nasal breathers in early infancy, long floppy U-shaped epiglottis, short trachea, and narrowest part at the cricoid (classical teaching; imaging under anaesthesia suggests the glottis, but the exam answer is the cricoid).

Inhalational and IV agents

Inhalational agents: key numbers

Agent	MAC (%)	Blood:gas	Notes
Nitrous oxide	**104**	0.47	Analgesic, least potent, cannot be sole agent
Desflurane	6	**0.42** (lowest of volatiles)	Most pungent, rapid; day care and the obese; Tec 6 heated vaporiser
Sevo-flurane	2	0.65	**Mask induction in children**; compound A with dry soda lime
Isoflurane	1.15	1.4	Cardiostable; coronary steal is theoretical; ICP effect smaller
Halothane	0.75	2.3	Sensitises heart to catecholamines; hepatitis; MH trigger
Methoxy-flurane	0.16	12	**Most potent**; obsolete as an anaesthetic, nephrotoxic (fluoride, high-output renal failure); revived at low dose as a self-given inhaled analgesic for trauma pain (Penthrox)

- **MAC** is the end-tidal concentration at 1 atmosphere that stops movement to a standard surgical incision in 50 % of patients. Potency is the reciprocal of MAC.
- **Meyer–Overton rule:** potency tracks **lipid (oil:gas) solubility**.
- **Speed** of induction and recovery depends on a **low blood:gas partition coefficient**, plus cardiac output, ventilation and concentration.
- **MAC rises with:** hyperthermia, chronic alcohol use, acute amphetamine or cocaine, MAO inhibitors, infancy (peak at about 6 months), hypernatraemia, red hair. **MAC falls with:** hypothermia, pregnancy, age (about 6 % per decade after 40), acute alcohol, opioids, sedatives, alpha-2 agonists, lithium, severe anaemia, hypoxia (PaO2 below 40 mm Hg), hypotension (MAP below 40 mm Hg), hyponatraemia. Sex, duration of anaesthesia and thyroid status have no effect.
- Volatiles raise cerebral blood flow and ICP (dose-dependent; least with sevoflurane); **propofol and thiopentone lower both**; ketamine raises them (see below).
- Desflurane is unsuitable for inhalational induction because its **pungency** causes coughing, breath-holding and laryngospasm. Desflurane has the **highest global-warming potential** of the agents; the EU's F-gas Regulation (2024/573) bars its use as an anaesthetic from 1 January 2026 unless no other agent can be used on medical grounds, and many hospitals have dropped it.
- Sevoflurane with soda lime yields **compound A** (nephrotoxic in rats, more at low flows and with warm absorbent); the label asks for a fresh gas flow of at least 1 L/min (2 L/min beyond 2 MAC-hours), and clinical injury has not been shown. **Carbon monoxide** is a different problem: it forms when volatiles (desflurane most) pass over **desiccated** absorbent.

- Halothane: “halothane hepatitis” (immune; avoid re-exposure within about 3 months), historically used for manual removal of placenta and in asthma.

Nitrous oxide

- Analgesic, second gas effect (fast uptake of N2O concentrates a companion volatile agent).
- **Diffusion hypoxia (Fink effect)**: at the end of anaesthesia, N2O leaves the blood into the alveoli faster than nitrogen enters, diluting alveolar oxygen; give 100 % oxygen for a few minutes.
- Expands closed air spaces, because it is about **30 times more soluble in blood than nitrogen** and enters faster than nitrogen leaves: contraindicated in **pneumothorax**, bowel obstruction, middle-ear and retinal gas surgery, air embolism, pneumocephalus.
- **Flammability:** the obsolete **ether, cyclopropane and ethylene** formed explosive mixtures with oxygen (ignited by static or diathermy), one reason they were abandoned; halothane, isoflurane, sevoflurane and desflurane are non-flammable. Nitrous oxide is not itself flammable but supports combustion like oxygen.
- Chronic exposure inactivates vitamin B12 (methionine synthase): megaloblastic change, myeloneuropathy; avoid in early pregnancy.
- Xenon, N2O and ketamine act on NMDA receptors; halothane does not.

Intravenous induction agents

Agent	Dose (mg/kg)	Key points
Propofol	1.5–2.5	GABA-A; pain on injection; antiemetic; lowers ICP; **day care, LMA, TIVA**; safe in porphyria and MH; propofol infusion syndrome in prolonged high-dose use (above about 4 mg/kg/h for over 48 h: acidosis, rhabdomyolysis, hyperkalaemia, heart failure); emulsion of soybean oil, glycerol and egg lecithin (egg allergy is not a contraindication)
Thiopentone	3–5	Barbiturate; anticonvulsant, cerebroprotective; falls in BP; avoid in **porphyria, asthma**; intra-arterial injection causes gangrene; short action by redistribution
Etomidate	0.2–0.3	**Most haemodynamically stable**; **inhibits 11β-hydroxylase** (adrenal suppression, even after one dose in sepsis); myoclonus, pain on injection, nausea
Ketamine	1–2 IV; 4–10 IM	NMDA blocker, dissociative, analgesic; raises BP, heart rate and bronchodilates: **choice in shock, haemorrhage, asthma, full stomach with hypotension**; airway reflexes largely kept; emergence reactions (blunted by benzodiazepine); caution in ischaemic heart disease and hypertension. Raised ICP: the classic answer is “avoid”; current evidence (ventilated patients) shows no harmful rise, and it is used in head-injured trauma patients
Midazolam	0.02–0.05 sedation; 0.1–0.3 induction	Sedation, amnesia; antagonist flumazenil
Dexmedetomidine	infusion	Alpha-2 agonist, sedation without respiratory depression

- Opioids: fentanyl is about 100 times morphine; remifentanil is metabolised by plasma esterases (context-insensitive half-time about 3 min), so it suits TIVA; rapid fentanyl can cause “wooden chest” rigidity. Pethidine is anti-shivering but its metabolite norpethidine is epileptogenic.
- **Morphine in renal failure**: morphine is conjugated in the liver to **morphine-6-glucuronide (M6G, potent and active) and morphine-3-glucuronide**; both are **cleared by the kidney, so they accumulate in renal failure** and cause prolonged sedation and respiratory depression. Prefer **fentanyl, alfentanil or remifentanil** (no active renal-dependent metabolites), with reduced doses. **Pethidine** gives **norpethidine** (seizures, accumulates in renal failure) and is avoided in renal failure and with MAOIs.
- **Flumazenil** is a competitive benzodiazepine antagonist at the GABA-A receptor (**0.1–0.2 mg IV increments**); its **half-life is about 1 hour, shorter than midazolam’s (about 2–3 hours, longer in the old and in liver disease)**, so **re-sedation can follow** after a reversal and the patient needs observation or a repeat dose or infusion. Avoid in chronic benzodiazepine users and mixed overdose with tricyclics (seizures). **Naloxone** reverses opioids (0.04 mg increments in the postoperative patient; short half-life, so renarcotisation is possible).
- Choice by situation: **cardiac with good LV: isoflurane or sevoflurane; neurosurgery: isoflurane/sevoflurane with propofol; shock: ketamine or etomidate; asthma: ketamine or propofol for induction, sevoflurane for maintenance (halothane in older books); epilepsy: thiopentone or propofol; day case: propofol and desflurane or sevoflurane; children: sevoflurane.**
- Triad of anaesthesia: unconsciousness (hypnosis), analgesia, muscle relaxation. Balanced anaesthesia adds amnesia and attenuation of reflexes. Guedel’s stages: I analgesia, II excitement, **III surgical anaesthesia**, IV medullary depression.

Muscle relaxants and reversal

Classes

Type	Drugs	Notes
Depolarising	**Succinylcholine**	Onset 30–60 s, duration 5–10 min; hydrolysed by plasma pseudocholinesterase
Benzylisoquinolines	Atracurium, cisatracurium, mivacurium, d-tubocurarine	Histamine release (except cisatracurium); **atracurium and cisatracurium undergo Hofmann elimination**
Aminosteroids	Rocuronium (fastest non-depolariser), vecuronium, pancuronium	Cardiostable; pancuronium vagolytic, tachycardia; rocuronium and vecuronium reversed by sugammadex

- Doses: succinylcholine 1–1.5 mg/kg, rocuronium 0.6 (1–1.2 for RSI), vecuronium 0.1, atracurium 0.5, cisatracurium 0.15.
- **Atracurium** is cleared by spontaneous Hofmann degradation (pH and temperature dependent) plus ester hydrolysis, independent of liver and kidney, so it suits renal or hepatic failure, neonates and the elderly. Its metabolite laudanosine is epileptogenic (more with atracurium than cisatracurium).
- Pancuronium accumulates in renal failure. Mivacurium is the shortest non-depolariser and depends on plasma cholinesterase.
- Aminoglycosides, magnesium, volatile agents, lithium, local anaesthetics and calcium-channel blockers potentiate non-depolarisers; chronic phenytoin and burns cause resistance. Myasthenia gravis: resistant to succinylcholine, extremely

sensitive to non-depolarisers. Lambert–Eaton: sensitive to both.

Succinylcholine in detail

- Side-effects: **hyperkalaemia** (rise about 0.5 mmol/L normally), fasciculations and postoperative myalgia, raised intra-ocular, intragastric and intracranial pressure, bradycardia (especially second dose, in children), masseter spasm, **malignant hyperthermia trigger**.
- **Avoid when potassium may surge:** burns (from about 24–48 h and for months), major trauma and crush injury, spinal cord injury and denervation, prolonged immobilisation, upper motor neuron disease, muscular dystrophy, severe sepsis. A man 10 days after 40% burns is in the danger period.
- **Pseudocholinesterase deficiency:** inherited atypical enzyme, liver disease, pregnancy, organophosphates, neostigmine, and others cause a prolonged block.
- **Dibucaine number** (percentage inhibition of enzyme): **normal 70–80 (homozygous typical)**, heterozygous 50–60 (40–60 in some texts), **homozygous atypical 20–30** (about 1 in 3,000). It gauges quality, not amount of enzyme. The block lasts about 5–10 min, 1.5–2 times longer (20–30 min), and **4–8 h** respectively (Morgan & Mikhail).
- Management of prolonged paralysis: keep the patient sedated and ventilated until spontaneous recovery (fresh frozen plasma or purified cholinesterase is optional); neostigmine does not reverse it.

Phase I and phase II block

Feature	Phase I	Phase II (or non-depolarising)
Fade on train-of-four, tetanus	**None**	**Present**
Post-tetanic facilitation	Absent	Present
TOF ratio	Above 0.7	Below 0.4
Anticholinesterase	Enhances	Antagonises

Phase II develops with high or prolonged succinylcholine doses (it begins at about 2–5 mg/kg in total and is usual beyond 7–10 mg/kg or a long infusion) and looks like a non-depolarising block.

Monitoring

- Peripheral nerve stimulator: **ulnar nerve with adductor pollicis** is the standard site; facial nerve second (corrugator supercilii or orbicularis oculi; facial muscles are resistant like the diaphragm, so they overestimate recovery at the airway). The diaphragm and laryngeal muscles recover and block earlier, so **the diaphragm is the most resistant** muscle.
- **Train-of-four (TOF)**: four pulses at 2 Hz (0.5 s apart); count 4, ratio T4/T1 for fade. **Ratio at least 0.9** is the target before extubation (0.7 in older books). Single twitch, tetanus 50 Hz for 5 s, double-burst and **post-tetanic count** (best for deep block) are other patterns. Mechanomyography is the gold standard; acceleromyography and electromyography are used clinically.
- **ASA 2023 and ESAIC 2023 guidelines**: use **quantitative** monitoring whenever a relaxant is given (subjective "no fade" by feel is unreliable above a ratio of about 0.4); confirm TOF ratio 0.9 or more at the adductor pollicis before extubation; prefer **sugammadex** for deep, moderate and shallow block by rocuronium or vecuronium; neostigmine is reasonable only for minimal block (ratio 0.4–0.9).

Reversal

- **Neostigmine** 0.04–0.05 mg/kg (maximum 5 mg; peak effect at about 10 min) with **glycopyrrolate** 0.2 mg per mg of neostigmine (or atropine) to block muscarinic effects (bradycardia, secretions, bronchospasm). Ceiling effect; give only when at least some twitches return. Edrophonium has a shorter, faster action.
- **Sugammadex**, a modified gamma-cyclodextrin, **encapsulates rocuronium or vecuronium** molecules in plasma, with no muscarinic effect: **2 mg/kg** for moderate block (TOF count 2 or more), **4 mg/kg** for deep block (post-tetanic count 1–2), 16 mg/kg for immediate reversal after rocuronium 1.2 mg/kg. Risks: anaphylaxis, bradycardia, binds progesterone (a hormonal contraceptive user needs back-up for 7 days). Does not reverse benzylisoquinolines or succinylcholine.
- Cholinesterase inhibitors increase the effect of succinylcholine and prolong its block; **edrophonium antagonises phase II**.

Local anaesthetics

Chemistry

- Structure: aromatic ring, intermediate chain (ester or amide), tertiary amine. **Esters** (cocaine, procaine, chloroprocaine, tetracaine, benzocaine) are broken down by plasma cholinesterase, form PABA and may cause allergy; **amides** (lignocaine, prilocaine, bupivacaine, levobupivacaine, ropivacaine, mepivacaine, articaine, dibucaine) are metabolised in the liver, with rare allergy. Amide names have two "i"s; esters have one.
- Weak bases. Only the **unionised** form crosses the nerve membrane; the **ionised (cationic) form blocks the voltage-gated sodium channel from the inside** (axoplasmic side), preferring open and inactivated states (use-dependent block). Resting membrane potential is unchanged.
- **Potency: lipid solubility; onset: pKa** (closer to tissue pH 7.4 means more base available and faster onset); **duration: protein binding.** Infected tissue is acidic, so ionisation rises and block fails. Adding bicarbonate speeds onset. Exception: **chloroprocaine** has a high pKa (about 9) but a fast onset, because it is used at high concentration (3 %).
- Differential block: small, myelinated B and thin A-delta fibres block earlier than large A-alpha; C fibres are blocked slowly in vitro but pain and temperature go first clinically. Sequence of loss: sympathetic, temperature, pain, touch, motor; proprioception is recovered first.

Individual agents

Drug	Points
Cocaine	Only natural LA; the **only one that is a vasoconstrictor** (blocks reuptake of catecholamines), so adrenaline is **not added** (exam answer: "never mixed"; the old ENT Moffett's solution did combine them, and the extra arrhythmia risk is why that is now discouraged); ENT topical use (4–10 %, maximum about 1.5–3 mg/kg); metabolised by liver and plasma esterase; arrhythmias, hypertension
Lignocaine	Amide; max **4.5 mg/kg plain (3 mg/kg in UK texts), 7 mg/kg with adrenaline**; also antiarrhythmic (class Ib); 0.5–1 % infiltration and Bier's block, 1–2 % nerve block and epidural, 2 % jelly, 4 % topical, 10 % spray; 5 % heavy spinal (abandoned because of transient neurological symptoms)

Drug	Points
Bupivacaine	Long acting; **most cardiotoxic** (slow dissociation from cardiac sodium channels); max **2 mg/kg** (about 150 mg; 2.5–3 mg/kg with adrenaline in US texts); never for Bier's block; 0.5 % **hyperbaric spinal ("heavy", with 8 % dextrose)**
Levobupivacaine, ropivacaine	S-enantiomers, less cardiotoxic; ropivacaine (max 3 mg/kg) less motor block; both mildly vasoconstrict at low concentration
Prilocaine	**Methaemoglobinaemia** (o-toluidine metabolite, above about 600 mg); max 6 mg/kg (8 with adrenaline); with lignocaine in EMLA (2.5 % each, a eutectic mixture); **0.5 % is the agent of choice for Bier's block** (least toxic amide). Benzocaine also causes methaemoglobinaemia
Chloroprocaine	Shortest acting; very rapid hydrolysis; used in short spinals
Tetracaine, dibucaine	Long-acting esters/amides; topical (0.5 % tetracaine drops for the eye)
Articaine	Dental; thiophene ring

- **Methaemoglobinaemia:** chocolate-brown blood, SpO2 near 85 %, normal PaO2, unresponsive to oxygen; treat with **methylene blue 1–2 mg/kg IV over 5 min** (not in G6PD deficiency: ascorbic acid or exchange transfusion instead).

Adrenaline

- Prolongs block, lowers peak blood level, reduces bleeding.
- Dilution: **1:1000 = 1 mg/mL; 1:200,000 = 5 µg/mL**. 20 mL of 1:200,000 contains **100 µg**.
- Exam answer: avoid in **end-arterial territories**: fingers, toes, pinna, nose tip, penis (spasm and gangrene). Current practice: dilute adrenaline (1:100,000–1:200,000) in digital blocks is shown safe in healthy fingers (WALANT hand surgery; no gangrene in large series; **phentolamine** reverses spasm), but it is still avoided in poor digital circulation. Also avoid in Bier's block and with halothane (arrhythmia); caution in uncontrolled hypertension, ischaemic heart disease and hyperthyroidism.
- **1 % solution = 10 mg/mL**; use that to compute volumes (a 70 kg adult may have 4.5 × 70 = 315 mg plain lignocaine, about 31 mL of 1 %).

Local anaesthetic systemic toxicity (LAST)

- Early: perioral numbness, metallic taste, tinnitus, lightheadedness; then agitation, **seizures**; then coma, respiratory arrest, **arrhythmias and cardiovascular collapse** (wide QRS, bradycardia, asystole).
- Treatment (ASRA checklist 2020): stop injection, call for help, airway and 100 % oxygen, seizure control with a **benzodiazepine** (avoid large propofol doses if unstable), **20 % lipid emulsion**: **bolus 1.5 mL/kg over 2–3 min** (100 mL if over 70 kg), then **infusion 0.25 mL/kg/min** (about 200–250 mL over 15–20 min if over 70 kg); repeat the bolus once or twice and double the infusion if still unstable; upper limit about **12 mL/kg**. CPR with **small adrenaline doses (1 µg/kg or less)**; prolonged CPR, consider bypass. Avoid vasopressin, calcium-channel blockers, beta-blockers and local anaesthetics for arrhythmia.
- Risk factors: intravascular injection, high dose, vascular site, pregnancy, hypoxia and acidosis, extremes of age, heart and liver disease. Peak blood level by site (most to least): **intravenous > intercostal > caudal > epidural > brachial plexus > femoral and sciatic > subcutaneous**. Ultrasound guidance lowers the risk.

Solution contents and uses

Classic dental-cartridge list: the drug, a vasoconstrictor, **sodium metabisulphite** as the vasoconstrictor's antioxidant, **methylparaben** as preservative (now left out of most cartridges because of allergy), **thymol** as fungicide, sodium chloride for isotonicity, and sterile water. Preservative-containing solutions are not used for spinal or epidural injection.
Uses: topical, infiltration, nerve block, **Bier's intravenous regional block** (prilocaine 0.5 % or lignocaine 0.5 %, about 3 mg/kg, 40 mL in an arm; **never bupivacaine**; tourniquet kept up at least 20 min after injection), neuraxial.

Spinal and epidural

Spinal (subarachnoid) block

- Adult cord ends at L1, so insert **below L2** (usually L3–L4 or L4–L5; Tuffier's line crosses L4); in children below L3.
- Layers pierced: skin, supraspinous and interspinous ligaments, **ligamentum flavum** (felt as resistance), dura and arachnoid ("pop"), then CSF.
- Hyperbaric bupivacaine 0.5 % with 8 % dextrose (about 2–2.5 mL, 10–12.5 mg, for caesarean section); spread depends chiefly on baricity, position and dose.
- Sympathetic block is about 2 segments higher than sensory (2–6 in some texts), and motor block about 2 segments lower. Caesarean section needs a sensory block to **T4**; T10 suffices for labour and TURP.
- First sensation lost, as commonly taught: temperature (cold), tested with ice or ethyl chloride; touch and motor last.
- **Cord and dural sac in the child:** the cord ends near **L3 at birth** (dural sac S3), reaching the adult L1–L2 by about 1 year; a neonatal spinal or caudal approach is therefore low (L4–L5 or below).

Complications of neuraxial block

- **Hypotension** (sympathetic block, venous pooling; the commonest effect) and bradycardia (high block, Bezold–Jarisch reflex). At caesarean, treatment is **left uterine displacement, IV fluid (co-load) and a vasopressor**, now **phenylephrine** first, ideally as a prophylactic infusion keeping systolic pressure at 90 % of baseline or more (international consensus 2018); ephedrine if the heart rate is low; noradrenaline is an alternative. Plus oxygen and anti-emetic for nausea (which is often a sign of hypotension). Older books answer ephedrine (it spares uterine blood flow in animal studies), but it causes more fetal acidosis.
- **Postdural puncture headache (PDPH):** usually begins in 24–48 h (ICHD-3: within 5 days), frontal or occipital, **worse upright, better supine within minutes**; often settles in 1–2 weeks; commoner in young women and with larger cutting needles. Reduce with fine **atraumatic (pencil-point, Whitacre or Sprotte) needles**. Treatment: hydration, analgesics and caffeine (weak evidence; bed rest does not prevent it), then **epidural blood patch** (15–20 mL autologous blood), which relieves most cases; sphenopalatine ganglion block is a newer option.
- **Cranial nerve palsy after dural puncture:** the **abducens (VI)** is commonest (diplopia).
- Total spinal or high block, urinary retention, backache, transient neurological symptoms (lignocaine), cauda equina syndrome, epidural haematoma and abscess, meningitis.

- **Spinal epidural haematoma** (anticoagulant given too close to the puncture or catheter removal, or coagulopathy): new severe back pain, then progressive leg weakness and bladder or bowel dysfunction, not a transient headache or radicular pain. **Urgent MRI and neurosurgical decompression**, ideally within 8–12 hours, decide the outcome; transient neurological symptoms (after lignocaine) appear within a day, with buttock pain and no motor loss.
- **Contraindications:** absolute: patient refusal, infection at the site, raised ICP, uncorrected severe hypovolaemia, coagulopathy or anticoagulation within the times below; relative: sepsis, fixed cardiac output (**severe aortic or mitral stenosis**), some neurological disease, deformity. Platelets: **75–80 × 10^9/L or more** is the usual threshold; SOAP 2021 judges 70 × 10^9/L or more low risk in obstetrics if stable and with no other bleeding risk.
- Spinal is favoured for caesarean section even in pre-eclampsia (provided platelets are adequate).

Anticoagulants and neuraxial block (ASRA)

Drug	Last dose before the block	Catheter removal and restart
Aspirin, NSAIDs	No interval needed when given alone	
Unfractionated heparin SC, low dose (5,000 U two or three times a day)	**4–6 h** (or normal coagulation)	Remove 4–6 h after a dose; may restart immediately
UFH SC, higher dose (7,500–10,000 U twice daily)	12 h, with coagulation checked	
UFH SC, therapeutic	24 h, with coagulation checked	
UFH IV	**4–6 h** and normal aPTT	Wait 1 h after the needle before heparin; remove 4–6 h after the last dose
LMWH low (prophylactic) dose	**12 h**	Once daily: first dose 12 h or more after the puncture, catheter out 12 h after a dose, next dose 4 h after removal
LMWH high (therapeutic) dose	**24 h**	Catheter out at least 4 h before the first postoperative dose; restart 24 h after surgery (48 h after high-bleeding-risk surgery)
Warfarin	**5 days and normal INR**	Catheter out when **INR is below 1.5**
Rivaroxaban, apixaban, edoxaban	**72 h** (ASRA 2018); ASRA 2025: 72 h for high dose, **36 h for low-dose apixaban (2.5 mg twice daily), 24 h for low-dose rivaroxaban (10 mg daily)**	Catheter out 6 h before the first postoperative dose
Dabigatran	By creatinine clearance: **72 h** (80 mL/min or more), **96 h** (50–79), **120 h** (30–49); not advised below 30	Catheter out 6 h before the first dose
Clopidogrel	**5–7 days**	
Prasugrel	**7–10 days**	
Ticagrelor	**5–7 days**	
Ticlopidine	10 days	
Thrombolytics	Avoid; if unavoidable, 48 h and normal clotting and fibrinogen	

The table is ASRA's 4th edition (2018), the one exam books follow. Among other changes, ASRA's 5th edition (2025) renames prophylactic and therapeutic as low and high dose, adds drug-level testing (a residual Xa-inhibitor level below 30 ng/mL allows an earlier block) and shortens the low-dose DOAC intervals shown.

Epidural

- Located by **loss of resistance** to air or saline after the ligamentum flavum; the epidural space spans the foramen magnum to the sacral hiatus (caudal approach).
- **Test dose**: 3 mL of 1.5 % lignocaine with adrenaline 1:200,000 (45 mg and 15 µg): a spinal block shows intrathecal placement, a heart-rate rise of 20/min or more shows intravascular placement.
- Slower onset, segmental, allows continuous catheter analgesia in labour and postoperative care. Accidental dural puncture about 1 % (0.5–1.5 %), with a PDPH in more than half after a 16–18 G Tuohy needle. Labour epidural: dilute bupivacaine or ropivacaine with fentanyl, now often by programmed intermittent boluses.
- Combined spinal–epidural joins both. **Caudal** block in children (through the sacral hiatus): bupivacaine 0.25 %, about 0.5 mL/kg for sacral, 1 mL/kg for lumbar and 1.25 mL/kg for low thoracic dermatomes (Armitage).
- **Neuraxial opioids:** itching (often facial), urinary retention and nausea; **hydrophilic morphine** spreads cephalad in CSF and may cause **delayed respiratory depression 6–12 hours later** (monitor for 24 hours), whereas lipophilic fentanyl acts early, locally and briefly. The site of action is the substantia gelatinosa of the dorsal horn.

Peripheral nerve and plexus blocks

Brachial plexus approaches

Approach	Level	Spares or misses	Specific hazards
Interscalene	Roots and trunks, C6 level	**Inferior trunk (C8–T1), the ulnar border**; suits shoulder and upper arm surgery	**Ipsilateral phrenic palsy (almost always)**, Horner syndrome, recurrent laryngeal palsy, vertebral artery or epidural or subarachnoid spread
Supraclavicular	Trunks and divisions over the first rib; the plexus is most compact here, giving the most complete block of the whole limb	Little spared (the lower trunk occasionally); suits arm, elbow, forearm and hand	**Pneumothorax** (pleural dome behind, Sibson's fascia), phrenic palsy less often

Approach	Level	Spares or misses	Specific hazards
Infraclavicular	Cords around the axillary artery	The shoulder (too distal); suits elbow, forearm and hand	Pneumothorax (rare), vascular puncture
Axillary	Terminal nerves around the axillary artery	**Musculocutaneous** (leaves the sheath early, within coracobrachialis) and **intercostobrachial (T2, not a plexus branch)**: lateral forearm and medial upper arm tourniquet pain	Intravascular injection, haematoma; the safest approach

- Ultrasound guidance is now the standard of care; nerve stimulators were used before.

Sympathetic and visceral blocks

- **Stellate ganglion block** (C6–C7, cervical sympathetic chain): indications are complex regional pain syndrome, Raynaud and Buerger disease, vascular insufficiency of the arm and refractory angina. **Success is shown by Horner syndrome** (ptosis, miosis, anhidrosis, enophthalmos), a warm flushed face and arm, conjunctival congestion, nasal stuffiness (Guttmann sign) and a rise in arm skin temperature (1–3 °C, the best sign that the limb's sympathetic supply is blocked; Horner syndrome alone shows only that the head's supply is). Side effects: hoarseness, phrenic palsy, pneumothorax, intravascular injection.
- **Coeliac plexus block** (neurolysis with alcohol or phenol, at L1 or T12): upper abdominal visceral pain from **pancreatic, gastric or hepatobiliary cancer**; side effects **hypotension and diarrhoea** (unopposed parasympathetic activity), rarely paraplegia. Pelvic cancer pain is blocked at the **superior hypogastric plexus**; the lumbar sympathetic chain serves ischaemic or CRPS pain in the leg.
- **Pudendal nerve block** (S2–S4, near the ischial spine): analgesia of the perineum, episiotomy and low forceps in the second stage of labour; it does not relieve uterine contraction pain (T10–L1).

Monitoring and circuits

Standard monitoring

Pulse oximetry, ECG, non-invasive BP, **capnography** (mandatory wherever a tracheal tube or supraglottic airway is used, including recovery and ICU), inspired oxygen, agent analyser, airway pressure, temperature, and a **quantitative** neuromuscular monitor when relaxants are used (AAGBI/Association of Anaesthetists standards 2021; ASA standards). A processed EEG (depth of anaesthesia) monitor is recommended with TIVA plus relaxant. Invasive arterial and central venous pressure as needed. **Bispectral index (BIS)** scores depth: **40–60 is general anaesthesia**; below 40 is deep; 100 awake.

Capnography

- Confirms tube placement and ventilation. Phases: I baseline (end of inspiration and dead-space gas at the start of expiration), II expiratory upstroke (mixed dead space and alveolar gas), III alveolar plateau (its end is the EtCO2), 0 inspiratory downstroke. Waveform capnography is the **surest confirmation of tracheal intubation** ("no trace, wrong place"); in cardiac arrest EtCO2 below 10 mm Hg after 20 min of CPR predicts poor outcome, and a sudden rise signals return of circulation.
- A **sudden fall** in EtCO2 with hypotension: pulmonary embolism, including **venous air embolism**; a **sudden zero**: disconnection, tube displacement or accidental extubation; **oesophageal intubation**: no trace, or a few small waveforms (stomach gas) that fade to zero within a few breaths; a gradual fall: hypothermia, falling cardiac output, hyperventilation; **shark-fin** shape: bronchospasm, COPD, kinked tube; **rising**: hypoventilation, MH, sepsis, thyroid storm, tourniquet release, bicarbonate, CO2 insufflation at laparoscopy; **raised baseline**: rebreathing (exhausted soda lime, faulty expiratory valve).
- Normal arterial–end-tidal CO2 gap is 2–5 mm Hg.

Venous air embolism

- Risk: neurosurgery in the **sitting position**, head-and-neck and caesarean surgery, central lines.
- Signs: fall in EtCO2, hypotension, arrhythmia, hypoxia; the **mill-wheel murmur is a late sign** of a large embolus. Detection: **most sensitive overall, transoesophageal echo**; **most sensitive non-invasive, precordial Doppler** (right sternal border, 3rd–6th space); then EtCO2 (sudden fall); a rise in end-tidal nitrogen is the most specific gas sign.
- Treat: tell the surgeon to flood the field with saline and wax bone edges, stop N2O, give 100 % oxygen, lower the head, left lateral head-down position (Durant manoeuvre), aspirate air from a multi-orifice right atrial catheter, support circulation.

Central venous access

- **Central venous catheterisation:** the commonest early mechanical complication of internal jugular puncture is **accidental carotid artery puncture** (a few per cent with landmarks, far fewer with real-time ultrasound, now the standard for internal jugular access); **pneumothorax** is commoner with the subclavian route, and infection is the commonest late complication.

Pulse oximetry

- Two wavelengths: red 660 nm and infrared 940 nm.
- **Carboxyhaemoglobin absorbs red light almost like oxyhaemoglobin, so the reading is falsely high** and normal in carbon monoxide poisoning (use co-oximetry).
- Methaemoglobin pulls the reading toward 85 %; methylene blue and indocyanine green give a falsely low value; motion, shivering, low perfusion and blue, green or black nail polish do too. **Dark skin pigmentation overestimates saturation**, missing "occult hypoxaemia" (Sjoding, NEJM 2020; FDA draft guidance, January 2025, asks for accuracy testing across skin tones). Jaundice and bilirubin have little effect; fetal haemoglobin has little effect.

Breathing systems

Mapleson	Features
A (Magill)	**Most efficient for spontaneous ventilation**; least efficient for controlled; fresh gas flow about equal to minute volume (about 70–100 mL/kg/min, 5–6 L/min in an adult); for controlled ventilation it needs about 3 times minute volume
B, C	Rarely used

Mapleson	Features
D (Bain coaxial)	**Most efficient for controlled ventilation**; fresh gas flow about 70 mL/kg/min controlled, 150–200 mL/kg/min spontaneous; fresh gas in the inner tube, exhaled gas in the outer, which warms it
E (Ayre's T-piece), F (Jackson–Rees)	Paediatric, under about 20–25 kg; Jackson–Rees (F, E with an open-tailed bag) is the usual circuit for infants; fresh gas 2.5–3 times minute volume

Efficiency, the classic mnemonic: **spontaneous A > D, F, E > C, B**; **controlled D, F, E > B, C > A** ("All Dogs Can Bite" for spontaneous, "Dog Bites Can Ache" for controlled).

- Circle system: carbon dioxide absorber (soda lime about 80 % calcium hydroxide, about 15 % water, a few per cent sodium hydroxide, silica for hardness, an indicator dye such as ethyl violet turning white to purple; potassium hydroxide removed from modern brands; Baralyme withdrawn after fires with sevoflurane; Amsorb, calcium hydroxide with calcium chloride, forms neither compound A nor CO), two unidirectional valves; allows low-flow anaesthesia and conserves heat and moisture.

Vaporisers and gas supply

- Variable-bypass, agent-specific, temperature compensated vaporisers. **Colour codes (international):** isoflurane purple, **sevoflurane yellow**, desflurane blue (Tec 6 is heated and pressurised), halothane red, enflurane orange.
- Cylinders: oxygen is **white** (ISO 32, international) or **black body with white shoulder** (the older British standard, still in use in some countries); N2O **blue**; CO2 grey; air grey body with black-and-white shoulder (or white-and-black body); Entonox (50 % N2O, 50 % O2) blue with blue-and-white shoulder. Liquid in cylinder: **N2O and CO2** (content judged by weight, not pressure).
- **Pin index** (small cylinders at the yoke): **oxygen 2, 5; N2O 3, 5; air 1, 5; Entonox 7; CO2 1, 6 (or 2, 6); cyclopropane 3, 6**. Pipelines use diameter-index safety (DISS) or non-interchangeable screw-thread connections.
- Pressures: full oxygen cylinder about **137 bar** (2,000 psi); N2O cylinder **44 bar** (750 psi, constant until the liquid is gone); pipeline about **4 bar** (400 kPa, 60 psi).
- Flowmeters (Thorpe tube): variable orifice, constant pressure.

Temperature and complications

- Heat loss: **radiation (about 40–60 %) > convection > evaporation > conduction**; most core temperature falls in the first hour from redistribution of heat to the periphery. Hypothermia: shivering, delayed recovery, coagulopathy; Osborn (J) wave on ECG.
- **Nerve injury from positioning: ulnar nerve is the commonest** (ASA closed claims), then brachial plexus; in the leg the **common peroneal** is the commonest (lithotomy, pressure at the fibular neck: foot drop).
- **Postoperative visual loss:** most common cause is **ischaemic optic neuropathy** (prone spinal surgery, hypotension, anaemia); the commonest eye complication is corneal abrasion.
- **PONV:** with pain, the commonest postoperative complaint; **Apfel score** (female, non-smoker, history of PONV or motion sickness, postoperative opioids: 0–4 factors give about 10, 20, 40, 60 and 80 % risk). Fourth consensus guidelines (2020): two antiemetics of different classes when 1–2 risk factors are present, three or four with more; dexamethasone 4–8 mg at induction, ondansetron 4 mg at the end, droperidol, aprepitant, propofol TIVA.
- Anaphylaxis in anaesthesia: neuromuscular blockers and antibiotics are the commonest triggers; the rank varies (France: relaxants, rocuronium and succinylcholine, first; UK NAP6 2018: **antibiotics first**, teicoplanin and co-amoxiclav, then relaxants, chlorhexidine and Patent Blue); latex is now rare. Hypotension is the commonest presenting sign. Treat with **adrenaline 50 µg IV boluses** (0.5 mg IM without monitoring), fluids; tryptase at once, at 1–2 h and after 24 h.
- Prophylactic antibiotic **within 60 min before incision** (vancomycin and fluoroquinolones within 120 min).

Malignant hyperthermia

- **Pharmacogenetic** disorder of skeletal muscle calcium control. **Autosomal dominant**; most often a mutation of the **ryanodine receptor (RYR1, chromosome 19q13.1)**, found in about 70 % of families; less often the dihydropyridine receptor (CACNA1S) or STAC3 (Native American myopathy). Incidence about 1 in 10,000–250,000 anaesthetics, higher in children.
- **Triggers:** all **volatile agents** (halothane the classic; sevoflurane, isoflurane, desflurane) and **succinylcholine** (most episodes today follow a volatile, with or without succinylcholine). **Safe:** N2O, propofol, etomidate, ketamine, benzodiazepines, opioids, non-depolarisers, local anaesthetics.
- **Earliest sign: rising end-tidal CO2** (unexplained hypercapnia despite increased ventilation), with tachycardia, masseter spasm, generalised rigidity, then **hyperthermia (a late sign, up to 1 °C per 5 min)**, acidosis, **hyperkalaemia**, rhabdomyolysis with myoglobinuria, DIC and arrhythmias.
- **Treatment:** stop triggers, hyperventilate with 100 % oxygen at high flow, change the circuit and machine if possible, give **dantrolene 2.5 mg/kg IV** (repeated until signs settle, usually up to 10 mg/kg, more if needed; then 1 mg/kg every 4–6 h for 24 h; it inhibits calcium release from the sarcoplasmic reticulum by binding RYR1; each 20 mg vial of the classic form holds 3 g mannitol and is mixed with 60 mL sterile water, so a 70 kg patient's first dose needs 9 vials; the newer Ryanodex is 250 mg in 5 mL); cool actively, stopping at about 38 °C; treat hyperkalaemia (calcium, insulin and glucose, bicarbonate); keep urine output up. Do not use calcium-channel blockers with dantrolene (hyperkalaemia and cardiovascular collapse). Watch 24 h in a critical-care bed (recrudescence in about 20 %).
- **Susceptible patient:** use a **non-triggering technique**: **propofol-based TIVA** or regional anaesthesia, a clean anaesthesia machine (flush and activated charcoal filters), monitor temperature and EtCO2. Dantrolene should be at hand; prophylactic dantrolene is no longer recommended.
- Testing: caffeine–halothane contracture test on muscle biopsy; genetic screening.
- Differential diagnosis: neuroleptic malignant syndrome, serotonin syndrome, thyroid storm, phaeochromocytoma, sepsis. Associated with **central core disease**, multiminicore disease, King–Denborough syndrome and Native American myopathy. **Duchenne and Becker dystrophy** are not true MH but carry a risk of rhabdomyolysis and hyperkalaemic arrest with succinylcholine (and volatiles), so the same non-triggering technique is used. **Masseter spasm** after

succinylcholine: an early warning; stop triggers if possible and watch for MH.

Oxygen therapy and ABG

Oxygen delivery devices

Device	Flow	Approximate FiO2
Nasal cannula (low flow)	1–6 L/min	24–44 % (about 21 % + 3–4 % per L/min; **max about 0.45 at 6 L/min**)
Simple face mask	5–10 L/min (minimum 5–6 to prevent rebreathing)	40–60 %
Mask with reservoir (non-rebreather)	10–15 L/min	about 0.6–0.8 (up to 0.9 with a tight fit)
Venturi mask	Fixed entrainment	**Fixed, predictable FiO2 (24–60 %) independent of breathing pattern**; choice in COPD
Heated humidified high-flow nasal cannula	Up to 60 L/min	Up to 1.0; some PEEP effect; first-line for many hypoxaemic patients

Low-flow devices give a variable FiO2 because the patient dilutes the gas with room air. Target SpO2 **94–98 %** for most acutely ill patients, **88–92 % in COPD** and others at risk of hypercapnic failure (BTS 2017); avoid hyperoxia.

Arterial blood gas interpretation

1. Look at pH: below 7.35 acidaemia, above 7.45 alkalaemia.
2. Decide the primary disorder from PaCO2 (respiratory) and HCO3- (metabolic).
3. Check compensation:
   - Acute respiratory acidosis: HCO3- rises 1 mmol/L per 10 mm Hg rise in PaCO2; pH falls about 0.08 per 10 mm Hg.
   - Chronic respiratory acidosis: HCO3- rises 3.5–4 per 10 mm Hg.
   - Metabolic acidosis: expected PaCO2 = 1.5 × HCO3- + 8 (±2) (**Winter's formula**).
   - Metabolic alkalosis: PaCO2 rises about 0.7 mm Hg per 1 mmol/L rise in HCO3-.
   - Respiratory alkalosis: HCO3- falls 2 per 10 mm Hg fall in PaCO2 acutely, 4–5 chronically.
   - A PaCO2 beyond the expected range means a second, respiratory disorder.
4. Anion gap = Na − (Cl + HCO3-), normal 8–12 (lower by about 2.5 for each 10 g/L fall in albumin); high-gap acidosis (MUDPILES: methanol, uraemia, DKA, paracetamol/propylene glycol, iron/isoniazid, lactate, ethylene glycol, salicylate; the newer GOLDMARK: glycols, oxoproline, L- and D-lactate, methanol, aspirin, renal failure, ketoacidosis); normal-gap (hyperchloraemic): diarrhoea, renal tubular acidosis, large volumes of saline.
5. Check oxygenation: **A–a gradient** = PAO2 − PaO2, with PAO2 = FiO2 (760 − 47) − PaCO2/0.8, normal about age/4 + 4 mm Hg (on air, PAO2 is about 100 mm Hg at sea level). **ARDS by PaO2/FiO2 (Berlin 2012**, with PEEP 5 cm H2O or more): **mild 200–300, moderate 100–200, severe 100 or less**; Berlin dropped the older term "acute lung injury" (P/F below 300 in the 1994 definition). The 2023 global definition (Matthay, 2024) also accepts high-flow nasal oxygen at 30 L/min or more and SpO2/FiO2 315 or less where gases are not available.

Example: **pH 7.26, PaCO2 62, HCO3- 27** is **acute respiratory acidosis** (high CO2, near-normal bicarbonate, acidaemia).

- Hypoxaemia is usually defined as **PaO2 below 60 mm Hg** (respiratory failure), with grades often described by 60–79 mild, 40–59 moderate, below 40 severe. Some sources grade mild as 50–60; check the grading a question uses.

Ventilation modes

Controlled mandatory ventilation (fully set, for paralysed patients, not for weaning), assist-control, **SIMV** and pressure support (weaning), pressure control (ARDS, fixed pressure with variable volume), PEEP (positive pressure at end expiration, recruits alveoli), CPAP (continuous). Lung-protective ventilation (ARDSNet): **6 mL/kg predicted body weight** tidal volume, **plateau pressure 30 cm H2O or less**, driving pressure below about 15 cm H2O, PEEP by FiO2 table; prone position for 16 h or more a day when P/F is below 150 (PROSEVA 2013).

Resuscitation, postoperative care and pain

Cardiopulmonary resuscitation (adult)

- **Sequence (AHA 2020 and 2025, ERC 2021)**: check responsiveness and breathing for **no more than 10 seconds**, call for help and a defibrillator, start **chest compressions**. The order is **CAB** (circulation, airway, breathing); **30 compressions to 2 breaths** for one or two rescuers without an advanced airway.
- **Compression quality**: **rate 100–120 per minute, depth 5–6 cm (at least 5 cm, not over 6 cm) in an adult, full chest recoil, minimal interruptions (hands-off time below 10 seconds)**, on a firm surface, heel of the hand on the **lower half of the sternum**. Children: about one third of the chest depth (5 cm); infants about 4 cm. After an advanced airway, **continuous compressions with 10 breaths a minute**; change the compressor every 2 minutes. **Too shallow or slow gives poor coronary perfusion; too deep or fast injures and prevents recoil.**
- **Shockable rhythms (ventricular fibrillation, pulseless ventricular tachycardia)**: **defibrillate at once** (biphasic 120–200 J, monophasic 360 J; one shock then 2 minutes of CPR). Non-shockable (asystole, pulseless electrical activity): CPR and **adrenaline 1 mg IV as soon as possible, repeated every 3–5 minutes**; for shockable rhythms **adrenaline after the 3rd shock (ERC 2021; AHA 2020 gives it once the first shocks have failed)** and **amiodarone 300 mg then 150 mg** (or lidocaine). Treat the **reversible causes: Hs (hypoxia, hypovolaemia, hypo/hyperkalaemia, hypothermia, hydrogen ion) and Ts (tension pneumothorax, tamponade, toxins, thrombosis, pulmonary or coronary)**.
- **Capnography**: **end-tidal CO_2 below 10 mmHg after 20 minutes of CPR predicts poor outcome**; a sudden rise suggests **return of spontaneous circulation**; sustained capnography confirms tracheal placement (see Airway). **Post-arrest care**: avoid hyperoxia (target SpO_2 94–98%), normocapnia, mean arterial pressure above 65, **exam answer: targeted temperature management (32–36 °C) for at least 24 hours** in comatose survivors (AHA 2015 and 2020, ERC-ESICM 2021). **Current practice**: TTM2 (2021) found no benefit of 33 °C over simply preventing fever, so the ERC-ESICM temperature guideline of 2022 advises **preventing fever (above 37.7 °C) for at least 72 hours**, and AHA 2025

advises deliberate temperature control (32–37.5 °C) for **at least 36 hours** in adults who do not obey commands.

- **Primary trauma care and transport of the critically ill**: the order is airway with cervical spine protection, breathing, circulation with haemorrhage control, disability, exposure (ATLS and primary trauma care). Basic care of the critically ill: **positioning (lateral/recovery position or head up 30° for raised intracranial pressure), airway, oxygenation, fluid resuscitation and protection of the brain** (glucose, normothermia, oxygenation). **Safe transport** needs stabilisation first, a trained escort, airway secured, a monitor, oxygen supply for twice the journey, drugs and communication with the receiving team.

Anaphylaxis during anaesthesia

- **Exam answer: neuromuscular blocking drugs (suxamethonium, rocuronium) are the commonest cause**, then latex and antibiotics (the French and Australian series). **Current UK data (NAP6, 2018): antibiotics 47%, neuromuscular blockers 33%, chlorhexidine 9%**; local patterns differ. Volatiles and opioids rarely cause immune reactions (opioids can release histamine); true propofol allergy is rare and not predicted by egg allergy.
- **Features**: **hypotension, tachycardia, bronchospasm, rash or flushing** within minutes of induction (hypotension is the commonest sign under anaesthesia, cutaneous signs may be hidden under drapes). **Treatment: stop the suspected agent, call for help, 100% oxygen, lie flat with legs raised, fluids (20 mL/kg), IV adrenaline 50 µg titrated boluses (0.5 mg IM if no IV and monitoring)**; second-line antihistamines, hydrocortisone and bronchodilators do not treat cardiovascular collapse. **Send mast cell tryptase at once, 1–2 hours and 24 hours**; refer to allergy for skin testing at 4–6 weeks.
- **Local anaesthetic systemic toxicity** is treated with **20% lipid emulsion** (see Local anaesthetics).

Transfusion complications

- **TRALI (transfusion-related acute lung injury)**: within **6 hours**, hypoxia, bilateral infiltrates, fever and hypotension, **normal central venous pressure**; donor anti-HLA or anti-neutrophil antibodies (from multiparous women's plasma); supportive treatment; **classically the commonest cause of transfusion death** (the exam answer), though **TACO now leads the reported deaths** (FDA reports 2017–2021: TACO 32%, TRALI 21%) since plasma from women donors was restricted. **TACO (circulatory overload)**: hypertension, raised venous pressure, a good response to diuretics. **Acute haemolytic reaction** (ABO): stop the transfusion, check, treat. **Febrile non-haemolytic reaction**: the commonest. **Massive transfusion**: hypocalcaemia, hyperkalaemia, hypothermia, coagulopathy. **Delayed haemolytic reaction**: days 3–14 with jaundice.
- **Massive transfusion and citrate:** citrate in stored blood chelates ionised calcium and is metabolised mainly by the liver, so **hypocalcaemia** (hypotension, prolonged QT) is worse with rapid infusion, liver disease or hypothermia; treat with **calcium chloride**. Early hyperkalaemia comes from potassium leaked from stored red cells.

Post-anaesthesia care

- **Recovery room (PACU)**: monitor oxygen saturation, ECG, blood pressure, respiratory rate, temperature, pain, nausea and consciousness; discharge criteria by **Aldrete score** (activity, respiration, circulation, consciousness, colour, each 0–2; the modified score uses SpO_2 in place of colour; **9 or more of 10** to leave).
- **Commonest airway problem: obstruction** (PONV is the commonest complication in recovery overall), from the tongue falling back (the commonest cause in the unconscious), laryngospasm, secretions or residual relaxant: **snoring, see-saw (paradoxical) chest and abdominal movement**, falling SpO_2. **Treat with jaw thrust or chin lift, oral or nasopharyngeal airway and oxygen**; laryngospasm: 100% oxygen with positive pressure, jaw thrust and, if it persists, **suxamethonium 0.1–0.5 mg/kg** (or propofol). **Naloxone is for slow shallow breathing with small pupils, not obstruction.** Other early problems: hypoxia, hypotension, arrhythmia, shivering, delirium (emergence), pain, **PONV**, bleeding and hypothermia.
- **PONV**: Apfel risk factors (female, non-smoker, history of PONV or motion sickness, postoperative opioids). **First-line prophylaxis: 5-HT_3 antagonists (ondansetron 4 mg) and dexamethasone 4–8 mg**; add droperidol, aprepitant or propofol TIVA for higher risk (Fourth Consensus, 2020); rescue with a drug of another class.

Pain management

- **WHO analgesic ladder (cancer pain)**: **step 1 non-opioid (paracetamol, NSAID) ± adjuvant; step 2 weak opioid (codeine, tramadol) ± step 1; step 3 strong opioid (morphine, fentanyl, oxycodone) ± step 1**; oral route, by the clock, by the ladder, for the individual, with attention to detail. **Adjuvants**: gabapentinoids, amitriptyline, carbamazepine for neuropathic pain, steroids for bone and nerve compression pain. Modern practice **uses multimodal analgesia and regional blocks, and opioid-sparing**; the WHO 2018 cancer pain guideline treats the ladder as a guide, not a strict sequence. **Morphine is the standard strong opioid; give a laxative; the PCA** (patient-controlled analgesia) bolus has a lockout, no background infusion in the opioid-naive.
- **Opioid classes:** pure µ agonists (morphine, fentanyl, pethidine, methadone); **partial agonist buprenorphine** (high µ affinity, a ceiling on analgesia and respiratory depression, poorly reversed by naloxone); mixed agonist-antagonists (nalbuphine, pentazocine; κ agonism, ceiling effect, may precipitate withdrawal); pure antagonists **naloxone** (IV, short) and **naltrexone** (oral, long). Morphine **raises sphincter of Oddi tone** (it can worsen biliary colic: the exam answer; current evidence finds all µ-agonists, pethidine included, do this, with little clinical effect, so opioids are not withheld from biliary pain), releases histamine, causes miosis and nausea and is avoided in head injury; pethidine tends to cause tachycardia and mydriasis.
- **Acute pain**: **paracetamol plus NSAID** (not in renal impairment, peptic ulcer or asthma sensitivity), **regional blocks (epidural, TAP, nerve blocks)**, short-acting opioids; **ketamine low dose and lidocaine infusions** as adjuncts. **Chronic pain**: neuropathic pain first-line drugs are gabapentinoids, tricyclics and duloxetine; neuromodulation or nerve ablation for refractory cases.
- **Fluid and electrolyte care perioperatively**: maintenance (adults 25–30 mL/kg/day; children by the 4-2-1 rule, mL/kg/h), losses, and the deficit (classically the fasting hours times maintenance; small now that clear fluids are allowed until 2 hours, so not replaced routinely in ERAS practice); **balanced**

crystalloids are the usual fluid; urine output of 0.5 mL/kg/h is the target.

Sources

- Miller's Anesthesia (9th and 10th editions); Morgan & Mikhail's Clinical Anesthesiology; Barash Clinical Anesthesia; Stoelting's Pharmacology and Physiology in Anesthetic Practice; Lee's Synopsis of Anaesthesia.
- ASA Practice Guidelines for Preoperative Fasting (2017, modular update 2023); ESAIC paediatric fasting guideline (2022); ASA consensus on GLP-1 agonists (2023) and AGA/ASMBS/SAGES multisociety guidance endorsed by ASA (2024).
- ASA/APSF joint statements on surgery after COVID-19 (December 2020, revised 2022); Association of Anaesthetists and Royal Colleges multisociety consensus (2021, updated 2023); COVIDSurg Collaborative (Anaesthesia 2021).
- ACC/AHA perioperative cardiovascular guideline (2024); ESC non-cardiac surgery guideline (2022); ACCP perioperative antithrombotic guideline (2022) and the PAUSE and BRIDGE trials.
- ASRA regional anaesthesia and antithrombotic therapy guidelines (4th edition 2018; 5th edition 2025); ESAIC/ESRA antithrombotic guideline (2022); ASRA LAST checklist (2020); SOAP platelet consensus (2021); international consensus on vasopressors at caesarean section (2018); ICHD-3 for PDPH; Vandermeulen et al. (Anesth Analg 1994) on spinal haematoma and the timing of decompression.
- ASA practice advisory on operating room fires (2013); Hadzic's Textbook of Regional Anesthesia and Acute Pain Management for the plexus and sympathetic blocks.
- ASA difficult airway guideline (2022); Difficult Airway Society guidelines (2015, updated 2025) and awake intubation guideline (2020).
- ASA (2023) and ESAIC (2023) guidelines on neuromuscular monitoring and reversal; Association of Anaesthetists standards of monitoring (2021); NAP6 (2018) on perioperative anaphylaxis; Fourth consensus guidelines on PONV (2020).
- MHAUS and EMHG malignant hyperthermia guidance; Berlin ARDS definition (2012) and the global definition (2023); BTS oxygen guideline (2017); EU F-gas Regulation (2024) on desflurane.
- KD Tripathi and Katzung for pharmacology cross-checks; First Aid Step 1 2022 for local anaesthetic, malignant hyperthermia and drug facts.
- Resuscitation and care: AHA Guidelines for CPR and ECC (2020; 2025 update, post-cardiac arrest care); ERC Guidelines 2021, ERC-ESICM post-resuscitation care (2021) and temperature control after cardiac arrest (2022); TTM2 trial (NEJM 2021); Association of Anaesthetists anaphylaxis guideline (2021); FDA transfusion fatality reports (FY2021 summary); WHO guidelines for cancer pain (2018).