Acute Pulmonary Embolism (PE)

Acute Pulmonary Embolism (PE): Evaluation, Workup, and Treatment

Acute pulmonary embolism (PE) is a life-threatening condition caused by a sudden blockage of pulmonary arteries, often due to a venous thromboembolism (VTE). This document provides a comprehensive overview of PE for physician assistant (PA) students in a hospital setting.

Pathophysiology

• Definition:

Acute PE occurs when a thrombus (usually from a deep vein thrombosis [DVT] in the lower extremities) dislodges and travels to the pulmonary arteries, obstructing blood flow.

• Mechanism:

- **Obstruction:** Thrombus blocks pulmonary artery → Increased pulmonary vascular resistance → Right ventricular (RV) strain.
- **Hypoxemia:** V/Q mismatch (increased dead space) → Reduced oxygenation → PaO2 <60 mmHg.
- **Inflammatory Response:** Release of vasoactive mediators (e.g., serotonin) →Pulmonary vasoconstriction → Worsened RV afterload.

• Systemic Effects:

- **RV failure:** Increased RV pressure → RV dilation → Decreased cardiac output → Hypotension, shock.
- **Hypoxemia:** Tissue hypoxia → Lactic acidosis, organ dysfunction (e.g., AKI, encephalopathy).

• Risk Factors:

- **Immobility**:
  - Prolonged bed rest (e.g., post-surgery, illness)
  - Long-distance travel (e.g., flights >4 hours)
  - Sedentary lifestyle
- **Surgery and Trauma**:
  - Major surgery (e.g., orthopedic, abdominal, pelvic)
  - Trauma or fractures (especially lower limbs or pelvis)
  - Central venous catheterization
- **Medical Conditions**:
  - Cancer (active or history of malignancy)
  - Heart failure or cardiovascular disease
  - Chronic obstructive pulmonary disease (COPD)
  - Inflammatory bowel disease (e.g., Crohn's, ulcerative colitis)
  - Nephrotic syndrome
  - Obesity (BMI >30)
  - Varicose veins
  - Previous DVT or PE
  - Stroke with limb paralysis
- **Hormonal Factors**:
  - Oral contraceptives or hormone replacement therapy (especially estrogen-containing)
  - Pregnancy and postpartum period (up to 6 weeks)
  - Polycystic ovary syndrome (in some cases)
- **Thrombophilia (Clotting Disorders)**:
  - Factor V Leiden mutation
  - Prothrombin gene mutation
  - Protein C or S deficiency
  - Antithrombin deficiency
  - Antiphospholipid syndrome
  - Hyperhomocysteinemia
- **Medications and Treatments**:
  - Chemotherapy or immunosuppressive therapy
  - Erythropoiesis-stimulating agents
  - Tamoxifen or other selective estrogen receptor modulators
- **Lifestyle and Environmental Factors**:
  - Smoking
  - Dehydration
  - Advanced age (>60 years)
  - High-altitude exposure (e.g., mountaineering)
- **Infections and Inflammation**:
  - Severe infections or sepsis
  - Chronic inflammatory conditions (e.g., rheumatoid arthritis, lupus)
- **Other**:
  - Family history of DVT/PE
  - Recent hospitalization or ICU stay
  - Spinal cord injury
  - Blood transfusion or erythropoietin use

Clinical Presentation

• Symptoms:

- Dyspnea (acute onset, 70-80% of cases).
- Pleuritic chest pain (50%, worse with inspiration).
- Hemoptysis (10%, more common in massive PE).
- Syncope or presyncope (10-20%, indicates RV strain).
- Leg swelling/pain (if concurrent DVT).

• Physical Exam:

- Vital Signs:
  - Tachypnea (RR >20/min), tachycardia (HR >100 bpm), hypoxemia
  - (SpO2 <90%), hypotension (SBP <90 mmHg in massive PE).
- Lung Exam:
  - Clear lungs (most common), crackles/wheezing (infarction), pleural rub.
- Cardiac Exam:
  - RV strain signs—jugular vein distension (JVD), loud P2, right-sided S3/S4, tricuspid regurgitation murmur.
- Extremities:
  - Unilateral leg swelling, erythema, tenderness (DVT signs).

• Red Flags:

- Hypotension (SBP <90 mmHg) → Massive PE.
- Syncope, cyanosis, RV strain → High-risk PE.
- SpO2 <88% despite O2 → Consider mechanical ventilation.

Diagnostic Workup

• Step 1: Assess Clinical Probability:

- Wells Score for PE:
  - **DVT symptoms/signs:** +3 points.
  - **PE most likely diagnosis:** +3 points.
  - **HR >100 bpm:** +1.5 points.
  - **Immobilization/surgery (past 4 weeks):** +1.5 points.
  - **Prior DVT/PE:** +1.5 points.
  - **Hemoptysis:** +1 point.
  - **Malignancy:** +1 point.
    - Interpretation: Low (<2), intermediate (2-6), high (>6).
- Modified Geneva Score:
  - **Age >65:** +1 point.
  - **Prior DVT/PE:** +3 points.
  - **Surgery/fracture (past 1 month):** +2 points.
  - **Active malignancy:** +2 points.
  - **Unilateral leg swelling/pain:** +3 points.
  - **HR 75-94 bpm:** +3 points; ≥95 bpm: +5 points.
  - **Hemoptysis:** +2 points.
    - Interpretation; Low (0-3), intermediate (4-10), high (≥11).

• Step 2: Initial Labs and Tests:

- D-dimer: High sensitivity (95%), low specificity (40%); Use in low/intermediate probability (Wells <6).
  - Negative D-dimer (<500 ng/mL) rules out PE in low-risk patients.
  - Elevated D-dimer → Proceed to imaging.
- Arterial Blood Gas (ABG):
  - **Hypoxemia:** PaO2 <60 mmHg.
  - **Respiratory alkalosis:** PaCO2 <35 mmHg, pH >7.45 (due to hyperventilation).
  - **A-a gradient:** Elevated (>15 mmHg on room air).
- EKG:
  - Sinus tachycardia (most common).
  - **S1Q3T3 pattern (5-10%):** S wave in lead I, Q wave in lead III, T-wave inversion in lead III.
- **RV strain:** Right axis deviation, RBBB, T-wave inversions V1-V4.
- Troponin/BNP:
  - **Troponin:** Elevated in 30-50% (RV strain, poor prognosis).
  - **BNP:** Elevated (>90 pg/mL) indicates RV dysfunction.

• Step 3: Imaging:

- CT Pulmonary Angiography (CTPA):
  - **Gold standard:** Sensitivity 90%, specificity 95%.
  - **Findings:** Filling defects in pulmonary arteries, "Westermark sign" (oligemia), "Hampton hump" (wedge-shaped infarction).
  - **Contraindications:** Contrast allergy, renal failure (CrCl <30 mL/min).
- Ventilation-Perfusion (V/Q) Scan:
  - Alternative if CTPA contraindicated.
  - **High probability:** ≥2 large mismatched defects.
  - Normal scan rules out PE (sensitivity 98% for normal result).
- Chest X-ray (CXR):
  - Often normal; may show Westermark sign, Hampton hump, pleural effusion.
  - Rules out other causes (e.g., pneumothorax, pneumonia).
- Echocardiogram:
  - **RV dysfunction:** RV dilation, "McConnell's sign" (RV free wall hypokinesis with apical sparing), tricuspid regurgitation.
  - **D-sign:** Flattened interventricular septum (RV pressure overload).

• Step 4: Lower Extremity Ultrasound:

o Assess for DVT: Non-compressible vein, thrombus visualization. Positive DVT + clinical suspicion → Treat as PE even without CTPA.

• Key Tips:

- Wells score <2 + negative D-dimer → No further workup.
- CTPA is first-line; V/Q scan if CTPA contraindicated.
- RV dysfunction on echo → High-risk PE, even if normotensive.

Risk Stratification

• Pulmonary Embolism Severity Index Simplified PESI

■ Variables: ■ **Age:** +1 point per year. ■ **Male:** +10 points. ■ **Cancer:** +30 points. ■ **Heart failure:** +10 points. ■ **Chronic lung disease:** +10 points. ■ **HR ≥110 bpm:** +20 points. ■ **SBP <100 mmHg:** +30 points. ■ **RR ≥30/min:** +20 points. ■ **Temp <36°C:** +20 points. ■ **AMS:** +60 points. ■ **SpO2 <90%:** +20 points. ■ Classes: ■ **I-II (≤85 points):** Low risk, 1-2% mortality. ■ **III (86-105):** Intermediate, 3-7% mortality. ■ **IV-V (>105):** High risk, 10-25% mortality.	Variables ■ Age >80 years ■ History of cancer ■ Chronic cardiopulmonary disease ■ Heart rate ≥110 beats per minute ■ Systolic blood pressure <100 mmHg ■ Oxygen saturation <90% Scoring: ■ Add up the points for each criterion met (0 to 6 points total). ■ **0 points**: Low risk (30-day mortality ~1%). ■ **≥1 point**: High risk (30-day mortality ~10-25%, increasing with higher scores).

• Hemodynamic Status:

- **Massive PE:** SBP <90 mmHg for >15 min, or requiring inotropes, or cardiac arrest.
- **Submassive PE:** Normotensive but RV dysfunction (echo, BNP >90 pg/mL troponin elevation).
- **Low-Risk PE:** Normotensive, no RV dysfunction, PESI Class I-II.

• ESC Guidelines (2019):

- **High-risk:** Shock/hypotension.
- **Intermediate-high:** RV dysfunction + troponin elevation.
- **Intermediate-low:** RV dysfunction or troponin elevation.
- **Low-risk:** None of the above.

Diagnostic Criteria and Risk Stratification Table

Category	Criteria	Risk Level	Notes
Diagnostic	Low: <2, Intermediate: 2-6, High: >6	Guides workup	D-dimer in low/intermediate; CTPA if high probability or D-dimer elevated.
Massive PE	SBP <90 mmHg >15 min, inotropes, arrest	High-risk	Immediate thrombolysis or embolectomy; mortality 25-50%.
Submassive PE	Normotensive, RV dysfunction, +troponin	Intermediate-high	Consider thrombolysis if clinical deterioration; mortality 3-15%.
Low-Risk PE	Normotensive, no RV dysfunction, PESI I-II	Low-risk	Outpatient anticoagulation possible; mortality <2%.

Treatment

• General Principles:

Stabilize patient, prevent clot propagation, restore pulmonary flow, treat complications.

• Supportive Care:

- Oxygen Therapy: Nasal cannula (2-6 L/min) or non-rebreather mask (10-15L/min); goal SpO2 88-92%.
- IV Fluids: Cautious use (500 mL NS bolus) in hypotension; avoid overhydration (worsens RV strain).
- Vasopressors: Norepinephrine (5-20 mcg/min IV) if hypotensive despite fluids.

• Anticoagulation:

- **Initial Therapy:**
  - **LMWH:** Enoxaparin 1 mg/kg SC BID (preferred in non-massive PE, CrC >30 mL/min).
  - **UFH:** Heparin 80 units/kg IV bolus, then 18 units/kg/h infusion (adjust to aPTT 60-80s); use in renal failure or high bleeding risk.

- **Direct Oral Anticoagulants (DOACs):** Rivaroxaban 15 mg PO BID x 21 days, then 20 mg daily (low-risk PE, outpatient).
    - Duration:
        - **Provoked PE:** 3-6 months.
        - **Unprovoked PE:** ≥6 months, consider indefinite if low bleeding risk.
- **Cancer-associated:** LMWH (e.g., dalteparin) for ≥6 months.
- **Monitoring**: PTT (UFH), Cr (LMWH/DOACs), Hgb (bleeding risk).

• Thrombolytic Therapy:

- Indications:
    - Massive PE (SBP <90 mmHg, cardiac arrest).
    - Submassive PE with clinical deterioration (worsening RV dysfunction, hypoxemia, shock).
- Agent:
    - Alteplase 100 mg IV over 2h (or 0.6 mg/kg over 15 min in cardiac arrest).
        - Contraindications:
            - Recent stroke, active bleeding, major surgery (<3 weeks),
            - severe HTN (>180/110 mmHg).
        - Monitoring: Signs of bleeding (Hgb drop, melena), neuro status (ICH risk 2-3%).

• Interventional Therapies:

- Catheter-Directed Thrombolysis (CDT) Low-dose alteplase (1-2 mg/h) via catheter; for submassive PE with high bleeding risk.
- Surgical Embolectomy: Massive PE with thrombolytic contraindications; mortality 20-30%.
- IVC Filter: Recurrent PE despite anticoagulation, or anticoagulation contraindicated.

• Long-Term Management:

- Anticoagulation:
    - Transition to DOACs (apixaban 5 mg BID after 6 months) or warfarin (INR 2-3).
- Follow-Up:
    - Echo at 3-6 months (assess RV function), consider thrombophilia testing (unprovoked PE).

• Key Tips:

- Start anticoagulation immediately if high suspicion (before CTPA).
- Thrombolysis in massive PE; consider in submassive with deterioration.
- Avoid overhydration; RV strain worsens with excess fluids.

Treatment Guidelines Table

Risk Level	Treatment	Agent/Dose	Notes
Low-Risk PE	Anticoagulation (outpatient)	Rivaroxaban 15 mg BID x 21d, then 20 mg daily	Ensure CrCl >30 mL/min; follow-up in 1-2 weeks.
Intermediate (Submassive)	Anticoagulation + monitoring	Enoxaparin 1 mg/kg SC BID	Consider thrombolysis if deterioration; echo for RV function.
High-Risk (Massive)	Thrombolysis + anticoagulation	Alteplase 100 mg IV over 2h + UFH	Contraindications: Stroke, bleeding; consider embolectomy if contraindicated.
All	Supportive care	O2 (SpO2 88-92%), fluids (500 mL bolus)	Avoid overhydration; norepinephrine if hypotensive.

Complications

• Acute:

- **RV failure:** RV dilation → Decreased cardiac output → Shock, death.
- **Hypoxemia:** Tissue hypoxia → Lactic acidosis, organ failure (AKI, encephalopathy).
- **Hemorrhagic complications:** From thrombolysis/anticoagulation (e.g., ICH 2-3%, major bleed 5-10%).

• Long-Term:

- **Chronic thromboembolic pulmonary hypertension (CTEPH):** 2-4% of PE survivors; persistent dyspnea, RV dysfunction.
- **Post-thrombotic syndrome (PTS):** If concurrent DVT; leg swelling, pain, ulcers.
- **Recurrent VTE:** 20-30% risk within 5 years if anticoagulation stopped prematurely.

Complications Table

Category	Acute Complications	Long-Term Complications	Treatment-Related
Acute PE	RV failure, hypoxemia, shock	CTEPH, post-thrombotic syndrome	ICH, major bleeding (thrombolysis)

Prognosis

• Mortality:

- **Massive PE:** 25-50% 30-day mortality.
- **Submassive PE:** 3-15% 30-day mortality.
- **Low-risk PE:** <2% 30-day mortality.

• Recovery:

- **Low-risk:** 90% recover fully with anticoagulation; return to baseline in 1-3 months.
- **Submassive:** 70-80% recover RV function within 6 months; 10-20% develop CTEPH.
- **Massive:** Survivors often have residual RV dysfunction (30-50%).

• Key Factors:

- **Hemodynamic status:** Hypotension → Worse prognosis.
- **RV dysfunction:** Troponin/BNP elevation → Increased mortality.
- **Comorbidities:** Cancer, age >70, sepsis increase mortality risk.

Examples

1. Case 1: Low-Risk PE

- Presentation: 40 y/o F, recent long flight, dyspnea, Wells score 4.5, D-dimer 800ng/mL, CTPA shows segmental PE, SpO2 92%, PESI Class I.
- Interpretation: Low-risk PE (normotensive, no RV dysfunction).
- Management: Rivaroxaban 15 mg BID x 21 days, outpatient follow-up, leg ultrasound (rule out DVT).

2. Case 2: Submassive PE

- Presentation: 55 y/o M, unprovoked PE, CTPA confirms large PE, echo shows RV dilation, troponin elevated, SBP 110 mmHg, PESI Class III.
- Interpretation: Submassive PE (normotensive, RV dysfunction).
- Management: Enoxaparin 1 mg/kg SC BID, admit for monitoring, repeat echo in 48h, consider thrombolysis if deterioration.

3. Case 3: Massive PE

- Presentation: 65 y/o F, sudden collapse, SBP 80 mmHg, PaO2 50 mmHg, CTPA shows saddle PE, echo with McConnell's sign.
- Interpretation: Massive PE (hypotension, RV strain).
- Management: Alteplase 100 mg IV over 2h, UFH infusion, norepinephrine 10 mcg/min, ICU admission.

Key Pearls

- Suspect PE in acute dyspnea + risk factors (immobility, malignancy); Wells score guide workup.
- D-dimer rules out PE in low-risk (Wells <2); CTPA is gold standard for diagnosis.
- **Risk stratify with PESI, echo, troponin:** Massive (SBP <90 mmHg), submassive (RV dysfunction), low-risk.
- **Anticoagulation for all:** LMWH (enoxaparin) or DOACs (rivaroxaban); thrombolysis for massive PE.
- Avoid overhydration; RV strain worsens with excess fluids, but avoid hypovolemia that would worsen preload
- Monitor for CTEPH in survivors (dyspnea >3 months post-PE → Echo, V/Q scan).
- **Recurrent PE risk:** 20-30% in 5 years; consider indefinite anticoagulation in unprovoked PE.

References

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- • **NEJM:** "Thrombolytic Therapy in Submassive PE" (2023).
- • **Eur Heart J:** "ESC Guidelines on Acute PE" (2019).

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