
Q1. Describe in brief, protocol for CT pulmonary angiography for a suspected case of pulmonary thromboembolism. Describe plain radiographic & CT features of pulmonary thromboembolism.

Answer

CTPA Protocol

1. Pre-Procedure Preparation

A. Patient Assessment & Consent

- **History check**: Exclude contraindications – severe renal insufficiency, prior severe contrast reactions, hyperthyroidism (iodinated contrast risk), pregnancy considerations.
- **Consent**: Explain purpose (pulmonary embolism detection), potential risks (contrast reaction, radiation), and obtain informed consent.
- **Renal function**: Confirm recent eGFR/serum creatinine, especially in elderly, diabetic, or high-risk patients.

B. Fasting

- Fasting for **4–6 hours** to minimize risk of nausea/vomiting and possible aspiration.

C. IV Access

- Large-bore cannula **(preferably 18G, Green)** in **antecubital vein**.
- Secure line and check for free, pain-free saline flush prior to contrast.

Parameter	Details
IV Contrast	✔️ **Non-ionic iodinated contrast** • **Injection rate**: 4–5 mL/sec • 20–30 mL saline flush recommended to reduce SVC streak artifact
Trigger	✔️ **Bolus tracking (preferred)** **• ROI: Main pulmonary artery (or right atrium)** **• Threshold: 80 HU** **• Delay: 0–3 seconds after trigger for peak opacification**
Scan Phase	Single arterial phase – timed for peak opacification of pulmonary arteries
Scan Coverage	From thoracic inlet to just below the diaphragm
Slice Thickness	Acquisition: ≤1 mm Recons: axial, coronal, sagittal (1–2 mm) Thin slices for MIP/3D recons

Breath-Hold Instructions

- Practice with patient before scan.
- Single, full inspiration breath-hold during acquisition to reduce motion and atelectasis.

ECG Gating *(Optional)*

- Consider in cases of suspected subsegmental PE in motion-prone cardiac regions, or in patients with arrhythmias.

Aetiology

Embolic Sources

- **Most common origin**: **Proximal deep** veins of the lower limbs – *iliac, femoral, popliteal*.
- **Others**: Renal veins, upper extremity veins (esp. catheter-associated), pelvic veins.
- **Note**: Isolated calf vein thrombi rarely embolize and typically resolve spontaneously.
- **Up to 50% of patients with proximal DVT have concurrent PE**.

Virchow's Triad – Underlying Mechanism

1. **Stasis** – prolonged immobility, post-surgery, or stroke.
2. **Endothelial Injury** – trauma, surgery, catheterization.
3. **Hypercoagulability** – inherited or acquired thrombophilic states.

Risk Factors

Hereditary (Thrombophilia)	Acquired
Factor V Leiden	Immobilization (surgery, stroke)
Prothrombin gene mutation	Trauma, pregnancy, abdominal mass
Antithrombin III deficiency	Malignancy (GI, myeloproliferative)
Protein C/S deficiency	Nephrotic syndrome, APLA
	Smoking, Central venous catheters
	Hormonal therapy (OCP/HRT), UFH
	Prior thromboembolism, Infections

Pathophysiology

- **Acute PE** increases **pulmonary vascular resistance (PVR)**, leading to **right ventricular (RV) pressure overload**.
- Pulmonary artery pressures do not significantly rise until **>30% of vasculature is occluded**.

- RV dilation → ↑ wall tension → ↓ coronary perfusion → RV ischemia → ↓ contractility
- Interventricular septal shift → ↓ LV filling → systemic **hypotension**
- Concomitant **hypoxemia** results from:
    - V/Q mismatch
    - Shunting (e.g., through PFO)
    - Loss of hypoxic vasoconstriction

Clinical Presentation

- **Most common**: ***Acute onset dyspnea*** **followed by** ***pleuritic chest pain*** (from exudative, often hemorrhagic pleural effusion)
- **Other symptoms**:
    - Cough
    - Haemoptysis (uncommon)
    - Leg swelling/pain (suggestive of DVT)
    - Palpitations, syncope
- **Severe cases**: Shock, arrhythmias
- **Silent PE**: Can be asymptomatic – requires high clinical suspicion

Investigations

Blood Tests

- Leukocytosis (may be eosinophilic)
- Elevated ESR, LDH, AST
- Troponin T/I (suggest RV strain or infarction)

Arterial Blood Gas (ABG)

- Hypoxemia (unexplained)
- Respiratory alkalosis
- Hypocapnia

Electrocardiography (ECG)

- Tachycardia (most common)
- S1Q3T3 pattern
- T wave inversions (esp. in anterior leads)
- Right heart strain patterns (e.g., right bundle branch block)

D-Dimer

- Indicates fibrin degradation products → elevated in VTE
- **Positive**: ≥ 500 ng/mL
- **Rule-out thresholds**:
    - < 1000 ng/mL in **low C-PTP**
    - < 500 ng/mL in **moderate C-PTP**
- **Sensitive tests**: Immunoturbidimetric, latex agglutination-based, rapid ELISA

Clinical Probability and Risk Stratification

Wells Score (Clinical Prediction Guideline – CPG)

Clinical Feature	Points

Signs of DVT	3.0
PE more likely than alternative diagnosis	3.0
Immobilization/Surgery (within 4 weeks)	1.5
Heart rate >100 bpm	1.5
Previous PE/DVT	1.5
Hemoptysis	1.0
Malignancy	1.0

- **Traditional Wells Score**:
  - High: >6
  - Intermediate: 2–6
  - Low: <2
- **Modified Wells Score**:
  - PE Unlikely: ≤4
  - PE Likely: >4

PERC (Pulmonary Embolism Rule-out Criteria)
Used to exclude PE in **low-risk** patients per Wells score:

- Age <50
- HR <100 bpm
- SaO_2 >94% on room air
- No unilateral leg swelling
- No hemoptysis
- No recent trauma/surgery (≤ 4 weeks)
- No prior VTE
- No estrogen use

All 8 must be satisfied to rule out PE without D-dimer testing.

Radiologic Implication

Radiologists play a crucial role in:

- Suggesting PE in undifferentiated dyspnoea
- Reporting RV/LV ratio on CTPA (prognostic value)
- Assessing thrombus burden and location
- Differentiating PE from mimics (tumor embolus, artifact)

Risk Stratification - Based on mortality risk and **hemodynamic stability**:

Feature	Massive PE	Submassive PE	Low-risk PE
Blood Pressure / Vasopressors	Hypotension (<90 mmHg for >15 min) or requiring vasopressors	Normotensive	Normotensive
RV Strain (echo/CT/ECG)	Present	Present	Absent

Myocardial Injury (Troponins)	Present	Present	Absent
30-day Mortality	25–65%	~3%	<1%

sPESI (Simplified Pulmonary Embolism Severity Index) is used to predict mortality risk.

Imaging in Pulmonary Embolism (PE)

1. Chest Radiograph (CXR)

Purpose

- Initial evaluation to exclude differential diagnoses (e.g., pneumothorax, pneumonia).
- Prerequisite for V/Q scan interpretation.

Common Findings

Radiographic Sign	Description
Westermark Sign	Peripheral oligemia—lucent area due to vessel collapse. (↓ sensitivity)
Hampton's Hump	Wedge-shaped peripheral opacity—represents pulmonary infarction.
Fleischner Sign	Dilated central pulmonary artery due to large embolus.
Palla Sign	Enlarged right descending pulmonary artery ("sausage" shape).
Chang Sign	Abrupt change in vessel caliber—amputated appearance.
Knuckle Sign	Abrupt tapering of a vessel; better seen on CTPA.

2. CT Pulmonary Angiography (CTPA)

Modality of Choice

- **Gold standard** for suspected PE in **hemodynamically stable patients**.

Direct Signs of PE

Acute PE	Chronic PE
Central or eccentric **filling defect**	**Pouch defect** or web within vessel
Acute angle with vessel wall	**Obtuse angle**, eccentric
Enlarged artery at site of embolus	Decreased diameter distally
Smooth intima	Intimal irregularity
No collaterals	Bronchial collateral vessels present

Parenchymal Findings

- Wedge-shaped GGO/consolidation (infarct/hemorrhage)

- Mosaic attenuation (reflects oligemia)
- Pleural effusion

Clot Burden Score
Qanadli index:
- Each lung: 10 segmental branches
- Score = number of obstructed segments × weighting factor (1 = partial, 2 = complete)
- Max = 40

CT Imaging Prognostic Markers

CT Feature	Prognostic Implication
RV/LV ratio >1	↑ mortality risk (OR 2–7)
Septal bowing	RV pressure overload
Central emboli	Associated with RV dysfunction
Contrast reflux in IVC	↑ RV pressures
Obstruction Index (e.g., Qanadli) >40%	Modest correlation with outcome

3. Dual-Energy CT (DECT)
- Detects **perfusion defects** via iodine maps.
- Differentiates **true wedge-shaped segmental defects** vs **non-thrombotic defects**.
- Useful for **subsegmental PE** or **equivocal CTPA**.

4. MR Pulmonary Angiography (MRPA)
Indications
- **Pregnancy** and **renal dysfunction** (gadolinium safer than iodinated contrast).
- Non-contrast MRA feasible but less sensitive.

Sequences
- 2D/3D TOF
- Heavily T1W GRE (coronal)
- bFFE / SSFP / FIESTA
- FLASH gradient echo perfusion
- Parallel imaging: **SENSE, GRAPPA**
- ECG gating, bolus tracking

Limitations
- Long breath hold
- Limited availability
- Lower spatial resolution than CT

5. V/Q Scintigraphy
Basis
- **Mismatch** between ventilation and perfusion (high V/Q ratio in PE).

Agents

Component	Radiotracer
Ventilation	Xe-133, Tc-99 DTPA aerosol, Tc-99 sulfur
Perfusion	Tc-99m MAA

Findings
- Multiple **wedge-shaped peripheral perfusion defects**
- Normal ventilation = classic **mismatch**

Performance
- Sensitivity: ~77%
- Specificity: ~97%
- V/Q SPECT increases diagnostic accuracy
- **PIOPED classification** used for interpretation
- Cannot **definitively exclude or confirm PE** alone

6. Venous Doppler Ultrasound
Use
- **First-line** to evaluate for DVT in suspected PE

Findings in DVT
- **Non-compressible** vein
- Absent **respiratory variation**
- Absent **color Doppler flow**
- **Echogenic thrombus**
- No augmentation or Valsalva response

7. Echocardiography
Indications
- **Hemodynamically unstable patients** (CTPA not feasible)

Findings
- Clot in right heart
- RV strain (↑size, septal bowing)
- **McConnell's sign**: akinesia of mid-RV free wall
- **60/60 sign**: RVSP <60 mmHg + Pulm Accel Time <60 msec

8. CT Venography
Advantages
- Single session evaluation of PE + DVT
- Visualizes **pelvic veins** and non-thrombotic pathology
- Complements CTPA

Limitations
- Radiation
- Iodinated contrast

- Transport risk in unstable patients

Special Considerations in Pregnancy

Aspect	Notes
DVT more common **postpartum** (2–5x)	Left iliac vein most often affected
Risk factors	Multiparity, CS, obesity, preterm delivery, PPH, smoking, HTN
D-dimer not reliable	Lacks pregnancy-adjusted cutoffs
V/Q scan preferred if CXR is **normal**	Lower radiation to breast vs CTPA
MRA (non-contrast)	Used in centers with expertise

Management

1. Anticoagulation (Mainstay)
- Initiate promptly unless contraindicated
- LMWH, DOACs, or unfractionated heparin
- Continue 3–6 months or lifelong based on etiology

2. Systemic Thrombolysis
- Indicated in **massive PE** (cardiogenic shock)
- Drug: Alteplase 100 mg over 2 hours
- Major bleeding risk: 20%, ICH: 2–5%
- Consider reduced dose in elderly/comorbid patients

3. Catheter-Directed Thrombolysis (CDT)
- Preferred in submassive PE with high risk of decompensation
- Benefits:
    - Targeted thrombolysis (10–24 mg tPA)
    - Less bleeding than systemic lysis
- Devices: Unifuse, EKOS (ultrasound-assisted CDT)

4. Mechanical Thrombectomy
- Used alone or with CDT
- Devices: FlowTriever, AngioJet, Penumbra Indigo
- Risks: bradyarrhythmia, bleeding, distal embolization

5. Surgical Embolectomy
- For failed thrombolysis or contraindications
- Requires cardiothoracic surgical support
- Mortality ~10% (modern series)

6. IVC Filter
- Only if:
    - Contraindication to anticoagulation
    - Recurrent PE despite adequate anticoagulation
- No proven benefit in submassive PE routinely

Post-PE Syndrome and Long-term Sequelae

- Up to **50%** of PE survivors report exercise intolerance or dyspnoea
- Mechanisms:
  - Persistent RV dysfunction
  - Residual thrombi → **CTEPH** (chronic thromboembolic pulmonary hypertension)
- Imaging follow-up:
  - Echo at 3–6 months
  - V/Q scan or right heart catheterisation if CTEPH suspected

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Q2. Describe the imaging protocol and role of MRI in evaluation of ischemic heart disease.

Answer

I. Imaging Protocols for Cardiac Evaluation

1. Coronary Computed Tomography Angiography (CCTA)

Purpose: Non-invasive assessment of coronary artery anatomy, stenosis, and anomalies.

Patient Preparation:

- Fasting 4–6 hours.
- Heart rate control (<60 bpm) with beta-blockers.
- Sublingual nitroglycerin to dilate coronary arteries.

Acquisition:

- Supine position, arms above head.
- ECG-gated acquisition (prospective or retrospective).
- Coverage: From carina to below diaphragm.

Contrast Administration:

Parameter	Value
Agent	Iodinated contrast (350–400 mg I/mL)
Dose	80–100 mL (weight adjusted)
Rate	4–6 mL/sec
Saline flush	20–40 mL
ROI / Timing	Ascending aorta, trigger at ~100 HU

2. Cardiac Magnetic Resonance Imaging (CMR)

Purpose: Comprehensive assessment of function, perfusion, viability, and myocardial tissue characterization.

Patient Preparation:

- Fasting 2–4 hours.
- Remove metallic objects.
- Breath-hold training.

Acquisition:

- ECG-gated sequences.
- Multiple planes (short axis, long axis, 4-chamber).

Contrast Administration (for LGE and Perfusion):

Parameter	Value
Agent	Gadolinium-based contrast
Dose (LGE)	0.1–0.2 mmol/kg

Rate	2–3 mL/sec
Saline flush	10–20 mL
Timing	First-pass perfusion during injection; LGE at 10–20 min

3. Single Photon Emission Computed Tomography (SPECT)
Purpose: Myocardial perfusion imaging (rest and stress).
Radiopharmaceuticals:

Agent	**Dose**
Technetium-99m	8–12 mCi (rest), 24–36 mCi (stress)
Thallium-201	2–4 mCi

Stress Protocol: Exercise or pharmacologic (adenosine, dipyridamole, dobutamine).

4. Positron Emission Tomography (PET)
Purpose: Quantitative myocardial perfusion and viability.
Radiopharmaceuticals:

Agent	**Use**
Rubidium-82	Perfusion
N-13 Ammonia	Perfusion
FDG	Viability (metabolism)

Stress Protocol: Pharmacologic stress agents.

5. Coronary Angiography (Invasive)
Purpose: Gold standard for coronary anatomy.
Contrast Administration:

Aspect	Description
Agent	Iodinated contrast
Dose	Variable (30–150 mL)
Injection Site	Selective coronary injection
Timing	Real-time fluoroscopic acquisition

II. Role of MRI in Ischemic Heart Disease

Cardiac MRI offers **multimodal tissue characterization** that no other modality fully replicates, combining anatomical, functional, perfusion, and viability assessment in one session.

1. Assessment of Myocardial Function (Cine MRI)

- **Technique:** Steady-State Free Precession (SSFP).
- **Purpose:** Quantify LV/RV volumes, ejection fraction, wall motion.
- **Value:** Highly reproducible and gold standard for volumetrics.

2. Detection of Myocardial Ischemia (Stress Perfusion MRI)

- **Technique:** First-pass perfusion with gadolinium during pharmacologic stress (adenosine, regadenoson, or dobutamine).
- **Purpose:** Identify reversible perfusion defects.
- **Value:** High spatial resolution; detects subendocardial ischemia.

3. Myocardial Viability (Late Gadolinium Enhancement – LGE)

- **Technique:** Gadolinium administered, imaging at 10–20 min post-injection.
- **Purpose:** Differentiate viable from non-viable myocardium.
- **Value:** Predicts recovery after revascularization.

4. Characterization of Acute Infarction (Edema Imaging)

- **Technique:** T2-weighted and T2 mapping.
- **Purpose:** Identify myocardial edema (acute injury).
- **Value:** Distinguishes acute from chronic infarction.

5. Diffuse Myocardial Disease (T1/T2 Mapping & ECV)

- **Technique:** Quantitative mapping sequences.
- **Purpose:** Detect diffuse fibrosis and inflammation.
- **Value:** Adds prognostic information beyond focal LGE.

6. Detection of Complications

- **Examples:** LV thrombus (seen as non-enhancing mass on LGE), ventricular aneurysm, pseudoaneurysm.
- **Value:** Guides surgical vs conservative management.

Q3. Hilum overlay sign and its significance on diagnostic radiology.

b) Cervicothoracic sign and its significance on diagnostic radiology.

Answer

Hilum Overlay Sign

The **Hilum Overlay Sign** is a **chest radiograph sign** used to localize an opacity in relation to the hila and to help distinguish **cardiac** from **non-cardiac** mediastinal opacities.

Key Concept:

- If the normal hilar vessels (pulmonary arteries) can be seen *through* an opacity that seems to overlap the hilum or heart border, the mass is **not arising from the heart or hilum**.
- This indicates the lesion is **either anterior or posterior** to the hilum in the mediastinum.

Radiographic Appearance

- **View:** Most useful on the **posteroanterior (PA) chest radiograph**.
- **Normal hilum:** On PA CXR, the right and left pulmonary arteries appear as central branching opacities.
- **Hilum overlay:** When these vessels are clearly seen within the lateral margin of an apparent mediastinal opacity, the opacity is not replacing or engulfing them.

Criterion:

If the right/left pulmonary artery is visible ≥ **1 cm inside** the lateral border of the apparent cardiac silhouette or mediastinal opacity → positive Hilum Overlay Sign.

Mechanism

- Cardiac enlargement or a mass in the hilum would obscure the vessels because it is in the **same plane** as the vessels.
- If the vessels are still visible, the opacity must be **in a different plane** — either anterior (prevascular) or posterior (postvascular) mediastinum.

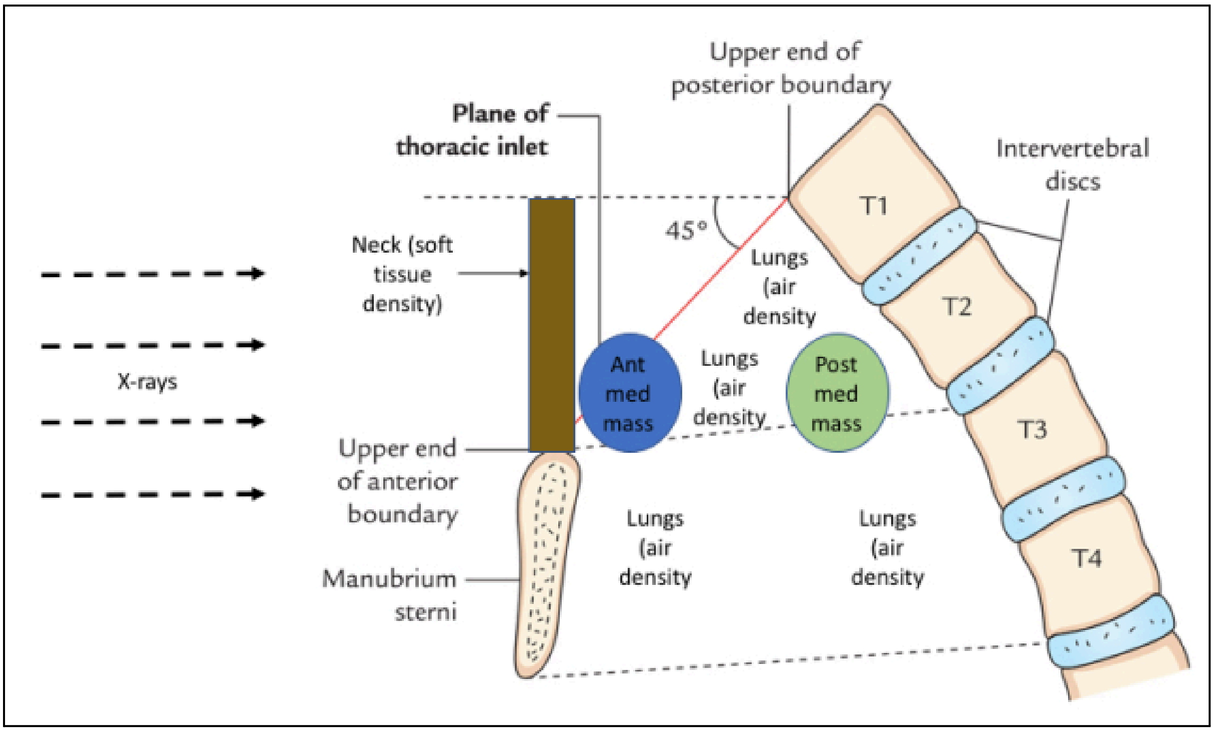
Differential Localisation Logic

Hilum Overlay Sign	**Possible Location of Mass**
Positive (vessels seen)	Anterior mediastinum (e.g., thymoma, teratoma, lymphoma) OR Posterior mediastinum (e.g., neurogenic tumor)
Negative (vessels obscured)	Cardiac enlargement, hilar mass, middle mediastinum lesions involving vessels

Clinical Significance

1. **Distinguishes cardiac vs. non-cardiac causes** of mediastinal opacities on CXR without advanced imaging.
2. **Narrows localization**:
    - **Anterior → Thymic lesions, teratoma, lymphoma.**
    - **Posterior → Neurogenic tumors, esophageal lesions.**
3. **Avoids misdiagnosis**:
    - **Prevents assuming cardiac enlargement when opacity is actually mediastinal.**
4. **Guides further imaging**:
    - **Positive sign → proceed with CT/MRI for precise localization and characterization.**

Cervicothoracic Sign



A chest radiographic sign that helps **localize a superior mediastinal mass** to the **anterior** or **posterior mediastinum** based on its relationship with the thoracic inlet and surrounding soft tissues.

Mechanism

- The **thoracic inlet** is bordered superiorly by the clavicles and first ribs, and is continuous with the neck.
- **Anterior mediastinum**:
    - Bounded anteriorly by the sternum and posteriorly by the pericardium/great vessels.
    - Filled with **soft tissue density structures** (e.g., thymus, lymph nodes), which **silhouette out** soft tissue in the neck if they extend superiorly.

- **Posterior mediastinum**:
    - Bordered by vertebral bodies and paravertebral soft tissues.
    - Contains mostly **air-filled lung anteriorly** up to the thoracic inlet, allowing the posterior mass to be seen **clearly above the clavicles** against aerated lung background.

Radiographic Appearance

On **upright PA or AP chest radiograph**:

1. **Posterior mediastinal mass**
    - **Upper margin sharp and well-defined.**
    - **Extends above the clavicles into the neck region without being obscured — because lung tissue extends anteriorly into the thoracic inlet.**
2. **Anterior mediastinal mass**
    - **Upper margin obscured (silhouetted) by soft tissues of the neck.**
    - **Typically ends at or below the level of the clavicles.**

Significance

- **Helps in anatomic localization** of superior mediastinal masses without advanced imaging.
- Guides **differential diagnosis**:
    - **Anterior mediastinal masses**: thymoma, retrosternal goiter, lymphoma, germ cell tumors.
    - **Posterior mediastinal masses**: neurogenic tumors, vertebral lesions, paravertebral abscess, extramedullary hematopoiesis.
- Often used in combination with other localization signs (e.g., **Hilum Overlay Sign**, **Silhouette Sign**, **Spine Sign**).

Q4. Describe various types of aortic dissection. Discuss the role of imaging in evaluation of aortic dissection.

Answer

Aortic dissection is a life-threatening condition involving a **tear in the intima** of the aorta, allowing blood to enter the **medial layer**, creating a **false lumen**. It is the most common acute aortic syndrome (AAS), alongside **intramural hematoma** and **penetrating atherosclerotic ulcer**.

Pathophysiology

- Initiated by **intimal tear** → blood tracks into the media → **separation of layers**.
- Formation of **true and false lumens**; false lumen may re-enter the true lumen (re-entry tear) or be blind-ended (cul-de-sac).
- False lumen can lead to **malperfusion**, **rupture**, or **aneurysmal degeneration**.

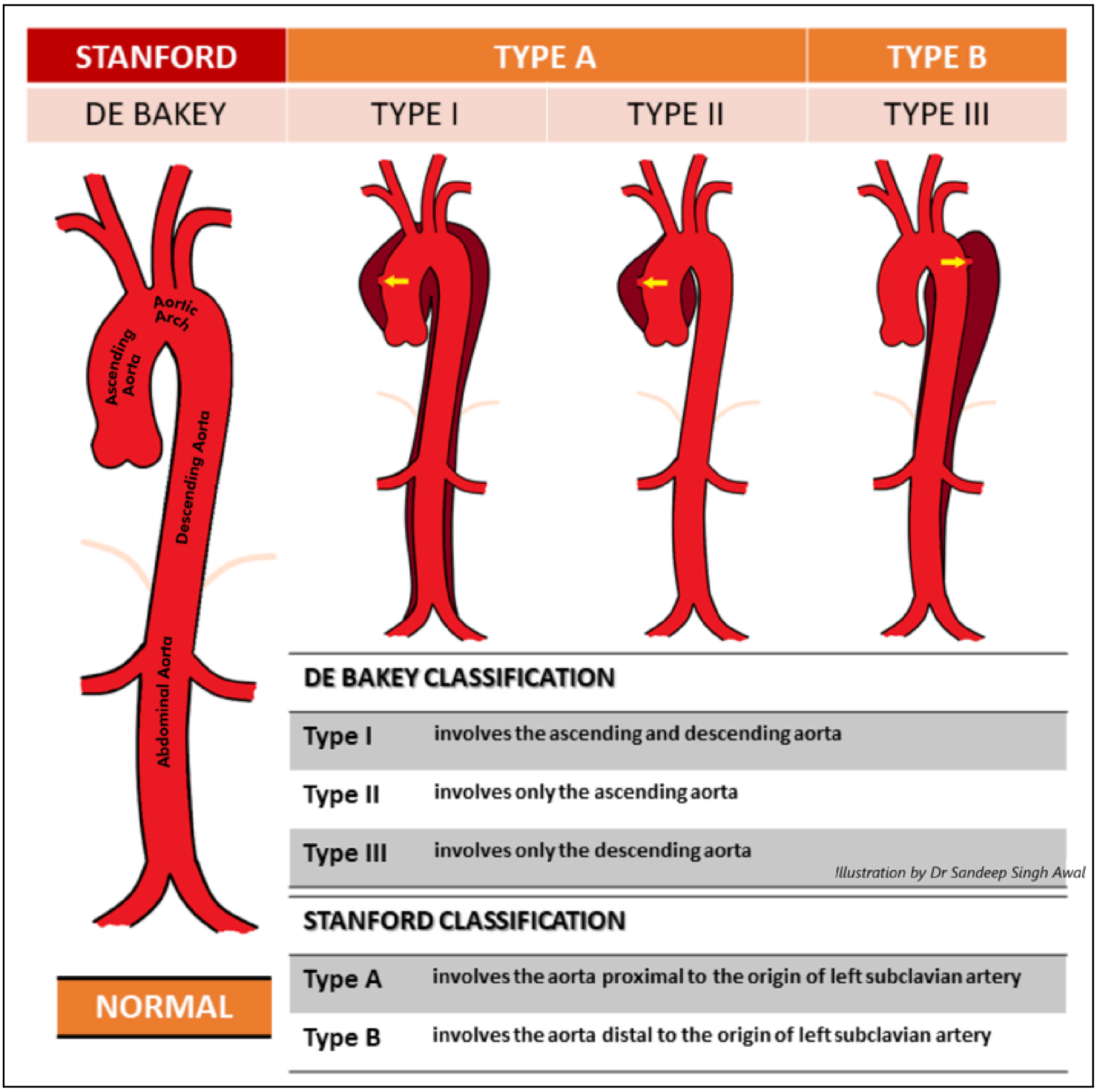
Classification Systems

A. Stanford Classification (Clinically most relevant)

Type	**Involvement**	**Management**
A	Involves ascending aorta (± descending)	**Surgical emergency**
B	Only descending aorta (distal to left subclavian artery)	**Medical ± endovascular**

B. DeBakey Classification (Anatomy based)

Type	**Origin**	**Extent**
I	Ascending aorta	Propagates to arch & descending
II	Ascending aorta only	Confined proximally
IIIa	Descending thoracic aorta	Limited to thorax
IIIb	Descending aorta	Extends to abdomen/pelvis



Imaging Modalities and Findings

A. CT Angiography (CTA) – Gold Standard

Parameter	CTA Findings
Intimal flap	Linear structure separating true and false lumen
False lumen signs	Larger, delayed enhancement, “beak sign”, “cobweb sign”
Entry tear	Seen as contrast-filled defect in intima
Branch vessel involvement	Malperfusion, vessel origin from false lumen
Complications	Rupture, hemothorax, pericardial effusion, organ ischemia

B. MRI Angiography

- Used in **stable patients or chronic dissection**.
- Phase contrast cine MRI can demonstrate **flow dynamics** in true vs. false lumens.
- Delayed enhancement helps identify **thrombosed false lumen**.

C. Transesophageal Echocardiography (TEE)

- Useful in unstable patients.
- Shows **intimal flap**, pericardial effusion, aortic valve involvement.

D. Chest Radiograph (CXR)

Finding	**Description**
Widened mediastinum	Most common
Obliteration of aortic knob	Suggestive of ascending involvement
Pleural effusion (left)	Suggestive of rupture

Key Imaging Differentiators – True vs. False Lumen (on CT/MRI)

Feature	**True Lumen**	**False Lumen**
Size	Smaller	Larger
Enhancement	Enhances first	Delayed
Location	Outer curvature	Inner curvature
Beak sign		Acute angle at flap
Cobweb sign		Linear structures (residual media)
Origin of visceral arteries	Often from true lumen	Can be from false (risk of malperfusion)

Complications of Aortic Dissection

Complication	**Imaging Features**
Aortic rupture	Hemomediastinum, hemothorax, contrast extravasation
Pericardial tamponade	Pericardial effusion with RA/RV compression
Organ malperfusion	Non-enhancing kidneys/bowel, SMA/celiac/renal artery involvement
Stroke	Carotid artery involvement
Acute aortic regurgitation	TEE shows diastolic regurgitation
Chronic aneurysmal degeneration	False lumen expansion, sac formation

Chronic vs. Acute Dissection (Imaging Clues)

Feature	Acute	Chronic
Flap	Mobile, thin	Thickened, immobile
Lumen contrast	Delayed, heterogenous	Uniform
False lumen	May thrombose partially	May show calcification
Symptoms	Severe pain	Asymptomatic or vague symptoms

Management Overview

Stanford Type	Management
Type A	**Immediate surgery** (ascending aorta replacement ± root/valve)
Type B – uncomplicated	**Medical** (BP control: β-blockers, target SBP <120)
Type B – complicated	**TEVAR** (Thoracic Endovascular Aortic Repair) if malperfusion, persistent pain, aneurysm, rupture

Summary Points

- Aortic dissection is a critical **acute aortic syndrome** requiring prompt diagnosis.
- **CTA is the gold standard**, with MRI as a preferred modality for follow-up or in renal impairment.
- Correct identification of **true vs. false lumen**, **extent**, and **complications** dictates therapy.
- Use the **DISSECTION mnemonic** to systematically assess dissection features.
- Type A requires **surgery**; Type B often **medical**, unless complicated.

Q5. Describe various types of lung collapse. Discuss radiologic features of collapse in general and the specific imaging features which help in localization of collapse.

Answer

Lung collapse (**atelectasis**) is defined as **loss of lung volume** due to alveolar collapse.
It may involve **a segment, lobe, or entire lung**, and can be **acute or chronic**.
According to the Fleischner Society, **collapse** and **atelectasis** are synonymous.

Classification
A. By Mechanism

1. **Resorptive (Obstructive) Atelectasis**
   - **Mechanism**: Complete airway obstruction → trapped air distal to the blockage is absorbed into the pulmonary circulation → alveoli collapse.
   - **Common causes**:
     - Endobronchial tumor (e.g., bronchogenic carcinoma)
     - Mucus plug (asthma, post-op, ICU patients)
     - Foreign body aspiration (children)
   - Key feature: Volume loss with mediastinal shift toward collapse (if large).
2. **Passive (Relaxation) Atelectasis**
   - **Mechanism**: Loss of contact between visceral and parietal pleura → negative pressure lost → lung recoils.
   - **Common causes**: Pleural effusion, pneumothorax, diaphragmatic elevation.
3. **Compressive Atelectasis**
   - **Mechanism**: Space-occupying lesion (e.g., large effusion, pneumothorax, mass) compresses alveoli.
   - Often coexists with passive atelectasis.
4. **Cicatrization Atelectasis**
   - **Mechanism**: Chronic fibrosis/scarring contracts and pulls lung tissue.
   - Common causes: TB, necrotizing pneumonia, radiation fibrosis.
5. **Adhesive Atelectasis**
   - **Mechanism**: Surfactant deficiency → alveolar collapse.
   - **Common** in: ARDS, neonatal RDS.
6. **Gravity-Dependent Atelectasis**
   - **Mechanism**: Prolonged recumbency → dependent lung regions collapse under their own weight.
   - Seen in ICU patients.

B. By Morphology

1. **Linear (Plate/Discoid) Atelectasis**
    - **Thin linear opacities parallel to diaphragm, usually basal.**
    - **Seen in post-op patients, rib fractures, pleuritic pain.**
2. **Round Atelectasis**
    - **Spherical mass-like opacity.**
    - **Often with adjacent pleural thickening (asbestos exposure).**

C. By Anatomical Extent

- **Lung atelectasis**: Complete lung collapse.
- **Lobar atelectasis**: Collapse of a lobe.
- **Segmental/Subsegmental**: Collapse of smaller lung units.

Imaging Features

1. Direct Signs of Atelectasis

- Displacement of **fissures** toward the collapsed lobe.
- **Crowding** of pulmonary vessels & bronchi.
- **Crowded air bronchograms** (if bronchus is patent).
- Increased **opacity** in collapsed region.

2. Indirect Signs

- Mediastinal shift **toward** collapse.
- Diaphragm **elevated** on affected side.
- Rib crowding.
- Compensatory overinflation of opposite lung.
- Shifting of pre-existing calcified nodules or granulomas.

Lobar Patterns on CXR

- **RUL collapse**: Triangular opacity in upper zone, elevation of horizontal fissure.
- **RML collapse**: Wedge-shaped opacity obscuring right heart border.
- **RLL collapse**: Triangular opacity, downward/medial displacement of oblique fissure.
- **LUL collapse**: Homogeneous opacity, loss of left heart border, upward displacement of oblique fissure.
- **LLL collapse**: Retrocardiac triangular opacity.

Ultrasound

- **Compressive atelectasis**:
    - Hepatization (“tissue-like” echotexture)
    - Regular triangular margins.
    - Large adjacent pleural effusion.
- **Obstructive atelectasis**:
    - Static or fluid-filled bronchograms.
    - Early air bronchograms may be seen before complete absorption.

CT

- **Volume loss**: Crowded bronchi and vessels.
- **Air bronchograms**: Suggest patent bronchus (resorptive type may lack them).
- **Marked enhancement** of collapsed lung on contrast (distinguishes from pneumonia).
- **Round atelectasis**: Comet-tail sign of bronchi/vessels curving toward lesion.

Key Radiological Differentiation

Feature	**Atelectasis**	**Pneumonia**
Volume loss	Present	Usually absent
Mediastinal shift	Toward opacity	None or away (if effusion)
Enhancement (CT)	Marked	Moderate
Air bronchograms	May be absent (obstruction)	Usually present
Clinical correlation	Often asymptomatic/chronic	Fever, acute symptoms

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Q6. Discuss the indications of imaging in a suspected COVID-19 patient. Describe imaging features and pattern of involvement of respiratory system in COVID-19.

Answer

Imaging Indications in COVID-19

General principles

- **CT not recommended as a primary screening tool**
  - Sensitivity ~94%, specificity ~37% (selection bias in early studies)
  - RT-PCR has 10× higher PPV than CT in low-prevalence settings
- **Imaging only when results are likely to change management**

Fleischner Society consensus (7 April 2020)

- **No imaging**: suspected COVID-19 with mild symptoms unless at risk of progression
- **Imaging indicated**:
  - COVID-19 with **worsening respiratory status**
  - **Moderate–severe clinical features** in resource-constrained settings for triage

Reasons to avoid unnecessary CT

- PPE depletion
- Increased cross-infection risk
- Extra radiation exposure

Portable Imaging

- Prefer **portable CXR** to limit patient transport
- “Through-the-glass” CXR possible in some settings

CT Protocol

- **Non-contrast chest CT** preferred
- Thin section reconstructions (0.625–1.5 mm, gapless)
- CTPA only if **clinically indicated** (e.g., high D-dimer)
- Avoid contrast initially—may obscure GGOs

Imaging Patterns in COVID-19

A. Chest Radiograph

- **Normal** in up to 18% (early/mild), ↓ to 3% in severe disease
- Abnormal in ~69% on admission, ~80% during hospitalization
- Peak abnormalities at **10–12 days** post-symptom onset
- **Typical findings**:
  - Airspace opacities (consolidation > GGO)

    - Bilateral, peripheral, lower zone predominance
    - Pleural effusion rare (~3%)
- Portable CXR preferred

B. CT Chest (Adults)

Typical patterns:

- **Ground-glass opacities (GGO)** – bilateral, subpleural, peripheral
- **Crazy paving** – GGO + inter-/intra-lobular septal thickening
- **Airspace consolidation**
- **Bronchovascular thickening in lesions**
- **Traction bronchiectasis**
- Distribution: **bilateral, peripheral, basal**
- **Pulmonary target sign** – rare, uncertain specificity
- **Subpleural lines/bands** – up to ~56%

Atypical patterns (consider other diagnoses or superinfection):

- Mediastinal lymphadenopathy
- Pleural effusion
- Multiple tiny pulmonary nodules
- Tree-in-bud pattern
- Pneumothorax, pneumomediastinum
- Cavitation, atoll sign

C. Temporal CT Changes

Stage	**Timing**	**Findings**
Early/Initial	0–4 days	Normal or GGO only
Progressive	5–8 days	↑ GGO, crazy paving
Peak	9–13 days	Consolidation
Absorption	>14 days	Resolving changes, fibrous stripes

D. Pediatric CT

- Often milder, sometimes normal
- If abnormal: **bilateral patchy GGO**
- Many resolve completely with recovery

E. Lung Ultrasound

- Bilateral posterobasal predominance
- Findings:
    - Multiple B-lines (focal–diffuse, with spared areas)
    - Irregular/thickened pleural line
    - Subpleural consolidations (usually avascular)
    - Alveolar consolidation with air bronchograms in severe disease
    - A-lines reappear with recovery

F. Nuclear Medicine (PET-CT)

- FDG uptake increased in GGOs
- Higher SUV may indicate slower recovery

Q7. Discuss various imaging signs of diaphragmatic injury. Describe the differences between blunt and penetrating diaphragmatic injury. Discuss signs to differentiate diaphragmatic hernia from eventration and paralysis.

Answer

Imaging Signs of Diaphragmatic Injury

General Key Imaging Signs (across modalities):

1. **Direct signs**
    - **Diaphragmatic discontinuity (visible defect)**
    - **Collar sign / hourglass sign – waist-like constriction of herniated hollow viscus at tear site**
    - **Dependent viscera sign – abdominal viscera lying against posterior ribs in supine CT (no diaphragm support)**
    - **Segmental non-visualization of the diaphragm**
    - **Focal thickening at injury site**
2. **Indirect signs**
    - **Elevated hemidiaphragm (loss of normal contour)**
    - **Intrathoracic herniation of abdominal contents**
    - **Nasogastric tube above diaphragm on left**
    - **Associated thoracic/abdominal injuries: rib fractures, hemothorax, pneumothorax, hemoperitoneum**

Blunt vs Penetrating Diaphragmatic Injury – Imaging & Features

Feature	**Blunt Trauma**	**Penetrating Trauma**
Mechanism	High-energy deceleration/compression (MVCs) – lateral or AP impaction	Gunshot wounds, stab injuries
Location	Posterolateral diaphragm (weakest zone)	Anywhere along diaphragm – usually focal
Laterality	Left > Right (liver protective effect on right)	Left more common (dominant hand of assailant)
Defect size	Larger tears (>10 cm), often radial	Smaller, localized defects
Associated injuries	Solid organ injury, rib fractures, lung contusion	Adjacent organ injury along wound track
Imaging yield	CT sensitive if large defect; herniation often present	Small defect may be occult unless herniation occurs

CT signs	Collar sign, dependent viscera sign, discontinuity	Small focal discontinuity ± minimal herniation; sometimes best seen on multiplanar reformats
Detection difficulty	Sometimes delayed diagnosis (hours–years)	Often detected early due to associated injuries

Differentiating Diaphragmatic Hernia, Eventration, and Paralysis

Feature	Diaphragmatic Hernia (traumatic or congenital)	Eventration	Paralysis
Definition	True defect in diaphragm with herniation of abdominal contents into thorax	Thinned/atrophic but intact diaphragm	Intact diaphragm with loss of motor function
Cause	Trauma (acute or chronic), congenital defect (Bochdalek, Morgagni)	Developmental hypoplasia of muscle fibers	Phrenic nerve injury, neuromuscular disorders
Contour	Discontinuity or abnormal bulge with abdominal viscera above diaphragm	Smooth elevation of entire hemidiaphragm	Smooth elevation; no herniation
Contents above diaphragm	Present (bowel, stomach, liver) – visible on CXR/CT	None (only lung above diaphragm)	None
CT / CXR findings	Herniated bowel/stomach ± collar sign, dependent viscera sign	Smooth, uniform dome elevation; diaphragm continuous on multiplanar CT	Elevated hemidiaphragm, continuous on CT
Dynamic imaging	Herniated viscera move with respiration; may change with patient position	Minimal movement, but no paradoxical motion	Paradoxical upward motion on sniff test / M-mode US
Ultrasound	Discontinuity; abdominal viscera in thorax	Intact but thin echogenic line	Intact echogenic line; absent or paradoxical motion

- **Blunt trauma** → Actively look for *dependent viscera sign* and *collar sign* on CT
- **Penetrating trauma** → High suspicion for small focal defects; use multiplanar CT
- **To distinguish hernia vs eventration** → Check for **abdominal contents above diaphragm** and **diaphragmatic continuity**
- **To differentiate paralysis** → Use **dynamic fluoroscopy or M-mode ultrasound** for motion assessment

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Q8. Discuss the radiological anatomy of coronary arteries. Describe the technique of CT coronary angiography. Discuss the recent advances in assessment of coronary artery stenosis by CT angiography.

Answer

The coronary artery system supplies oxygenated blood to the myocardium. It consists of:

- **Right Coronary Artery (RCA)**
- **Left Main Coronary Artery (LCA)**, which bifurcates into:
  - **Left Anterior Descending (LAD)**
  - **Left Circumflex (LCx)**

Dominance depends on which artery gives rise to the **Posterior Descending Artery (PDA)**:

- **Right dominant**: RCA (85%)
- **Left dominant**: LCx (8%)
- **Codominant**: Both RCA and LCx (7%)

Anatomic Course (Based on MDCT and Cath Correlation)

Vessel	Origin	Course	Main Branches
RCA	Right coronary sinus	Courses in the right AV groove	• Conus • SA nodal (60%) • Acute marginal • PDA
LCA	Left coronary sinus	Short stem, bifurcates behind pulmonary trunk	• LAD • LCx, ± Ramus intermedius • SA nodal (40%)
LAD	From LCA	Anterior IV groove toward apex	• Diagonal • Septal perforators
LCx	From LCA	Left AV groove	• Obtuse marginal branches

MDCT VISUALIZATION

Modern **ECG-gated MDCT** allows:
- Non-invasive, isotropic imaging
- Multiplanar reconstructions
- Excellent depiction of ostia, proximal course, and anomalous pathways

Standard reconstructions include:
- Axial and oblique MIP
- Curved MPR
- Volume-rendered 3D images

Coronary CT Angiography (CCTA)

Coronary CT Angiography (CCTA) is a **non-invasive imaging modality** that visualizes the **coronary arteries, cardiac chambers**, and adjacent **vascular structures** using **contrast-enhanced multislice CT**. It plays a pivotal role in:
- **Detection of coronary artery disease (CAD)**
- **Evaluation of congenital anomalies**
- **Pre-surgical and structural heart disease planning**

CCTA has evolved significantly with **advances in temporal resolution**, **motion correction**, **dual-energy CT**, **CT-derived FFR**, and **AI integration**.

TECHNIQUE AND PROTOCOLS

1. Patient Preparation

Parameter	**Requirement**
Heart Rate	Ideally <60 bpm for best motion-free imaging; **beta-blockers** used unless contraindicated
Rhythm	Sinus rhythm preferred (irregular rhythms → artifacts)
Nitroglycerin	Sublingual (optional) to dilate coronaries and improve visualization
IV Access	18–20G in right antecubital vein for high flow (~5 mL/s)
Contrast	60–100 mL of iodinated contrast (350–400 mgI/mL), bolus tracking or test bolus

2. Scanner Requirements
- **≥64-slice CT** (128–320 preferred for high-res/volume imaging)
- **Temporal resolution**: <75 ms optimal
- **ECG gating**: Prospective (dose-saving) or Retrospective (functional assessment)

3. Scan Techniques

Technique	Description	Notes
Prospective gating	Axial scan during diastole (fixed RR interval)	Lower dose, limited functional data
Retrospective gating	Continuous helical scan + ECG	Higher dose, allows cine recon
High-pitch spiral (FLASH)	Whole heart in a single beat	Used in dual-source CT, lowest dose
CT-FFR / CT perfusion	Functional assessment of stenosis significance	Post-processing needed

CLINICAL INDICATIONS

A. Coronary Artery Disease (CAD)

Clinical Setting	Role of CCTA
Stable chest pain	Rule out obstructive CAD in low to intermediate pretest probability (Class I indication per ESC 2019)
Equivocal stress test	Anatomical clarification
In-stent restenosis / grafts	Limited by metal artifact (better with modern scanners)

Negative predictive value of CCTA exceeds 95%, making it excellent to **exclude CAD**.

B. Acute Chest Pain (Triple Rule-Out, ED Use)

- Rule out **coronary obstruction**, **aortic dissection**, and **PE**
- Requires higher contrast, tailored timing
- Best in **low-intermediate risk**, not for ST-elevation or troponin-positive ACS

C. Pre-Interventional Planning

Use	Application
TAVI (TAVR)	Aortic annulus sizing, root height, iliofemoral access
LAA occlusion	Evaluate LAA morphology (Watchman procedure)
Bypass surgery	Coronary anatomy, ascending aorta
EP ablation	Pulmonary vein anatomy for AF ablation

D. Coronary Anomalies & Congenital Disease

- **Anomalous coronary origin/pathway**
- **Myocardial bridging**
- **Single coronary ostium**
- **Coronary fistulas**

CCTA provides **3D overview**, superior to invasive angiography for origin/path visualization.

E. Post-revascularization Evaluation

Scenario	**Utility**
Post-CABG	High accuracy for graft patency
Stents	≥3 mm stents better visualized; metal artifacts may limit assessment

IMAGE RECONSTRUCTION AND INTERPRETATION

1. Reconstruction Techniques

- **Multiplanar reformation (MPR)**
- **Curved planar reformation (CPR)**: Follows vessel axis
- **Maximum intensity projection (MIP)**
- **Volume rendering (VR)**: 3D display

2. Coronary Segmentation

Standardized using **AHA 17-segment model** or **SCCT 18-segment model**:

- Proximal, mid, distal LAD
- RCA (proximal to PDA)
- LCx and OM branches

3. CAD-RADS Classification

CAD-RADS	**Stenosis**	**Interpretation**
0	0%	No plaque
1	1–24%	Minimal
2	25–49%	Mild
3	50–69%	Moderate
4A	70–99%	Severe
4B	Left main ≥50% or 3-vessel disease	High-risk
5	100%	Occluded vessel

Modifiers: S (Stent), G (Graft), V (Vulnerable plaque)

PLAQUE CHARACTERIZATION

Plaque Type	**CT Appearance**	**Clinical Significance**
Calcified	High attenuation (>130 HU)	Less likely to rupture
Non-calcified	Iso/hypoattenuating	Higher risk
Mixed	Both components	Intermediate risk

High-risk features	Low-attenuation core (<30 HU), positive remodeling, napkin-ring sign, spotty calcification	Suggestive of vulnerability

ADVANCES IN CCTA

Innovation	**Application**
CT-FFR	Estimates pressure drop across lesion using computational fluid dynamics
CT Perfusion (CTP)	Stress/rest perfusion imaging
Dual-energy CT	Plaque composition, iodine maps
Photon-counting CT	Higher resolution, lower dose
AI-based recon	Automated segmentation, FFR prediction, plaque quantification

LIMITATIONS AND CONTRAINDICATIONS

Limitations

- **Motion artifacts** at HR >75–80 bpm
- **Heavy calcification** obscures lumen
- **Small stents (<2.5 mm)** poorly visualized
- **Radiation exposure** (although greatly reduced with new protocols)

Contraindications

- Contrast allergy
- Renal insufficiency (GFR <30 mL/min/1.73 m^2 unless essential)
- Inability to follow breath-hold commands
- Pregnancy

Radiation Dose Considerations

Technique	**Typical Dose (mSv)**
Retrospective ECG gating	10–15
Prospective gating (step-and-shoot)	1–5
High-pitch spiral (dual-source)	<1
CT-FFR / CTP (combined)	8–15

Dose reduction strategies include **prospective gating, tube current modulation, iterative reconstruction, lower kVp** for small patients, and **ECG-based tube pulsing**.

Q9. Discuss the imaging approach to acute limb ischemia. Discuss the interventional radiological treatment options for it.

Answer

Imaging Approach to Acute Limb Ischaemia (ALI)

1. Clinical First

- **History & Examination**
  - Risk factors: Atrial fibrillation, atherosclerosis, recent vascular procedures, hypercoagulable states.
  - Assess:
    - **6 Ps**: Pain, Pallor, Pulselessness, Poikilothermia, Paresthesia, Paralysis.
    - Limb viability (Rutherford classification).
- **Immediate priority:** If limb is *threatened*, call vascular surgery **before** advanced imaging.

2. Initial Imaging & Bedside Tools

Modality	Purpose	Key Points
Duplex Ultrasound	First-line in most centers	Real-time arterial flow, thrombus detection, vessel patency, non-invasive, no radiation.
Ankle-Brachial Index (ABI)	Quick perfusion check	ABI < 0.4 suggests severe ischaemia; may be unreliable in calcified vessels (e.g., diabetics).

3. Cross-Sectional Imaging

A. CT Angiography (CTA)

- **Indications:** Inconclusive duplex, planning intervention, proximal occlusion.
- **Technique:** Arterial phase acquisition with IV contrast; 3D reconstruction.
- **Advantages:** High spatial resolution, fast, wide availability.
- **Limitations:** Iodinated contrast risk in renal impairment.

B. MR Angiography (MRA)

- **Indications:** When iodinated contrast contraindicated (CKD, allergy) or to avoid radiation (pregnancy, young patients).
- **Technique:** TOF or contrast-enhanced sequences.
- **Advantages:** Good for large-vessel mapping; no ionizing radiation.
- **Limitations:** Slower, contraindicated in certain devices or severe claustrophobia.

4. Catheter-Based Imaging
Digital Subtraction Angiography (DSA)

- **Role:** Gold standard for diagnosis & **immediate endovascular treatment**.
- **Advantages:** Diagnostic + therapeutic (thrombolysis, thrombectomy, PTA, stent).
- **Considerations:** Invasive; contrast + radiation exposure.

5. Additional Imaging

- **MRI / Nuclear Medicine** → Assess tissue viability (if viability unclear before revascularization/amputation).
- **Plain radiographs** → Occasionally to check for foreign bodies or calcified vessels.

Interventional Radiology Role

A. Digital Subtraction Angiography (DSA)

- **Gold standard** for vascular mapping.
- Allows immediate **therapeutic intervention**.

B. Endovascular Treatment Options

1. **Catheter-Directed Thrombolysis**
   - Indication: Recent clot (<14 days), viable limb.
   - Method: Multi-sidehole infusion catheter, alteplase/urokinase infusion under fluoroscopy.
   - Advantage: Preserves vessel integrity.
   - Risk: Bleeding (intracranial, GI).
2. **Mechanical Thrombectomy**
   - Indication: Large thrombus burden or thrombolysis contraindicated.
   - Devices: Aspiration catheters, rheolytic devices, rotational thrombectomy.
   - Advantage: Rapid flow restoration.
   - Risk: Vessel injury, distal embolisation.
3. **Percutaneous Transluminal Angioplasty (PTA) ± Stenting**
   - Indication: Atherosclerotic stenosis/dissection as cause of ALI.
   - Advantage: Immediate vessel lumen gain.
   - Risk: Dissection, perforation, restenosis.

Imaging–Intervention Workflow

Step 1 – Clinical Stratification
Step 2 – Initial Imaging (Duplex US → CTA/MRA if viable limb)
Step 3 – If threatened limb → Direct to Angio Suite
Step 4 – DSA (diagnostic)
Step 5 – Endovascular therapy:

- Thrombolysis
- Mechanical thrombectomy
- PTA ± Stent

Step 6 – Post-procedure imaging (completion angiogram)
Step 7 – Follow-up with Duplex US

Q10. Discuss the imaging evaluation of various catheters, tubes and lines seen on a chest radiograph in an ICU setting.

Answer

Evaluation of Common Tubes, Catheters, and Lines on Chest X-ray

1. Endotracheal Tube (ETT)

- **Position:**
  - Tip **2–5 cm above carina** (mid-trachea).
  - In neck flexion → tube moves down; in extension → moves up.
- **Alignment:**
  - Follows tracheal curve; no deviation/kinking.
- **Complications:**
  - Too low → mainstem intubation (usually right) → collapse of contralateral lung.
  - Too high → risk of extubation.
  - Kinking or cuff herniation.

2. Central Venous Catheter (CVC)

- **Position:**
  - Tip at **SVC–RA junction**, roughly at the level of carina on CXR.
- **Alignment:**
  - Smooth course along expected venous pathway; should not cross midline (unless femoral approach).
- **Tip confirmation:**
  - In SVC or RA — avoid azygos vein, internal jugular loop, or right atrium over-insertion.
- **Complications:**
  - Malposition → arrhythmias, vessel injury, thrombosis.
  - Pneumothorax from insertion.

3. Pulmonary Artery Catheter (PAC / Swan-Ganz)

- **Position:**
  - Tip in **proximal or mid-right/left pulmonary artery**.
- **Alignment:**
  - Smooth venous course → right atrium → right ventricle → main PA → branch PA.
- **Complications:**
  - Distal over-insertion → PA rupture, infarction.
  - Malposition → looping, arrhythmias.

4. Nasogastric Tube (NGT)

- **Position:**
  - Tip in stomach (antrum or body) beyond gastroesophageal junction.
  - Side holes **below the diaphragm**.
- **Alignment:**
  - Crosses midline from esophagus, passes below diaphragm.
- **Complications:**
  - In lung/bronchus → risk of aspiration.
  - Coiling in esophagus or pharynx.

5. Chest Tubes

- **Position:**
  - Within pleural space.
    - Pneumothorax → anterior & apical position.
    - Effusion → posterior & basal position.
- **Alignment:**
  - Runs along chest wall into pleural space, no kinking/looping.
- **Complications:**
  - Malposition into fissure, lung parenchyma, abdominal cavity.
  - Tube dislodgement.

Device	**Ideal Tip Location**	**Main Checkpoints**	**Common Malposition / Complication**
ETT	2–5 cm above carina	Mid-trachea, straight course	Endobronchial, too high, kinking
CVC	SVC–RA junction	Straight venous course	Azygos placement, RA over-insertion
PAC	Proximal/mid PA	Smooth heart → PA course	Distal over-insertion, looping
NGT	Gastric body/antrum	Cross diaphragm, in stomach	Pulmonary placement, coiling
Chest Tube	Pleural space	Position depends on purpose	Intraparenchymal, abdominal

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