Radiology

MBBS Recap: high-yield notes for revision

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Revision notes for the MD/MS entrance: radiation physics and safety, contrast, the best test for each problem, and the signs an examiner names.

Radiation physics and protection

Units (old and SI)

Quantity	SI unit	Old unit	Conversion
Activity	becquerel (Bq)	curie (Ci)	1 Ci = 3.7 x 10^10 Bq
Absorbed dose (energy per unit mass)	**gray (Gy)** = 1 J/kg	rad	**1 Gy = 100 rad**
Equivalent dose	sievert (Sv)	rem	1 Sv = 100 rem
Effective dose	sievert (Sv)	rem	
Exposure (ionisation of air)	coulomb/kg	roentgen	

- Activity conversions asked: **1 mCi = 37 MBq**, 1 Ci = 37 GBq (3.7 x 10^10 Bq, the activity of 1 g of radium-226).
- **Absorbed dose** ignores the kind of radiation and the tissue hit.
- **Equivalent dose** = absorbed dose x radiation weighting factor (w_R), so it corrects for the **type of radiation**. X-rays, gamma rays and beta particles have w_R = 1; protons 2; **alpha particles 20**; neutrons a continuous function of energy, about 2.5 to 20 (ICRP 103, 2007; the older ICRP 60, 1990, used steps of 5 to 20).
- **Effective dose** = sum of the equivalent doses to each organ x its tissue weighting factor (w_T), so it also corrects for **tissue radiosensitivity**. It estimates whole-body cancer and heritable risk from a partial-body exposure (ICRP 103, 2007: breast, colon, lung, stomach, red marrow 0.12 each; gonads 0.08; skin and bone surface 0.01).
- Ionising power: alpha > beta > gamma and X-rays (photons of the same energy behave alike; they differ only in origin, gamma from the nucleus, X-rays from electrons). Penetrating power is the reverse. Alpha is stopped by paper or the outer skin yet damages most because of high **linear energy transfer** (LET): dense ionisation along a short track makes clustered double-strand DNA breaks.
- The **oxygen enhancement ratio** is highest for low-LET radiation (X-rays, gamma: about 2.5 to 3) and falls towards 1 for high-LET radiation (fast neutrons about 1.6; alpha particles and heavy ions about 1). Hypoxic tumour cells are radioresistant; hyperbaric oxygen, carbogen with nicotinamide, and the hypoxic-cell sensitiser nimorazole (in head and neck cancer) are used against it.

Deterministic versus stochastic effects

	Deterministic (tissue reaction)	Stochastic
Threshold	**Yes**	**No** (linear no-threshold model)
Dose changes	**Severity**	**Probability** (not severity)
Examples	**Erythema, cataract**, infertility, hair loss, myelosuppression, radiation sickness	**Cancer**, heritable (hereditary) effects
Who	Only the irradiated person	Irradiated person or descendants

- Lens: ICRP 118 (2011) lowered the threshold for radiation cataract to about **0.5 Gy** and the occupational lens limit to **20 mSv a year** (averaged over 5 years), so the lens is now treated as more sensitive than once thought; posterior subcapsular cataract is the type.
- **Acute radiation syndrome** (whole body): haematopoietic from about 1 Gy, gastrointestinal from about 6 to 10 Gy, neurovascular above about 20 to 50 Gy; LD50/60 about 3.5 to 4.5 Gy without treatment (higher with supportive care).

Radiation can cause all leukaemias except **chronic lymphocytic leukaemia**. Infrared causes heat cataract and photoretinitis; ultraviolet causes snow blindness (photokeratitis).

Radiosensitivity

- **Law of Bergonie and Tribondeau**: radiosensitivity is directly proportional to mitotic activity and inversely proportional to differentiation.
- Cell cycle: most sensitive at the **G2-M interface and M phase**; most resistant in **late S phase**.
- **Most radiosensitive mature blood cell: lymphocyte** (apoptosis at very low dose; the fall in lymphocyte count is the earliest marker of marrow exposure). Platelets and red cells are comparatively resistant; the marrow precursors are the sensitive part.
- Sensitive tissues: bone marrow, lymphoid tissue, gonads (ovary, testis), intestinal crypts, growing physis. Resistant: nerve and brain tissue, muscle, vagina.
- The **haematological system** is the first to fail (the haematopoietic syndrome from about 1 Gy); skin is the commonest organ affected in radiotherapy (erythema); the gut mucosa is the most sensitive mucosa.
- Radiosensitive tumours: **seminoma, dysgerminoma, lymphoma, myeloma, Ewing's sarcoma, Wilms' tumour**. Radioresistant: **melanoma, osteosarcoma, pancreatic carcinoma**.
- Radiosensitisers: hypoxic-cell sensitisers (metronidazole, misonidazole, nimorazole), 5-fluorouracil, hydroxyurea, paclitaxel, mitomycin C, cisplatin. Radioprotectors: **amifostine**, cytokines, pentoxifylline, GM-CSF.

Amifostine

- A thiol compound taken up by normal tissues, where it scavenges free radicals. Its recognised indication as a radioprotector is **reducing xerostomia** in head and neck radiotherapy (also reduces cisplatin nephrotoxicity).
- It **does not cross the blood-brain barrier**, so it gives no protection to the brain or spinal cord.

Pregnancy

- **0 to 2 weeks after conception: all-or-none** (the embryo dies or survives unharmed; no malformation). **Organogenesis, about 2 to 8 weeks after conception**: the most sensitive window for malformation (threshold about 200 mGy, ACOG). **8 to 15 weeks**: the greatest risk to the CNS (IQ reduction, microcephaly, intellectual disability; threshold of the order of 60 to 310 mGy); after 25 weeks the fetus is least sensitive.
- No increase in malformation or loss is shown below about **50 mGy** (ACOG; ICRP uses 100 mGy as the threshold). Doses above about 500 mGy can cause miscarriage and growth restriction.
- A chest radiograph gives the fetus about 0.0005 to 0.01 mGy (ACOG 2017; the mother's effective dose is about 0.02 mSv for a PA film), so a woman found to be pregnant after one **can continue the pregnancy**. Diagnostic studies rarely exceed 50 mGy; a CT abdomen and pelvis gives the fetus about 10 to 50 mGy. Termination is not justified below 100 mGy (ICRP 84).
- Imaging of choice in pregnancy: **ultrasound and MRI** (MRI without gadolinium).
- Women of reproductive age: the exam answer is the **10-day rule** (elective abdominal and pelvic radiation in the first 10 days after the start of menstruation). Current practice: ICRP 84 (2000) dropped the 10-day rule, and UK guidance (HPA, RCR and Society of Radiographers, 2009) asks every woman of 12 to 55 whether she could be pregnant before such a study at any time in the cycle (the **28-day rule**), with a pregnancy test when in doubt before high-dose studies.
- Typical background radiation is about **2.4 mSv a year** (world average, UNSCEAR); the public limit is **1 mSv a year**; the occupational limit **20 mSv a year averaged over 5 years, with no single year above 50 mSv** (ICRP 103); once a radiation worker declares a pregnancy, the fetus should receive no more than **1 mSv** for the rest of it.

X-ray production and the image

- History: **X-rays discovered by Roentgen (1895)**, radioactivity by Becquerel (1896), radium and polonium by the Curies (1898); **CT by Hounsfield** (first scanner 1971, Nobel 1979 with Cormack); MRI by Lauterbur and Mansfield (Nobel 2003).
- X-rays are made when electrons strike the anode; about 99% of the energy becomes heat and about 1% X-rays (bremsstrahlung and characteristic radiation). Penetrating power is inversely proportional to wavelength.
- **kVp** sets beam energy (penetration). A **lower kVp gives more contrast** (more photoelectric absorption); a higher kVp gives more penetration and lower contrast. **mAs** sets the quantity of photons, so film density and noise, not penetration.
- **Conventional tube**: tungsten anode (bremsstrahlung), aluminium filter, glass window. **Mammography tube**: **molybdenum anode** (its characteristic X-rays of about 17 to 20 keV suit breast tissue), molybdenum filter (rhodium in dense breasts), beryllium exit window, compression. Digital units may use tungsten or rhodium targets.
- Typical effective doses: chest film about **0.02 mSv** (PA), mammography about 0.4 mSv, lumbar spine film about 1.5 mSv, bone scan about 4 to 6 mSv, CT head about 2 mSv, **CT abdomen and pelvis about 8 to 10 mSv**, FDG PET-CT about 15 to 25 mSv. So CT, PET and bone scan give the most (a CT abdomen and pelvis is about 500 chest films, and CT is the largest source of medical radiation dose to the population); a chest film the least of the X-ray studies. Ultrasound and MRI use no ionising radiation; higher ultrasound frequency gives better resolution and less penetration.
- **Lead aprons**: the exam answer is **0.5 mm lead equivalent** (stops about 95% or more of scattered radiation at diagnostic energies); 0.25 mm is the usual minimum, and 0.35 to 0.5 mm is used in fluoroscopy and intervention. Protection rests on **time, distance (inverse square law: doubling the distance quarters the dose) and shielding**, and on keeping doses as low as reasonably achievable (**ALARA**).
- Personal dosimetry: thermoluminescent dosimeter (TLD, lithium fluoride, which stores energy and releases light on heating), the older film badge, and now **optically stimulated luminescence (OSL)** badges and electronic dosimeters.
- **CT numbers (Hounsfield units)** are attenuation relative to water: **water 0, air -1000** (the lowest, black), fat about -100 to -50, acute blood 60 to 80, dense bone +1000 or more (full list under MRI, ultrasound and nuclear medicine).
- Radiotherapy: ionisation and double-strand DNA breaks. Electron beams treat superficial tumours; **protons deposit most energy at the Bragg peak**, sparing deeper tissue. Gating compensates for breathing motion.

Contrast agents and reactions

Iodinated contrast

Type	Examples	Notes
High-osmolar ionic monomer	diatrizoate	Most toxic; now little used intravenously
Low-osmolar ionic dimer	ioxaglate	
Low-osmolar non-ionic monomer	iohexol, iopamidol, ioversol	Standard IV agents
Iso-osmolar non-ionic dimer	**iodixanol**	Least osmotic toxicity

- Contraindications and cautions: chronic renal impairment, congestive heart failure, dehydration, **multiple myeloma**, diabetes on metformin, previous reaction, hyperthyroidism (thyrotoxic crisis after a large iodine load), phaeochromocytoma (risk with ionic agents).
- **Metformin** is withheld around iodinated contrast because a contrast-related fall in GFR allows accumulation and **lactic acidosis**. Exam answer: stop it at the study and restart after **48 hours** once renal function is confirmed stable. Current practice: stop it only when **eGFR is below 30 or there is acute kidney injury** (ACR Manual on Contrast Media; ESUR 2018 the same, with more caution for intra-arterial contrast that reaches the kidneys undiluted), and recheck renal function at 48 hours before restarting; at eGFR 30 or more it is continued. Sulfonylureas, insulin and DPP-4 inhibitors carry no such specific risk.
- A **shellfish or iodine "allergy" is not a contraindication** (no cross-reactivity; it only marks an atopic person); a previous reaction to contrast is the strongest predictor of another.

Contrast-induced nephropathy (CIN or CI-AKI)

- Exam definition: creatinine rise of **25% or 0.5 mg/dL within 48 to 72 hours** of contrast. Current definition: **contrast-associated AKI by KDIGO criteria** (a rise of 0.3 mg/dL or more within 48 hours, or 1.5 times baseline within 7 days). Creatinine peaks at about 3 to 5 days. Risk factors: pre-existing CKD (the main one), diabetes with CKD, dehydration, high contrast volume, intra-arterial injection. Markers: creatinine, cystatin C, NGAL.
- Modern view (ACR and National Kidney Foundation consensus, 2020): the risk from IV contrast is **real only at eGFR below 30** (or AKI); at eGFR 45 or more it is negligible, and needed contrast is not withheld for fear of it.
- **The one proven preventive measure is volume expansion with isotonic (0.9%) saline** before and after the study, for those at risk (eGFR below 30); the AMACING trial (2017) found no benefit of prophylactic hydration at eGFR 30 to 59. Use the smallest dose of low- or iso-osmolar contrast, stop nephrotoxins (NSAIDs), and delay repeat contrast. Sodium bicarbonate, N-acetylcysteine, vitamin C and statins have inconsistent or negative trial results (PRESERVE, 2018). **Diuretics, mannitol and low-dose dopamine do not help.**
- Management is supportive: fluids, electrolytes, dialysis if needed.

Anaphylactoid (non-allergic hypersensitivity) reactions

- Most are **allergic-like** but not IgE-mediated (direct mast-cell release), so no prior sensitisation is needed; non-ionic low-osmolar agents cause far fewer than the old ionic agents (severe reactions about 0.01 to 0.04%). The ACR separates them from **physiological** reactions (nausea, vomiting, warmth, vasovagal reaction), which are dose-related. Severity of allergic-like reactions: **mild** (limited urticaria, itching, nasal congestion); **moderate** (diffuse urticaria, facial oedema without dyspnoea, bronchospasm with little or no hypoxia); **severe** (laryngeal oedema, bronchospasm with hypoxia, hypotension and shock, arrest).
- **Vasovagal reaction** (hypotension with **bradycardia**): raise the legs, IV fluids, **atropine** if it persists; anaphylaxis gives hypotension with **tachycardia**.
- **Severe reaction (stridor, wheeze, shock): intramuscular adrenaline 0.5 mg (1:1000 = 1 mg/mL, so 0.5 mL) into the anterolateral thigh first** (Resuscitation Council UK 2021; ACR gives 0.3 mg, as an auto-injector; child 0.01 mg/kg, at most 0.5 mg), repeated after 5 minutes if needed, then oxygen, fluids, airway support. Antihistamines and steroids act too slowly and do not treat shock. Salbutamol alone does not correct hypotension.
- Premedication (steroids with antihistamine) lowers but does not abolish risk in patients with a previous reaction.
- Delayed skin reactions can appear 1 hour to 1 week later.

Gadolinium

- **Nephrogenic systemic fibrosis (NSF)**: severe renal impairment (eGFR below 30 or acute kidney injury) plus gadolinium. Skin thickening ("woody" skin), joint contractures, sometimes organ fibrosis, appearing days to months later. Strongest links are with the older **linear agents** (ACR group I: gadodiamide, gadoversetamide, gadopentetate dimeglumine); **group II** agents (the macrocyclics gadobutrol, gadoterate and gadoteridol, the newer gadopiclenol, and the linear gadobenate; the ACR revised the liver agent gadoxetate's group in 2024) carry a very low risk, and the ACR makes the eGFR check before them optional. Gadolinium retention in brain (**dentate nucleus and globus pallidus**, bright on unenhanced T1) is recognised; its clinical significance is unproven, and the EMA (2017) suspended the linear IV agents for it, keeping only the liver-specific gadoxetate and gadobenate.
- Gadolinium crosses the placenta and is avoided in pregnancy unless essential. Breastfeeding need not be stopped after either gadolinium or iodinated contrast (ACR): under 0.04% of a gadolinium dose passes into milk (under 1% of an iodinated dose), and the infant's gut absorbs under 1% of that.

Contrast in pregnancy

- **Iodinated contrast crosses the placenta**; the free iodide may suppress the fetal thyroid, so **neonatal thyroid function is checked** (transient hypothyroidism). No teratogenic effect has been shown. Give it only when the information is essential.

Investigation of choice

Rules of thumb

- **MRI over CT**: no radiation, best soft-tissue detail (cord, brain stem, posterior fossa, marrow, joints). **CT over MRI**: faster, cheaper, better for **bone, acute haemorrhage and calcification**, usable with pacemakers and in unstable patients.
- Ultrasound first for children, pregnancy and fluid or gallbladder questions; CT for air and for complex trauma and acute abdomen.

The list an examiner asks

Problem	Investigation of choice
Acute head injury	**Non-contrast CT head** (acute blood is hyperdense; shows fracture)
Bony architecture and fractures	CT
Spinal metastasis, cord compression	**MRI whole spine**
Soft tissue, marrow, ligament	MRI
Bone metastasis (screening)	Bone scan (Tc-99m MDP); PET-CT or whole-body MRI are more sensitive
Gallstones, acute cholecystitis	**Ultrasound** first and investigation of choice; **HIDA (cholescintigraphy) is the most accurate test for acute cholecystitis** (gallbladder not filled = cystic duct obstruction), used when ultrasound is equivocal or for acalculous cholecystitis
CBD stone or stricture, choledochal cyst	MRCP; **ERCP is the gold standard and treats**
Microlithiasis, small CBD stones, idiopathic pancreatitis	Endoscopic ultrasound
Bile leak after cholecystectomy	**ERCP** (confirms and treats with stent or sphincterotomy); HIDA detects, MRCP maps
Biliary dyskinesia	HIDA with ejection fraction
Malignant obstruction, staging	Contrast CT (pancreatic protocol); MRCP for the biliary tree

Problem	Investigation of choice
Pulmonary embolism	**CT pulmonary angiography** (D-dimer only to exclude when probability is low; V/Q scan if contrast is unsuitable)
Peripheral artery disease	First **duplex** and ankle-brachial index; **CT angiography** best non-invasive map; catheter angiography is the gold standard and is kept for combined treatment
Renal artery stenosis	Screening Doppler ultrasound; **CT angiography or MR angiography** (similar accuracy) to confirm; catheter angiography (DSA) is the gold standard and is done with angioplasty or stenting
Deep vein thrombosis, venous disease	**Compression duplex ultrasound**; invasive venography is the gold standard
Coarctation of aorta	MRI (or CT angiography)
Hypertrophic pyloric stenosis	Ultrasound
Vesicoureteric reflux	Micturating cystourethrogram (MCUG)
Renal scars after infection	DMSA
Obstruction and function of kidney	Dynamic scan (MAG3 or DTPA)
Small bowel obstruction	Plain film first; **contrast CT** shows the transition point; ultrasound in children
Pneumoperitoneum	Erect chest film as the first film; **CT** is the investigation of choice
Early acute stroke	Non-contrast CT first to exclude haemorrhage; MRI diffusion most sensitive for ischaemia; **CT angiography** for large-vessel occlusion before thrombectomy, and CT or MR perfusion to select patients 6 to 24 hours from onset (AHA/ASA 2019)
Subarachnoid haemorrhage	Non-contrast CT (most sensitive in the first 6 hours); lumbar puncture for xanthochromia if CT is negative; CT angiography to find the aneurysm (DSA the gold standard)
Aortic dissection	**CT angiography** (transoesophageal echo if unstable)
Acute appendicitis	Ultrasound in children and pregnancy; contrast CT in adults (most accurate)
Ureteric colic	Non-contrast low-dose CT KUB
Rotator cuff, meniscal and ligament tears	MRI
Osteomyelitis, early	MRI (radiographs change only after 10 to 14 days)
Avascular necrosis of the femoral head	**MRI** (radiographs are normal early; both hips imaged, as disease is often bilateral; steroids, alcohol and sickle cell disease are common causes)
Osteoporosis	**DEXA** of the lumbar spine and hip (T-score, see the musculoskeletal section)
Blunt abdominal trauma	**FAST** at the bedside; **contrast CT** in the haemodynamically stable patient
Solitary pulmonary nodule	CT (thin-section; PET-CT for a solid nodule of 8 mm or more)
Acoustic neuroma (vestibular schwannoma)	**Gadolinium-enhanced MRI** of the internal auditory canals
Juvenile nasopharyngeal angiofibroma	**Contrast CT** (Holman-Miller sign: anterior bowing of the posterior maxillary wall); MRI for spread; biopsy is avoided
Cardiac tamponade, pericardial effusion	**Echocardiography**
Neuroendocrine tumour, localisation	Ga-68 DOTATATE PET-CT (older: octreotide scan)
Epileptic focus	MRI (epilepsy protocol) for the structural cause; interictal FDG PET (hypometabolism) or ictal SPECT (hyperperfusion) for the functional focus

Details worth remembering

- **MRCP** localises a distal biliary block without treating it, and carries no risk of pancreatitis; **ERCP** is reserved for when stenting or stone removal is planned. Percutaneous transhepatic cholangiography suits proximal blocks.
- **Acute cholecystitis**: ultrasound shows stones, wall thickening over 3 mm, pericholecystic fluid and a sonographic Murphy sign. Supportive care then early laparoscopic cholecystectomy, ideally within 72 hours of onset, and in the same admission even later (Tokyo Guidelines 2018).
- **Gallstone ileus: Rigler's triad** (pneumobilia, small bowel obstruction, an ectopic gallstone). **Chronic cholecystitis: WES triad** (wall, echo, shadow on ultrasound).
- Venous and arterial disease: **ankle-brachial index** above 1.4 means non-compressible calcified vessels; 1.0 to 1.4 normal; 0.91 to 0.99 borderline; **0.9 or below PAD** (AHA/ACC 2016); below about 0.4 severe disease, as in critical limb ischaemia.
- Choose the examination by what changes management; modern practice favours CT angiography and MR angiography over diagnostic catheter angiography, which is now mostly used with intervention.

Chest imaging signs

Reading a frontal film

- **Silhouette sign**: a border is lost where a density of the same radiographic density touches it.
  - Right heart border lost: **right middle lobe**.
  - **Left heart border lost: lingula of the left upper lobe.**
  - Aortic knuckle lost: left upper lobe (apicoposterior).
  - Descending aorta or left hemidiaphragm lost: left lower lobe.
  - Right upper mediastinum (SVC border) lost: right upper lobe anterior segment.
  - Right hemidiaphragm lost: right lower lobe.
- Normal borders: right (from above) brachiocephalic vein, SVC, right atrium, IVC; left aortic knuckle, pulmonary artery, left atrial appendage, left ventricle.
- **Hila**: the hilar shadows are formed chiefly by the **pulmonary arteries and the upper lobe pulmonary veins**, with the bronchi as lucent tubes within them; normal nodes and bronchial arteries are too small to show, and the SVC forms the right mediastinal border, not the hilum. The **left hilum lies higher** than the right (by up to about 1.5 cm) in most people. The right heart border is touched by the medial segment of the right middle lobe.
- The **air bronchogram** shows airspace disease (consolidation) with a patent bronchus; its absence in an opacified lobe suggests obstructive collapse.

Signs by condition

Sign	Condition
Bat-wing or butterfly peri-hilar opacities	**Alveolar pulmonary oedema** (with cardiomegaly, Kerley B lines, effusions, upper lobe diversion)
Cannonball shadows	Haematogenous metastases (renal cell carcinoma and choriocarcinoma classically; sarcoma, testicular tumours)
Tree-in-bud (CT)	Endobronchial spread of infection, classically active tuberculosis; also other infections and aspiration
Halo sign (CT: ground glass around a nodule)	Angioinvasive aspergillosis in a neutropenic patient (haemorrhage round the infarct)
Golden S sign	**Right upper lobe collapse due to a central hilar mass**
Luftsichel	Left upper lobe collapse
Flat waist sign	Left lower lobe collapse
Finger-in-glove	Allergic bronchopulmonary aspergillosis (mucoid impaction)
Monod sign, air crescent	Aspergilloma in a cavity; air crescent also in angioinvasive aspergillosis (late)
Westermark, Hampton's hump	Pulmonary embolism (oligaemia; wedge infarct)
Bulging fissure	Klebsiella pneumonia
Crazy paving	Pulmonary alveolar proteinosis
Meniscus sign	Pleural effusion: the lateral decubitus film (affected side down, free fluid layering along the dependent wall) shows about 5 to 50 mL, the lateral erect film blunts the posterior costophrenic angle at about 50 mL, the PA film the lateral angle at about **175 to 200 mL** (books give 175, 200 or up to 300); ultrasound finds a few millilitres
Spinnaker sail (thymus lifted, in infants), continuous diaphragm	Pneumomediastinum
Garland (1-2-3) sign: right paratracheal and both hilar nodes	Sarcoidosis
Eggshell calcification of hilar nodes	**Silicosis** (classic); also coal worker's pneumoconiosis, sarcoidosis, treated lymphoma
Split pleura sign	**Empyema** (enhancement of both thickened pleural layers on CT)
Figure-3 sign	Coarctation (pre-stenotic dilatation, indentation, post-stenotic dilatation)

Foreign body in a child

- A partial one-way (ball-valve) obstruction traps air: **the affected lung is hyperinflated, and on the expiratory film the mediastinum shifts away from the affected side** (here to the left for a right-sided object). Complete obstruction gives collapse. Radiolucent objects such as peanuts are missed on the film; inspiratory and expiratory (or decubitus) views are used and **rigid bronchoscopy** removes the object. The right main bronchus is the commoner site.

Coarctation of the aorta

- Commonest site: distal to the origin of the left subclavian artery at the ligamentum arteriosum. Upper-limb hypertension, weak or delayed femoral pulses (radiofemoral delay); associated with Turner syndrome, bicuspid aortic valve, PDA, VSD.
- **Rib notching** (Roesler sign): inferior margins of the **posterior 3rd to 8th ribs**, bilateral but often asymmetrical, caused by enlarged intercostal collaterals. **Ribs 1 and 2 are spared** because their intercostal arteries come from the **costocervical trunk (supreme intercostal)**, above the narrowing, and carry no reversed flow. Rib notching is rare before about 5 to 8 years of age. Notching on the **right only** means a coarctation proximal to the left subclavian origin; on the **left only**, an aberrant right subclavian artery arising below the narrowing. It also occurs in neurofibromatosis type 1 (ribbon ribs), after a Blalock-Taussig shunt (on its side), and in SVC or subclavian obstruction. Barium swallow shows the reversed 3 (E sign). **Superior** rib notching has other causes: rheumatoid arthritis, SLE, scleroderma, hyperparathyroidism, poliomyelitis and other paralyses. Modern: MRI or CT angiography for the anatomy and its collaterals; balloon dilatation and stenting are now common, with surgery in infants.

Other pearls

- Tension pneumothorax is a clinical diagnosis; do not delay for a film. A **pneumothorax** is seen as a visceral pleural line with no lung markings beyond it; the deep sulcus sign on a supine film.
- Miliary tuberculosis gives uniform 1 to 3 mm nodules; bronchiectasis gives tram-track and signet-ring signs, best shown on HRCT.
- **CO-RADS** (Dutch Radiological Society, 2020): a 1 to 5 score of how likely COVID-19 pneumonia is, read from **non-contrast chest CT** (typical: bilateral, peripheral, posterior ground-glass opacities, with crazy paving or consolidation later); CO-RADS 6 means RT-PCR proven.

Heart, pleura and mediastinum on the plain film

- **Technique**: a **PA erect film** at full inspiration (6 or more anterior ribs above the diaphragm) with the **scapulae rotated out of the lung fields**; an **AP film** (bed-bound patients) magnifies the heart and is not used to judge heart size. **Cardiothoracic ratio** = maximum transverse cardiac width over internal thoracic width: **normal below 0.5 in adults on a PA film** (up to 0.6 in neonates and infants).
- **Cardiomegaly (CTR above 0.5)**: left ventricle (apex down and out, **boot-shaped** with hypertrophy; the classical **aortic configuration**), right ventricle (apex up), **pericardial effusion**, and cardiomyopathy.
- **Pericardial effusion**: **globular or "water-bottle" heart with sharp outlines, a clear lung field and absent chamber contour**; at least 200–250 mL is needed to show on plain film; a **fat pad (Oreo cookie) sign** on the lateral film; echocardiography is the investigation of choice (it detects 20 mL or more), and tamponade is clinical.
- **Mitral stenosis (the "mitral heart" of the curriculum)**: **left atrial enlargement**, with a **straight left heart border (loss of the cardiac waist from the enlarged left atrial appendage)**, a **double right heart border (double density: the enlarged left atrium behind the right atrium)**, **splaying of the carina (above 90°)** and posterior displacement of the barium-filled

oesophagus on the lateral film; **upper-lobe venous diversion, Kerley B lines**, a small aortic knuckle and later pulmonary arterial hypertension (**pruned peripheral vessels**); calcified mitral valve on fluoroscopy. The right ventricle enlarges late.

- **Other classical outlines**: **boot shape (coeur en sabot) tetralogy of Fallot** with oligaemic lungs; **egg on its side, narrow pedicle: transposition of the great arteries**; **snowman or figure of 8: supracardiac total anomalous pulmonary venous return**; **rib notching (inferior margins of the posterior 3rd to 8th ribs, see above): coarctation**, with the **figure of 3 sign**; **box-shaped large heart: Ebstein's anomaly**.
- **Pleural fluid and gas**: **simple effusion gives a meniscus curving up the lateral chest wall and blunts the costophrenic angle**; **hydropneumothorax** (air and fluid together) gives a **sharp horizontal air-fluid level across the whole hemithorax on an erect film, with no meniscus**, because air lies above the fluid; **pneumothorax**: visceral pleural line with no lung markings beyond; **tension** shifts the mediastinum away.
- **Widened mediastinum (above 8 cm on a supine AP film in trauma)**: **traumatic aortic injury at the isthmus** until proved otherwise (loss of the aortic knuckle, apical cap, tracheal and NG tube deviation to the right, depressed left main bronchus); **stable patient: CT angiography of the chest is the investigation of choice**; unstable: transoesophageal echocardiography or immediate surgery. Other causes: venous bleeding, thymus (infant), lymphoma, goitre.
- **Lung parenchyma in the curriculum**: **post-primary tuberculosis: upper-lobe apical and posterior segments, cavities, fibrosis with volume loss**; **primary TB: hilar lymphadenopathy (Ghon focus and complex)**; **lobar pneumonia: air bronchogram and a lobar or segmental opacity**; **lung abscess: cavity with an air-fluid level and thick wall**; **tumours: spiculated mass, cavitation in squamous cell cancers, hilar enlargement, rib destruction**.

CNS imaging

Extra-axial versus intra-axial

- **Extra-axial** (outside the brain parenchyma): **meningioma**, schwannoma, pituitary adenoma, chordoma, craniopharyngioma. Features: broad dural base, dural tail, cortex buckled inwards, cerebrospinal fluid cleft.
- **Intra-axial**: astrocytoma and glioblastoma, ependymoma, oligodendroglioma, medulloblastoma, lymphoma, metastases.
- **Glioblastoma** (the commonest primary malignant brain tumour in adults): a heterogeneous mass with an irregular thick enhancing rim, central necrosis, surrounding oedema and mass effect, often crossing the corpus callosum (butterfly glioma); in the WHO CNS 5 classification (2021) glioblastoma is IDH-wildtype by definition. **Oligodendroglioma** is the glioma that calcifies most often (about 70 to 90%, coarse nodular calcification in the frontal cortex); its "fried egg" is the histology (perinuclear halos), not an imaging sign; IDH-mutant with 1p/19q codeletion (WHO 2021).
- Meningioma: "mother-in-law" sign on angiography (the tumour blush **comes early and stays late**), sunburst pattern of its supply from meningeal arteries; hyperostosis of adjacent bone; calcification in about 25%.
- Spinal tumours: commonest overall is extradural **metastasis**; commonest primary spinal tumour is a nerve sheath tumour (schwannoma, intradural extramedullary); commonest intramedullary tumour is ependymoma (adults) or astrocytoma (children).

Extradural versus subdural haematoma

	Extradural	Subdural
Shape	**Biconvex (lentiform)**	**Crescentic**
Sutures	**Limited by sutures** (unless a fracture crosses one); can cross the midline over the falx	**Crosses sutures**, not the falx or tentorium
Source	Middle meningeal artery (arterial), temporal bone fracture	**Bridging veins** (venous)
Typical patient	Young, trauma	Elderly, alcohol, anticoagulants, boxers, child abuse
Lucid interval	**Classic** (though seen in only about a third)	Rare
Outcome	Better if evacuated early	Worse

- Acute blood on non-contrast CT is **hyperdense (60 to 80 HU)**; active bleeding may show a hypodense "swirl sign". A subdural is hyperdense for about the first week, **isodense at about 1 to 3 weeks** (subacute, easily missed: look for effaced sulci and midline shift) and **hypodense after about 3 weeks** (chronic).

Neurocysticercosis (common in Nepal)

- **Stages**: vesicular (cyst with a dot-like scolex, "hole with dot"), colloidal vesicular (ring enhancement, oedema), granular nodular, **calcified nodular**. The "**starry sky**" appearance is disseminated disease: on CT, **multiple tiny calcified nodules** (the usual exam picture); on MRI, many small cysts each with its scolex. Muscle cysts calcify as rice-grain shadows on soft-tissue films. A small calcified cortical lesion in a patient with seizures in Nepal is a calcified neurocysticercus until proved otherwise (it can still cause seizures, especially with surrounding oedema). A **single small enhancing lesion** (under 2 cm, round, with an eccentric scolex) is the commonest form in South Asia; it is told from a tuberculoma, which is usually larger (over 2 cm), irregular, with more oedema and midline shift, and shows a **lipid peak** on MR spectroscopy.
- Treatment (IDSA/ASTMH 2017): **albendazole** (15 mg/kg a day for 10 to 14 days) with corticosteroids for viable parenchymal cysts, adding praziquantel when there are more than two; antiepileptics; no antiparasitic drug for calcified lesions alone, or in cysticercal encephalitis (raised pressure from many cysts).

Other signs

Sign	Condition
Dawson's fingers	**Multiple sclerosis**: ovoid T2/FLAIR periventricular lesions perpendicular to the ventricles, along medullary veins; also in the corpus callosum, juxtacortical, infratentorial and spinal cord. Exam answer: McDonald 2017, dissemination in space (2 of 4 sites) and time. Current: McDonald 2024 (Lancet Neurology 2025) adds the **optic nerve as a fifth site**, the **central vein sign** and paramagnetic rim lesions as supporting MRI markers, and the kappa free light chain index beside oligoclonal bands.
Hummingbird, Mickey Mouse	Progressive supranuclear palsy
Hot cross bun	Multiple system atrophy (cerebellar type)

Sign	Condition
Molar tooth	Joubert syndrome
Eye of the tiger	PKAN (Hallervorden-Spatz)
Face of the giant panda	**Wilson disease** (midbrain, T2), the exam answer; entrance books also list Japanese encephalitis, which involves the thalami, basal ganglia and substantia nigra
Tram-track (gyriform) calcification	Sturge-Weber (tram-track also in optic nerve sheath meningioma)
Popcorn	Cavernous haemangioma
Puff of smoke	Moyamoya (angiography)
Tigroid pattern	Metachromatic leukodystrophy (also Pelizaeus-Merzbacher)
Racing car (Viking helmet)	Agenesis of the corpus callosum
Lemon skull, banana cerebellum	Chiari II
Mount Fuji	Tension pneumocephalus
Empty delta (contrast CT)	**Cerebral venous sinus thrombosis**: non-enhancing clot in the posterior superior sagittal sinus inside its enhancing dural walls and collaterals; the dense clot itself on plain CT is the cord or dense triangle sign; confirm with CT or MR venography

- **Chiari I**: tonsillar descent over 5 mm, with syringomyelia (dissociated sensory loss, painless burns). **Chiari II**: vermis, tonsils and medulla herniate, with spina bifida and hydrocephalus. **Dandy-Walker**: cystic fourth ventricle, vermian agenesis, enlarged posterior fossa.
- **Pineal calcification** is normal in many adults (more with age) and marks the midline, so its shift shows mass effect; pineal calcification in a child under about 10 years (some say 6) suggests a pineal germ cell tumour. Other physiological intracranial calcification: choroid plexus, habenula, dura and falx, arachnoid granulations.
- **Basal ganglia calcification**: physiological with age (globus pallidus commonest); hypo-, hyper- and pseudohypoparathyroidism, hypothyroidism; **Fahr disease**; Cockayne syndrome; lead, carbon monoxide and birth anoxia; toxoplasmosis, CMV, rubella and neurocysticercosis; chemoradiation.

OPLL (ossification of the posterior longitudinal ligament)

- A strip of ossification behind the vertebral bodies; more frequent in East Asian people (Japanese disease). Commonest in the **mid and lower cervical spine**; narrows the canal and causes myelopathy.
- **MRI is the investigation of choice** in the exam's sense and for the cord (low signal on all sequences, shows cord compression and myelomalacia); **CT shows the ossification itself best** and is used to plan surgery, with the "double layer" sign when the dura is ossified too; blooming on gradient-echo exaggerates the stenosis.

Gastrointestinal imaging

Plain abdominal film

- **Small bowel obstruction**: loops over **3 cm, central**, **valvulae conniventes crossing the full width** (stack of coins, stepladder), multiple air-fluid levels, **little or no gas in the colon**. Commonest cause in the West: **adhesions**, then hernias; in low-income countries, South Asia included, **obstructed hernia** remains a leading cause, with abdominal tuberculosis and, in children, a roundworm (Ascaris) bolus.
- **Large bowel obstruction**: colon over **6 cm (caecum over 9 cm; the "3-6-9" rule)**, **peripheral** loops with **haustra that do not cross the lumen**, few levels, abrupt gas cut-off; caecum over 9 cm risks perforation. Carcinoma is the commonest cause in adults in the West; **sigmoid volvulus** is a much commoner cause in the "volvulus belt" (parts of Africa, the Middle East, South Asia, Russia and South America); consider pseudo-obstruction (Ogilvie) too.
- **Sigmoid volvulus**: massively dilated inverted U (coffee-bean, kidney bean) loop rising from the pelvis, apex towards the right upper quadrant, with a medial crease; elderly, institutionalised, constipated. Contrast enema shows a **bird's-beak** taper. Treat by rigid or flexible sigmoidoscopic decompression, then elective sigmoid colectomy. **Caecal volvulus**: comma-shaped loop in the left upper abdomen; treated by operation (right hemicolectomy), not endoscopy. **Malrotation and midgut volvulus**: the **upper GI contrast study is the investigation of choice** (duodenojejunal flexure low and right of the spine; corkscrew duodenum in volvulus); whirlpool sign (SMV wrapped round the SMA) on Doppler ultrasound, the whirl sign of twisted mesentery on CT in any volvulus; bilious vomiting in a neonate is malrotation with volvulus until proved otherwise.
- **Pneumoperitoneum**: causes are hollow viscus perforation, trauma, recent laparotomy, laparoscopy or dialysis, hysterosalpingography, ruptured liver abscess. The **erect chest film** is the best first film because free gas rises and **outlines the diaphragm** as a crescent; small amounts (about 1 mL) can show after the patient sits upright for 5 to 10 minutes. If the patient cannot stand, a left lateral decubitus film for 10 minutes. CT is the most sensitive. Signs: cupola, **Rigler's sign** (on a supine film both sides of the bowel wall are seen, because free gas outlines its outer surface and luminal gas its inner; it usually needs a large volume of gas; not to be confused with Rigler's triad of gallstone ileus), football sign, falciform ligament sign, Doge's cap (Morrison's pouch). Mimics: Chilaiditi syndrome (colon between liver and diaphragm), normal fundic gas.
- **Gallstones on plain film**: most are cholesterol or mixed stones with little calcium, so only **10 to 15% are radiopaque** (black pigment stones, commoner in haemolysis and cirrhosis, are opaque more often, about half); **ultrasound** (echogenic foci with acoustic shadowing) is the investigation of choice. Most renal stones (about 90%) are radiopaque, **calcium oxalate the commonest**; cystine and struvite are faintly or moderately opaque; radiolucent stones are uric acid, xanthine and drug stones (indinavir, triamterene). Indinavir stones are the only ones also invisible on CT. Gallstones lie anterior to the spine on a lateral film, with lucent centres (Mercedes-Benz or crow's foot sign from gas in fissures); renal stones overlie the spine. Medical dissolution (ursodeoxycholic acid) suits small (under about 10 mm) radiolucent cholesterol stones in a functioning gallbladder; they often recur.
- Emphysematous cholecystitis (diabetics, older men; gas-forming organisms such as Clostridium): gas in the gallbladder wall or lumen; an emergency.

Neonatal obstruction

- **Duodenal atresia: double bubble** sign (gas in stomach and dilated duodenum, no distal gas), **vomiting from the first day, bilious in about 85%** (the block is usually below the ampulla), polyhydramnios and a double bubble on antenatal ultrasound; the commonest cause of **congenital duodenal obstruction**; about 30% have **Down syndrome**; treated with duodenoduodenostomy (Kimura's diamond). Gas beyond the duodenum means an incomplete block (web, stenosis) or malrotation, which needs an urgent contrast study. Other causes of double bubble: duodenal web, annular pancreas, malrotation with Ladd's bands, midgut volvulus.
- **Jejunal atresia: triple bubble**. Ileal atresia: multiple air-fluid levels with distal gas absent. A **microcolon** (an unused colon) on contrast enema points to a distal small bowel block: meconium ileus, ileal atresia, total colonic aganglionosis.
- **Hypertrophic pyloric stenosis**: non-bilious projectile vomiting from about 3 to 6 weeks, commoner in first-born boys, **olive mass**, hypokalaemic hypochloraemic metabolic alkalosis with paradoxical aciduria; **ultrasound** (muscle thickness **3 mm or more** (some use 4 mm), canal length **15 mm or more**, some use 17 mm) confirms it; string sign, shoulder sign and double track on barium meal; single large gastric bubble on films. It is not present at birth. Treatment: correct the fluids and alkalosis first, then **Ramstedt pyloromyotomy** (open or laparoscopic).
- Imperforate anus: the exam answer is the **invertogram** (Wangensteen-Rice); current practice is a **prone cross-table lateral film** after about 24 hours (the gas needs time to reach the rectum), with perineal ultrasound; a gap over 1 cm between rectal gas and the perineum means a high lesion needing colostomy first.

Oesophagus on barium

Appearance	Condition
Bird's beak or rat tail, dilated oesophagus above	**Achalasia** (failure of lower oesophageal relaxation; also Chagas)
Corkscrew or rosary beads	Diffuse oesophageal spasm
Apple core, irregular shouldering	Carcinoma
Smooth tapering stricture	Benign (peptic) stricture
Serpiginous filling defects	Varices
Feline oesophagus (fine transient transverse folds)	Reflux oesophagitis
Ringed (fixed concentric rings, "trachealisation") oesophagus	Eosinophilic oesophagitis
Schatzki ring (at the squamo-columnar junction)	Intermittent dysphagia to solids, with hiatus hernia
Double barrel	Dissection

- Achalasia: **high-resolution manometry is the gold standard** (Chicago classification v4.0, 2021: types I, II and III; type II responds best); barium shows the taper and the absent gastric air bubble; endoscopy excludes pseudoachalasia from a cardia carcinoma. Treatment: laparoscopic Heller myotomy with fundoplication, **peroral endoscopic myotomy (POEM, best for type III)**, pneumatic dilatation; botulinum toxin for the unfit.

Pancreas and biliary signs

- **Acute pancreatitis**: **sentinel loop** (a localised ileus: a single dilated loop of jejunum or duodenum beside the inflamed pancreas), colon cut-off (gas stopping at the splenic flexure), renal halo, gasless abdomen on films. **Contrast CT is the imaging of choice for severity and complications**, best done **after 72 hours** (earlier only when the diagnosis is in doubt); the CT severity index (Balthazar) grades it; the revised Atlanta classification (2012) names the collections (acute peripancreatic fluid collection and pseudocyst, after 4 weeks; acute necrotic collection and walled-off necrosis). Ultrasound looks for gallstones as the cause.
- **Chronic pancreatitis**: calcification (alcohol; also tropical pancreatitis, with large ductal stones), **chain of lakes** or **string of pearls** (dilated duct with strictures) on ERCP or MRCP, beaded duct, rat-tail stricture of the lower CBD; MRCP with secretin is the modern test.
- **Carcinoma of the head**: **double duct sign** (CBD and pancreatic duct both dilated), **Frostberg's inverted 3 sign** on hypotonic duodenography (in standard radiology texts chiefly carcinoma of the head; entrance books list it under chronic pancreatitis, and either can cause it), widened C-loop, antral pad sign, and the "scrambled egg" pattern entrance books list; pancreatic-protocol CT is the investigation of choice for diagnosis and resectability, EUS with biopsy for tissue. Annular pancreas: double bubble. Autoimmune pancreatitis: sausage-shaped pancreas with a capsule-like rim, raised IgG4.
- **Primary sclerosing cholangitis**: multifocal short strictures and dilatations, **beaded intra- and extrahepatic ducts**, prune-tree appearance; **strongly associated with ulcerative colitis**; risk of cholangiocarcinoma; raised ALP; onion-skin fibrosis; no proven medical therapy, liver transplant for end-stage disease. **MRCP is the best non-invasive test**; **ERC is the reference standard** (CT is not).
- Caroli disease: central dot sign. Hydatid cyst: water-lily sign, honeycomb, daughter cysts. CBD stone: meniscus sign on cholangiography (ERCP or MRCP). Pyogenic liver abscess: double target sign, cluster sign. Porcelain gallbladder is premalignant (exam answer: cholecystectomy; modern series put the cancer risk at only about 2 to 6%, highest with patchy mucosal calcification). Sphincter of Oddi spasm: pseudocalculus.
- Stomach: benign ulcer shows Hampton's line; malignant ulcer shows Carman meniscus; gastric volvulus gives an upside-down stomach (Borchardt's triad).
- Colon: **apple core** (carcinoma), thumbprinting (ischaemic colitis, splenic flexure commonest), lead pipe (long-standing ulcerative colitis), accordion sign (pseudomembranous colitis, C. difficile: exam answer oral vancomycin or metronidazole; current practice **fidaxomicin preferred, oral vancomycin acceptable**, metronidazole only when neither is available, IDSA/SHEA 2021), sawtooth (diverticular disease: sigmoid commonest in the West, right colon commoner in East Asians; **CT is the investigation of choice for acute diverticulitis**, barium enema and colonoscopy avoided acutely). **Ileocaecal tuberculosis**: Fleischner (inverted umbrella) sign, goose-neck, Stierlin sign, pulled-up caecum.

Plain abdominal film and the contrast studies in the curriculum

- **Plain abdomen**: **gas under the right hemidiaphragm** (best seen on an erect chest film after 10 minutes upright, or on a left lateral decubitus film for the sick) means a **perforated hollow viscus**; **multiple air-fluid levels** with **dilated small bowel (over 3 cm) in the central abdomen with valvulae**

conniventes crossing the whole width is small bowel obstruction; **large bowel (over 6 cm) peripheral with haustra** that do not cross the whole width; **calcifications**: renal and ureteric calculi (about 90% radio-opaque), gallstones (only 10–15% visible, see above), pancreatic calcification (chronic pancreatitis), phleboliths (round with a lucent centre) and calcified mesenteric nodes. The **psoas shadows, renal outlines and properitoneal fat line** are checked; in a pregnant abdomen the film shows the fetal skeleton, presentation and the number of fetuses (now ultrasound).

- **Barium swallow and meal**: **varices** (serpiginous filling defects in the lower oesophagus), **carcinoma (shouldered, irregular stricture, "apple core" in the colon)**, **achalasia (bird's beak)**, **gastric ulcer (a crater with radiating folds, Hampton's line)**, **malignant gastric ulcer (an ulcer within a mass, folds that stop short)**, duodenal ulcer (cap deformity, **trefoil**). **Barium enema (colon)**: **carcinoma is an apple-core stricture with shouldered edges, short and irregular**, diverticula (sawtooth), **polyp (filling defect)**, ulcerative colitis (**lead-pipe colon**, collar-button ulcers), Crohn's (string sign, cobblestoning, skip lesions). **Small bowel follow-through** (barium swallowed, films as it passes, with compression of the right iliac fossa to separate the loops) is the barium study for the whole small bowel and the **terminal ileum**; enteroclysis (barium through a tube into the jejunum) distends it better; a barium enema shows the ileum only when contrast refluxes through the valve. Modern practice: CT or MR enterography (MR preferred in the young, no radiation) for Crohn disease.
- **Oral cholecystography (obsolete; replaced by ultrasound)**: oral iodinated contrast (iopanoic acid) is concentrated in the gallbladder; **gallstones show as filling defects, a non-functioning gallbladder as non-opacification**; ultrasound is now the first test (stones, wall thickening, Murphy's sign).
- **Special procedures to recognise** (mostly historical, replaced by CT, MRI and ultrasound): **myelogram** (contrast in the subarachnoid space, replaced by MRI); **bronchogram** (replaced by HRCT); **lymphangiogram** (foot lymphatics; replaced by CT and PET); **sialogram** (parotid and submandibular ducts; stones, strictures with a "sausage-link" pattern); **intravenous and T-tube cholangiogram**, **percutaneous transhepatic cholangiogram** and ERCP (biliary tree); **arthrogram** (joint contrast, now MRI); **hysterosalpingogram** (uterine cavity and tubal patency; infertility; **contrast spills into the peritoneum if the tubes are open**; avoid in pregnancy and infection); **urethrogram** (retrograde, for **strictures and rupture**: extravasation at the bulbar or membranous urethra); **tomogram** (blurred out-of-plane structures, replaced by CT).

Genitourinary imaging

Urography patterns

Appearance	Condition
Spider-leg calyces, sweet-cheese nephrogram	**Autosomal dominant polycystic kidney disease** (bilateral; unilateral spider leg suggests renal cell carcinoma)
Striated or sunray nephrogram	ARPKD
Bouquet of flowers	Medullary sponge kidney
Ring or lobster-claw, egg-in-cup	Papillary necrosis
Flower vase ureters ("hand-shake" in entrance books), lower poles joined and medially placed	Horseshoe kidney (the isthmus is held below the inferior mesenteric artery)
Drooping lily	Duplex kidney with an obstructed upper moiety displacing the lower
Cobra head (spring onion)	Ureterocele
Fish-hook (J-shaped) lower ureters, elevated bladder base	Prostatic enlargement
Medial deviation of both ureters (maiden waist)	Retroperitoneal fibrosis
Pear-shaped (teardrop) bladder	Pelvic lipomatosis, pelvic haematoma

- Intravenous urography is now largely replaced by CT urography; **non-contrast CT KUB** is the investigation of choice for ureteric colic, and ultrasound for hydronephrosis and in pregnancy.

Renal tuberculosis

- Urography: moth-eaten calyces, calyceal destruction, **cement (putty) kidney** (autonephrectomy), beaded or corkscrew or pipe-stem ureter, golf-hole ureteric orifice, **thimble bladder** (small, thick-walled, contracted bladder).
- Presents with frequency and **sterile pyuria in acid urine**; diagnosis is by **urine culture for AFB (three to five early-morning samples)** and urine Xpert MTB/RIF. Imaging: the earliest urographic sign is an irregular, **moth-eaten calyx**; **CT urography** has replaced IVU and is now the imaging of choice; calcification is the commonest plain film or CT finding.
- **Christmas-tree (pine-cone) bladder** is **neurogenic**, not tuberculous. Schistosomiasis: calcified bladder wall (fetal head contour); posterior urethral valves: thick trabeculated bladder.

Nuclear renal scans

- **Dynamic** agents (**Tc-99m DTPA or MAG3**) assess perfusion, function and drainage or obstruction (diuretic renography): MAG3 is tubular secreted, DTPA is glomerular filtered (so **DTPA measures GFR**; **MAG3 is preferred in neonates and poor renal function**, as its higher extraction gives a clearer image). Diuretic (furosemide) renography tells obstruction from a dilated, unobstructed system, as in pelviureteric junction obstruction. For a patient with failure and a normal ultrasound, a dynamic scan assesses function.
- **Static** agent (**Tc-99m DMSA**): binds to proximal tubular cells and gives a cortical image; **best for renal scarring** after childhood pyelonephritis (done **4 to 6 months** after the infection (NICE), so acute changes are not read as scars; done during it, it shows acute pyelonephritis), differential function, and ectopic kidney.

Vesicoureteric reflux

- Investigation of choice: **micturating cystourethrogram (MCUG)**, with the international grading:

Grade	Finding
I	**Ureter only, not dilated**
II	Reaches pelvis and calyces, no dilatation
III	Mild to moderate dilatation, blunting of calyces
IV	Grossly dilated ureter, tortuosity

Grade	Finding
V	Massive dilatation, loss of papillary impressions

- Ultrasound in children screens for hydronephrosis and scars; radionuclide cystography has a lower radiation dose and is used for follow-up; **contrast-enhanced voiding urosonography** (no radiation) is a modern alternative to MCUG in children (European paediatric radiology guidance). MCUG remains the only test that shows the urethra, so it is needed for **posterior urethral valves** in boys. On antenatal or neonatal ultrasound, PUV gives the **keyhole sign** (dilated posterior urethra and bladder neck above a thick-walled, trabeculated bladder) with bilateral hydronephrosis and, in severe cases, oligohydramnios.

Kidney anomalies and the intravenous urogram

- **Horseshoe kidney** (the commonest fusion anomaly, about 1 in 400–600, more in Turner syndrome): **the lower poles fuse across the midline, and the isthmus passes in front of the aorta and IVC; its ascent is stopped by the root of the inferior mesenteric artery, so the kidneys lie low and have a malrotated pelvis (the pelvises face forward and the ureters course over the isthmus)**. IVU or CT shows **the lower calyces pointing medially, the long axes of the kidneys converging below (a V, the reverse of the normal inverted V, whose upper poles lie nearer the midline)**; complications: hydronephrosis (from the high insertion of the ureter), stones, infection and a slightly higher risk of Wilms tumour. **Pelvic (ectopic) kidney**: a kidney in the pelvis, short renal artery from the iliac artery.
- **Intravenous urogram**: **normal calyces are cup-shaped with sharp fornices**; **hydronephrosis shows clubbing, and a delayed or absent nephrogram**; **stones**: filling defects or obstruction with a "standing column"; **renal tumour: calyceal displacement, distortion or amputation**; **spider-leg calyces, stretched by many cysts, in adult polycystic kidney disease** (in one kidney only, think of a tumour); **bladder: filling defects, trabeculation (pine-tree) in neurogenic bladder**; **ureteric stones lie at three constrictions (pelviureteric junction, pelvic brim, vesicoureteric junction)**. **Retrograde urethrogram**: stricture appears as a segmental narrowing, rupture as extravasation. **Bladder rupture** (pelvic fracture with haematuria): **retrograde cystography, plain or CT, with the bladder actively filled** (at least about 300 mL) is the confirming test; passive filling on a routine CT or IVU misses it. Blood at the meatus means a retrograde urethrogram first, before a catheter. Intraperitoneal rupture (contrast outlining bowel loops) needs surgical repair; extraperitoneal rupture (flame-shaped extravasation round the bladder base) is usually managed with catheter drainage (EAU and AUA urotrauma guidelines). IVU has been **largely replaced by CT urography** (and **non-contrast CT KUB** for stones).

Musculoskeletal and paediatric imaging

Elbow ossification: CRITOE

Capitulum **1 year**, radial head **3**, medial (internal) epicondyle **5**, trochlea **7**, olecranon **9**, **lateral (external) epicondyle 11**. The lateral epicondyle appears last. The ages are approximate and earlier in girls; **the order matters more than the ages**: a bony fragment where the trochlea should be, before a medial epicondyle is seen, is an avulsed medial epicondyle trapped in the joint. Carpal bones: capitate (2 months), hamate (3 months), triquetral (3 years), lunate (4 years), scaphoid, trapezium and trapezoid (4 to 6 years), **pisiform (10 to 12 years)**.

Skull signs

Sign	Condition
Hair-on-end	**Thalassaemia major** (more than sickle cell; also hereditary spherocytosis, cyanotic heart disease); marrow hyperplasia widens the diploe with vertical spicules; the occipital bone is spared
Punched-out, raindrop	Multiple myeloma (older adults)
Geographic skull	**Langerhans cell histiocytosis** (eosinophilic granuloma; bevelled edge, children)
Salt-and-pepper (pepper-pot)	Hyperparathyroidism
Cotton wool, Tam o' Shanter; osteoporosis circumscripta in the early lytic phase	Paget disease
Copper-beaten (silver-beaten)	Chronic raised intracranial pressure in children (craniosynostosis); with **sutural diastasis** in raised pressure before the sutures fuse
Empty sella	Primary (arachnoid herniation, often incidental); idiopathic intracranial hypertension; after pituitary surgery, radiotherapy or apoplexy (Sheehan)
J-shaped sella	Optic chiasm glioma, mucopolysaccharidoses (Hurler), achondroplasia; can be normal
Luckenschadel (lacunar)	Chiari II

Metabolic and other bone signs

- **Rickets**: cupping, fraying and widening of metaphyses (first and best seen at the wrist and knee), widened physis, rachitic rosary, bowed legs (genu varum in toddlers, valgum later), triradiate pelvis in severe disease. **Scurvy**: Wimberger ring, Pelkan spur, Frankel line, Trummerfeld zone. **Osteomalacia**: Looser zones (Milkman pseudofractures), **triradiate pelvis**, biconcave (codfish) vertebrae. **Hyperparathyroidism**: subperiosteal resorption (radial side of middle phalanges), brown tumours, salt-and-pepper skull. **Hypothyroidism**: stippled epiphyses, Wormian bones, beaked vertebrae.
- **Osteopenia on plain film** shows only after **30 to 50%** of bone mineral is lost, so bone density is measured by **DEXA** (lumbar spine and hip). **T-score**: standard deviations from the mean peak bone mass of healthy young adults of the same sex; WHO: **–1 or above normal, between –1 and –2.5 osteopenia (low bone mass), –2.5 or lower osteoporosis, and severe (established) osteoporosis –2.5 or lower with a fragility fracture**. **Z-score**: against people of the same age and sex; used in premenopausal women, men under 50 and children (–2 or lower is "below the expected range for age").
- **Osteopetrosis** (marble bone disease; failure of osteoclast resorption, the adult type often CLCN7): uniformly dense bones with **bone within bone (endobone)**, **sandwich vertebrae** (dense end plates; the rugger-jersey spine is renal osteodystrophy's) and **Erlenmeyer-flask** metaphyses (the flask also in Gaucher disease); the bones are brittle despite their density. A transient bone-within-bone look is normal in infants.
- **Achondroplasia** (FGFR3 gain of function, advanced paternal age): champagne-glass pelvis, trident hand, short pedicles with the interpedicular distance narrowing down the lumbar

spine (it normally widens), rhizomelic shortening; normal intelligence and near-normal life span (foramen magnum stenosis in infancy is the main danger). **Acromegaly**: spade-like phalanges, arrowhead tufts, heel pad over about 23 mm (men; 21.5 mm women), enlarged sella. **Psoriatic arthritis**: pencil-in-cup, DIP involvement, opera-glass hand. **Gout**: Martel sign (overhanging edge). **Paget disease**: blade of grass, picture-frame vertebra, cotton-wool skull. **Vertebral haemangioma**: corduroy or polka-dot. **Vertebral metastasis**: winking owl (pedicle erosion).

- **Bone scan** (Tc-99m MDP) shows osteoblastic activity; multiple myeloma may be cold, so bone scan is not used for it. Exam answer for myeloma: **skeletal survey**. Current practice (IMWG 2019): **whole-body low-dose CT** replaces the survey, with PET-CT or whole-body MRI; more than one focal lesion of 5 mm or more on MRI counts as a myeloma-defining event (IMWG 2014).
- Bone tumour signs: **onion-peel periosteal reaction** (Ewing sarcoma, diaphysis, children); **sunburst and Codman triangle** (osteosarcoma, metaphysis about the knee); **soap-bubble** (giant cell tumour: eccentric, expansile, lytic, in the epiphysis after fusion reaching the subchondral bone, narrow zone of transition and no sclerotic rim, aged 20 to 40, commonest about the knee; the soap-bubble look also in aneurysmal bone cyst, which is metaphyseal and under 20; outside bone, soap bubbles are seen in meconium ileus and in cryptococcal gelatinous pseudocysts of the basal ganglia); permeative lysis in the diaphysis of a child with fever (Ewing sarcoma, which mimics osteomyelitis); nidus under 1.5 cm with night pain relieved by aspirin (osteoid osteoma; **CT is the investigation of choice**); eosinophilic granuloma gives vertebra plana in children. Dense metaphyseal lines in lead poisoning.

Paediatric points

- Non-accidental injury: metaphyseal corner (bucket-handle) fractures and posterior rib fractures are highly specific; a skeletal survey is done in infants.
- **Hypertrophic pyloric stenosis** (non-bilious projectile vomiting at 3 to 6 weeks, olive mass): **ultrasound confirms it** (muscle 3 mm or more thick, canal 15 mm or more long), with no radiation; barium meal (string sign) is rarely needed; details and duodenal atresia are in the GI section. **Ultrasound is the first-line test for most paediatric abdominal problems** because it spares radiation.

Bone infection, rickets and other bone signs

- **Acute osteomyelitis**: **plain films are normal for the first 7–14 days** because **30–50% of the bone mineral must be lost** before lysis shows (soft tissue swelling and loss of the fat planes may be earliest). **Radiographic sequence: soft tissue swelling, then periosteal reaction (lamellar) at 10–14 days, then metaphyseal lucency, a sequestrum (dead bone, dense), an involucrum (new bone shell) and a cloaca in chronic disease**. **The earliest imaging is MRI (marrow oedema: T1 low, T2 and STIR high, within 24–48 hours); the bone scan (triple phase, Tc-99m MDP) is also positive within 24–72 hours, with a sensitivity near 90%**; ultrasound shows a subperiosteal collection. **Brodie's abscess**: a lucent cavity with a sclerotic rim in the metaphysis (subacute). **Garre's sclerosing osteomyelitis**: dense new bone without a lucency.
- **Septic arthritis and TB**: **septic arthritis: joint effusion, soft tissue swelling and later joint-space loss and erosions**; **TB arthritis: Phemister's triad (periarticular osteoporosis, peripheral erosions, gradual joint-space narrowing)**; **TB spine: disc and adjacent vertebral destruction, paraspinal (cold) abscess, gibbus** (the disc is spared in metastases).
- **Rickets**: **wrist and knee radiographs show a widened growth plate, with a cupped, frayed, splayed metaphysis, a poorly defined zone of provisional calcification, osteopenia, and bowed bones; Looser's zones (pseudofractures) are the sign of osteomalacia in adults. Scurvy: a dense (white) line of Frankel at the metaphysis, a Wimberger ring (sclerotic ring around the osteopenic epiphysis), a Trümmerfeld zone and subperiosteal haemorrhage, with a pencil-thin cortex** and a Pelkan spur at the metaphyseal margin. **Healing rickets: a thin, dense line at the metaphysis**.
- **Arthritis**: **osteoarthritis: LOSS (loss of joint space, osteophytes, subchondral sclerosis, subchondral cysts) with asymmetric narrowing**; **rheumatoid arthritis: periarticular osteopenia, marginal erosions, uniform joint space loss, symmetric small joints of the hands, ulnar deviation**; **gout: punched-out "rat bite" erosions with overhanging edges and tophi, the joint space preserved until late**; **ankylosing spondylitis: bilateral sacroiliitis, the "bamboo spine" (syndesmophytes), squared vertebrae**; **MRI (bone marrow oedema on STIR) shows sacroiliitis before radiographs**.
- **Fractures and tumours**: **Colles**: dorsal tilt of the distal radius (dinner fork); **supracondylar fracture of the humerus: the anterior humeral line misses the capitellum and a posterior fat pad is seen**; tumours: **osteosarcoma (sunburst, Codman triangle), Ewing (onion-peel), giant cell tumour (soap-bubble, epiphyseal), osteochondroma (a stalk continuous with the marrow), multiple myeloma (punched-out lesions)** (see above).

MRI, ultrasound and nuclear medicine

MRI

	T1	T2	FLAIR	STIR
TR, TE	**Short**	**Long**	Long, with inversion time that nulls CSF	Fat-suppressed
Fat	**Bright**	Bright on fast spin-echo T2 (the usual sequence now); intermediate on conventional spin-echo		Black
Fluid (CSF)	**Dark**	**Bright**	**Black** (pathological fluid bright)	Bright
Use	Anatomy, contrast enhancement, subacute blood	Oedema, demyelination, infarct, most pathology	Periventricular and cortical lesions	Marrow oedema, optic nerve, fat-containing lesions

- **TR** is the time between successive pulse sequences on the same slice; **TE** is the time from the radiofrequency pulse to the echo. On T1, grey matter is darker than white matter; on T2 the reverse.
- Hyperacute infarct: **diffusion-weighted imaging** (restricted diffusion) is the earliest and most sensitive sequence. Gadolinium is the MRI contrast (it shortens T1, so enhancing tissue turns bright on T1). MRI images the **hydrogen nucleus (proton)**; field strength 1.5 to 3 tesla; the room is a Faraday

cage; **susceptibility-weighted imaging (SWI)** or gradient echo shows blood products and microbleeds. Haemorrhage on MRI changes with time: hyperacute oxyhaemoglobin, acute deoxyhaemoglobin (T2 dark), early subacute intracellular methaemoglobin (T1 bright), late subacute extracellular methaemoglobin (T1 and T2 bright), chronic haemosiderin rim (dark on both). Absolute contraindications: older pacemakers and implants not MR-conditional, cochlear implants (some), intra-orbital ferromagnetic foreign body. Modern MR-conditional devices can be scanned under protocol.

Ultrasound and CT numbers

- Ultrasound: no radiation; sound waves from a **piezoelectric** crystal, diagnostic frequencies about 2 to 15 MHz (low for the abdomen, high for superficial parts); higher frequency gives better resolution but poorer penetration. Average speed of sound in soft tissue **1540 m/s**, the figure the machine assumes. Gas and bone block it. Before hepatobiliary ultrasound the patient **fasts at least 6 hours** (6 to 8 hours) so the gallbladder is distended and bowel gas less; a contracted gallbladder after a meal can hide stones or mimic wall thickening. Doppler assesses flow (colour Doppler by convention **red towards the probe, blue away**: BART, blue away, red towards); **FAST** looks at four windows for free fluid (pericardial, right upper quadrant or Morison's pouch, left upper quadrant or splenorenal, pelvis), and **eFAST** adds both lungs for pneumothorax; **endoscopic ultrasound** stages tumours and finds small stones.
- **Hounsfield units**: **air -1000**, fat -100 to -50, water 0, CSF 0 to 15, white matter 22 to 32, grey matter 32 to 42, **acute blood 60 to 80**, calcium and dense bone above 1000. Air is the lowest value and appears black; fat is dark but well above air.

Principles of ultrasonography and mammography

- **Ultrasound physics**: a **piezoelectric crystal** converts electrical energy into sound pulses of **2–18 MHz (the human ear hears below 20 kHz)** and receives the **echoes**; the image shows **reflection at interfaces between tissues of different acoustic impedance (impedance = tissue density × speed of sound)**. **The bigger the impedance difference, the stronger the reflection: tissue–air and tissue–bone interfaces reflect nearly all of the beam (about 99% for soft tissue–air), so structures behind gas-filled lung or bowel, or behind bone, cannot be seen**; this is why **coupling gel** is used (to remove air). Average speed of sound in soft tissue is **1,540 m/s** (used to calculate depth), in air about 330 m/s and in bone about 4,000 m/s. **Higher frequency gives better resolution and poorer penetration**. **A-mode (amplitude, one dimension; once used in ophthalmic biometry and echoencephalography)**, **B-mode (brightness, the standard image), M-mode (motion, echocardiography), Doppler (blood flow velocity via the Doppler shift)**. **Artefacts**: posterior acoustic **shadowing behind stones and bone**, **posterior enhancement behind fluid (cysts)**, reverberation. **Advantages**: non-ionising, real-time, portable, cheap; **disadvantages**: operator dependent, limited by gas and bone, and obesity.
- **Mammography**: **a low-kVp (25–32 kVp) molybdenum or rhodium anode system with compression** (to reduce thickness and scatter) examines the breast; **screening from 40–50 years**; two views (craniocaudal and mediolateral oblique). **Signs of malignancy**: a **spiculated (stellate) mass with an irregular margin and increased density, architectural distortion, skin thickening and nipple retraction, enlarged axillary nodes**, and **clustered fine pleomorphic or linear branching microcalcifications (ductal carcinoma, especially DCIS)**. **Benign signs**: well-circumscribed round or oval masses with a halo (cysts, fibroadenoma), **coarse "popcorn" calcification (degenerating fibroadenoma)**, large rod-like calcification (duct ectasia), fat-containing lesions (lipoma, hamartoma, oil cyst; "lucent-centred"), **eggshell (rim) calcification** of oil cysts (fat necrosis) and cyst walls. **BI-RADS** categories: 0 incomplete, 1 negative, 2 benign, 3 probably benign (under 2% malignant), 4 suspicious (4A, 4B, 4C), 5 highly suggestive of malignancy (95% or more), 6 known biopsy-proven. **Ultrasound** separates solid from cystic masses (better under 35–40 years, dense breasts); **MRI** for high-risk screening, lobular cancer and implants.
- **CT, MRI and the recent advances in the curriculum**: **CT** (high-resolution anatomy, good for bone, lung, acute blood and calcification; ionising); **MRI** (soft tissue, marrow, brain; no radiation; contraindicated with older pacemakers, cochlear implants and some metal implants; MR-conditional pacemakers can be scanned under set conditions); **NMR** is the older name for MRI; **PET** (F-18 FDG metabolic imaging of cancers, usually fused with CT); **DSA (digital subtraction angiography)** subtracts a pre-contrast mask image to show only the contrast-filled vessels (the gold standard for vascular anatomy, now often done at the time of an endovascular procedure; CT and MR angiography are used for diagnosis).

Nuclear medicine

- **Chromium-51** labelled red cells measure **red cell survival** and red cell mass (and the spleen's sequestration).
- **Technetium-99m**: from a molybdenum-99 generator (Mo-99 half-life about 66 hours, so a generator lasts about a week), decays by isomeric transition, emits only a **140 keV gamma ray**, **half-life 6 hours** (it decays to Tc-99, half-life about 211,000 years, so weakly radioactive that it adds almost nothing). The most widely used isotope. Ideal diagnostic isotope: pure gamma, short half-life, low energy; ideal therapeutic: beta (with some gamma for imaging).
- **Fluorine-18** (half-life **110 minutes**, positron emitter) as **fluorodeoxyglucose** is the commonest PET agent; cancer cells take up glucose avidly (Warburg effect). Carbon-11 (20 minutes) and gallium-68 (68 minutes) also used; Ga-68 or Cu-64 DOTATATE for neuroendocrine tumours, Ga-68 or F-18 PSMA for prostate cancer. Rubidium-82 (about 75 seconds) and N-13 ammonia (10 minutes) for PET myocardial perfusion. FDG is taken up normally by brain, heart and the urinary tract, and by inflammation, so it gives false positives in tuberculosis (common in South Asia) and sarcoidosis.
- **Theranostics** (modern practice): the same target imaged then treated, with **lutetium-177** (half-life about 6.7 days, beta and some gamma): **Lu-177 DOTATATE** for neuroendocrine tumours (NETTER-1, 2017) and **Lu-177 PSMA-617** for metastatic castration-resistant prostate cancer (VISION, 2021).
- Agents: Tc-99m **pertechnetate** (thyroid, salivary glands, Meckel diverticulum), **MDP** (bone), **sestamibi** (parathyroid adenoma, myocardial perfusion), **HIDA** (cholecystitis, biliary atresia, bile leak), sulphur colloid (liver, spleen, gastric emptying), red cell labelled (GI bleeding: finds bleeding of about 0.1 to 0.5 mL/min, against about 0.3 to 0.5 for CT angiography and 0.5 to 1 for catheter angiography; cardiac

blood pool, MUGA), thallium-201 (half-life about 73 hours; myocardial perfusion), DMSA, DTPA and MAG3 (kidney), MAA (lung perfusion; krypton or xenon for ventilation), **MIBG** (phaeochromocytoma, neuroblastoma).

- **Iodine**: I-123 (13 hours, gamma 159 keV) for thyroid uptake, scans and MIBG; **I-131 (8 days, beta and gamma) for therapy** of hyperthyroidism and thyroid cancer; I-125 (about 60 days, low-energy gamma) for radioimmunoassay and prostate seeds.

Isotope	Half-life	Use
Tc-99m	6 hours	Most diagnostic scans
F-18	110 minutes	FDG PET
I-131	8 days	Thyroid therapy
Co-60	**5.27 years**	Teletherapy (gamma 1.17 and 1.33 MeV), Gamma Knife
Cs-137	**30 years**	Older brachytherapy
Ir-192	**74 days**	High-dose-rate brachytherapy (the commonest source now)
Ra-226	**1,600 years**	Historical brachytherapy
Ra-223	11.4 days	Alpha therapy of bone metastases from prostate cancer
P-32	14.3 days	Older therapy of polycythaemia vera
Sr-89	50.5 days	Bone metastasis pain
Y-90	64 hours	Radioembolisation of liver tumours (pure beta)
Lu-177	6.7 days	PSMA and DOTATATE therapy
U-235	about 7 x 10^8 years	Nuclear fuel

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