Chapter 73
Approach to Pulmonary Embolism in the ICU

73.1 Introduction

Pulmonary embolism (PE) is a potentially life-threatening condition resulting from the obstruction of the pulmonary arteries, most commonly due to thromboemboli originating from deep vein thrombosis (DVT). In the intensive care unit (ICU), prompt recognition and appropriate management are essential to reduce mortality and morbidity. This chapter provides a comprehensive approach for diagnosing and managing PE in critically ill patients, integrating the latest clinical guidelines, evidence-based recommendations, and special considerations for various patient populations [1, 2] [Ref: Algorithm 73.1].

73.2 Clinical Presentation and Risk Factors

PE often presents with nonspecific symptoms such as acute dyspnea, chest pain—which may be pleuritic or tachycardia, hypoxemia, syncope, and sometimes hemoptysis. Recognizing these symptoms in the context of risk factors is crucial for early suspicion. Key risk factors include recent surgery, major trauma, lower limb fracture, spinal cord injury, prolonged immobilization, myocardial injury, metastatic cancer, pregnancy, hormonal therapy, prior thromboembolism, obesity, smoking, and inherited thrombophilias. In the ICU setting, where patients may already be critically ill with overlapping symptoms, a high index of suspicion is necessary.

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73.3 Diagnostic Approach

73.3.1 Clinical Prediction Rules

To stratify patients based on the likelihood of PE, clinical prediction tools such as the Wells Score and the Geneva Score are utilized. These tools consider various clinical variables to categorize patients into low, intermediate, or high pretest probability for PE. An important advancement in this area is the use of age-adjusted D-dimer cut-offs. For patients over 50 years old, the D-dimer threshold is adjusted by multiplying the patient's age by 10 μg/L, improving specificity and reducing unnecessary imaging in older adults.

73.3.2 D-Dimer Testing

In patients categorized as low probability, D-dimer testing serves as a valuable diagnostic tool due to its high sensitivity. A negative D-dimer result effectively rules out PE in these patients, allowing clinicians to consider alternative diagnoses without subjecting patients to imaging studies. Point-of-care D-dimer assays are particularly beneficial in resource-constrained ICU settings, enabling rapid decision-making.

73.3.3 Imaging Studies

For patients with intermediate to high pretest probability or a positive D-dimer test, imaging studies are the next step. Computed tomography pulmonary angiography (CTPA) is the gold standard for diagnosing PE, offering direct visualization of emboli within the pulmonary arteries. Alternative imaging modalities include ventilation-perfusion (V/Q) scans, which are especially useful when CTPA is contraindicated due to contrast allergies or renal insufficiency. A high-probability V/Q scan confirms the diagnosis of PE, while a normal scan effectively excludes it. PE is diagnosed with high probability V/Q scan. Normal V/Q scan rejects the diagnosis of PE. Compression ultrasound of the lower extremities can help detect deep vain thrmbosis (DVT) when imaging for pulmonary embolism(such as CTPA or V/Q scan) is not feasible. In pregnant patients, modified imaging protocols are employed to minimize fetal radiation exposure while ensuring accurate diagnosis. When CTPA is not feasible, bedside transthoracic echocardiography should be done [3].

73.3.4 Echocardiography

In suspected high-risk PE, absence of echocardiographic signs of RV dysfunction excludes PE as the cause of hemodynamic instability. And when immediate CTPA is not feasible in suspected high-risk PE, the unequivocal echocardiographic signs of RV pressure overload, with specific findings such as 60/60 sign, McConnell sign, or presence of right-heart thrombi, justify emergency reperfusion treatment for PE.

73.4 Risk Stratification and Clinical Assessment

Upon confirmation of PE, risk stratification is vital to guide management decisions. The Pulmonary Embolism Severity Index (PESI) and its simplified version (sPESI) are validated tools combining clinical variables to predict 30-day mortality risk. Patients are classified into low-risk (PESI Class I-II or sPESI score of 0) or higher-risk categories based on these scores [4].

73.4.1 Hemodynamic Stability

Assessing hemodynamic status is a critical component of risk stratification. Hemodynamically unstable patients, defined by sustained hypotension (systolic blood pressure < 90 mmHg) or shock, are considered to have high-risk PE (massive PE) and require immediate reperfusion therapy. Stable patients without signs of shock are further evaluated for right ventricular (RV) dysfunction and elevated biomarkers to determine the risk of adverse outcomes.

73.4.2 Intermediate Risk Stratification

Stable patients are subcategorized into intermediate-high and intermediate-low risk based on the presence of RV dysfunction and elevated cardiac biomarkers such as troponins and B-type natriuretic peptide (BNP) or N-terminal pro-BNP. Intermediate-high risk patients exhibit both RV dysfunction and biomarker elevation, indicating a higher risk of deterioration and necessitating closer monitoring and management with anticoagulation. Intermediate-low risk patients have either RV dysfunction or elevated biomarkers and are managed with standard anticoagulation therapy while being vigilantly observed for any signs of clinical worsening [5].

73.4.3 Role of Biomarkers

Biomarkers play a significant role in the risk stratification and management of PE. Elevated cardiac troponins reflect myocardial injury due to RV strain, while elevated BNP or N-terminal pro-BNP levels indicate RV dysfunction. These biomarkers help identify patients at higher risk of adverse outcomes and guide decisions regarding the intensity of monitoring and the need for potential escalation of therapy. In low-risk patients with normal biomarker levels, early discharge and outpatient management may be considered, provided that adequate home support is available.

73.4.4 Therapeutic Management

Oxygen therapy should be started when $SaO_2 < 90\%$.
Noninvasive ventilation or high-flow nasal cannula should be preferred.

When invasive mechanical ventilation is used positive end-expiratory pressure should be applied with caution as it may reduce venous return and worsen the low cardiac output due to RV failure.

For hypotension, judicious volume loading should be done when there is absence of elevated filling pressure as assessed by ultrasound imaging of inferior vena cava, and vasopressor should be started early.

73.4.5 Anticoagulation Therapy

Anticoagulation is the cornerstone of PE management. Direct oral anticoagulants (DOACs), such as apixaban and rivaroxaban, are preferred as first-line agents due to their ease of use, predictable pharmacokinetics, and favorable safety profiles. They eliminate the need for routine laboratory monitoring and have fewer dietary restrictions compared to vitamin K antagonists like warfarin. In patients with contraindications to DOACs, such as severe renal impairment or antiphospholipid syndrome, low molecular weight heparin (LMWH), fondaparinux, or unfractionated heparin (UFH) may be used. Special populations, such as pregnant women, require careful consideration; LMWH is the anticoagulant of choice during pregnancy, as DOACs cross the placenta and are contraindicated [6].

73.4.6 Advanced Interventional Therapies

For patients with massive PE and hemodynamic instability, immediate reperfusion therapy is indicated. Systemic thrombolysis with agents like alteplase is strongly recommended, as it rapidly dissolves the thrombus, restores pulmonary perfusion,

and reduces RV afterload. UFH infusion is to be continued during infusion of alteplase. Catheter-directed thrombolysis is an alternative that delivers thrombolytics directly to the site of the clot at lower doses, minimizing systemic bleeding risks. Mechanical thrombectomy, including catheter-assisted and surgical embolectomy, is considered in patients with contraindications to thrombolysis or when thrombolytic therapy has failed. The utilization of pulmonary embolism response teams (PERT) facilitates rapid, multidisciplinary decision-making, integrating expertise from critical care, cardiology, pulmonology, hematology, and interventional radiology to tailor the best therapeutic approach for each patient. Drugs used for the management of PE with doses are shown in Table 73.1.

73.4.7 Special Considerations

73.4.7.1 Pregnancy

Managing PE during pregnancy presents unique challenges. Diagnostic imaging must balance the need for accurate detection with minimizing radiation exposure to the fetus. Modified protocols for V/Q scans or the use of MRI are considered.

Table 73.1 Table drugs for pulmonary embolism management

Drug name	Dose	Indications	Contraindications
Apixaban	10 mg BID for 7 days, then 5 mg BID	Treatment of acute PE and prevention of recurrence	Severe renal impairment (CrCl <15 mL/min)
Rivaroxaban	15 mg BID for 21 days, then 20 mg once daily	Treatment of acute PE and prevention of recurrence	Severe renal impairment (CrCl <15 mL/min)
Dabigatran	150 mg BID (after 5–10 days of parenteral anticoagulation)	Treatment of acute PE and prevention of recurrence	Severe renal impairment (CrCl <30 mL/min)
Edoxaban	60 mg once daily (after 5–10 days of parenteral anticoagulation)	Treatment of acute PE and prevention of recurrence	Severe renal impairment (CrCl <15 mL/min)
Warfarin	Dose adjusted to maintain INR between 2.0–3.0	Long-term anticoagulation for PE	Pregnancy, significant bleeding risk
Enoxaparin	1 mg/kg BID or 1.5 mg/kg once daily (adjust for renal function)	Preferred anticoagulant in pregnancy and cancer-associated thrombosis	Active bleeding, severe thrombocytopenia
Dalteparin	200 IU/kg once daily (max 18,000 IU/day)	Preferred anticoagulant in pregnancy and cancer-associated thrombosis	Active bleeding, severe thrombocytopenia
Heparin (UFH)	80 units/kg IV bolus, then 18 units/kg/hour infusion	Immediate anticoagulation in unstable patients	Active bleeding, severe thrombocytopenia
Alteplase (tPA)	100 mg IV over 2 hours	High-risk PE with hemodynamic instability	Active bleeding, recent intracranial hemorrhage
Tenecteplase	Weight-based bolus (e.g., 0.5 mg/kg)	High-risk PE with hemodynamic instability	Active bleeding, recent intracranial hemorrhage

LMWH remains the anticoagulant of choice due to its safety profile in pregnancy. Collaborative care involving obstetrics, maternal-fetal medicine, and critical care specialists is essential to optimize outcomes for both the mother and the fetus.

73.4.7.2 Outpatient Management

Selected low-risk patients with PE may be candidates for outpatient management. Criteria include hemodynamic stability, low PESI or sPESI scores, absence of severe comorbidities, and the availability of reliable home support systems. Outpatient management involves initiating anticoagulation therapy, providing thorough patient education on medication adherence and symptom monitoring, and arranging prompt outpatient follow-up.

73.4.7.3 Risk of Overuse in Diagnostics

While the prompt diagnosis of PE is crucial, there is a risk of overutilization of imaging studies, particularly in low-risk patients. Unnecessary exposure to radiation and contrast agents can be avoided by adhering to validated clinical prediction rules and using D-dimer testing judiciously. Clinicians are encouraged to apply careful clinical judgment, integrating patient history, physical examination findings, and pretest probability assessments before proceeding to imaging.

73.4.7.4 Long-Term Follow-Up and Complications

PE can have long-term sequelae, underscoring the importance of ongoing follow-up. Chronic thromboembolic pulmonary hypertension (CTEPH) is a serious complication resulting from persistent pulmonary artery obstruction, leading to increased pulmonary vascular resistance and right heart failure. Additionally, patients may develop post-PE syndrome, characterized by persistent dyspnea, reduced exercise capacity, and impaired quality of life. Regular follow-up visits should include clinical assessments, echocardiography, and functional tests to detect these complications early. Management strategies may involve pulmonary hypertension therapies, pulmonary endarterectomy for CTEPH, and rehabilitation programs to improve functional status.

73.4.7.5 Evidence-Based Recommendations

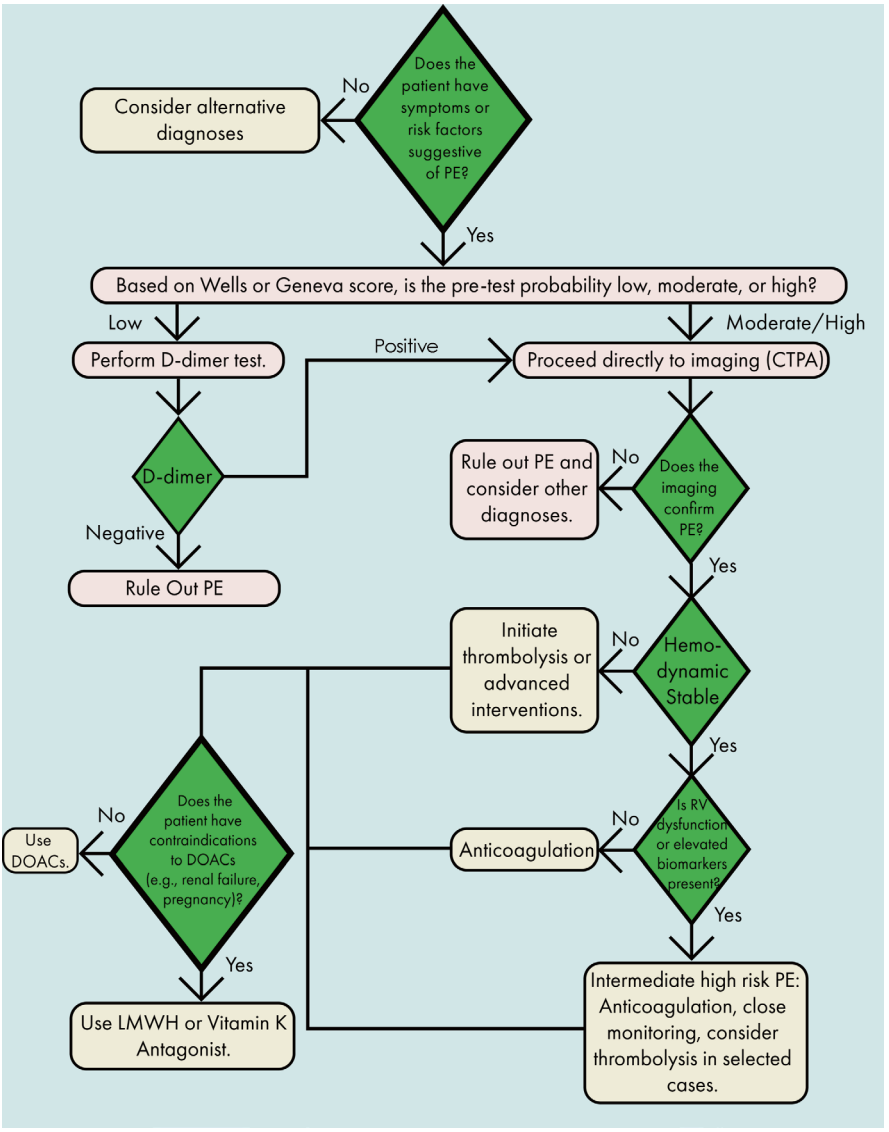
This chapter aligns with current guidelines from leading organizations such as the American Heart Association (AHA) and the European Society of Cardiology (ESC). Strong recommendations include the use of systemic thrombolysis for patients with high-risk (massive) PE and hemodynamic instability, and the preference for DOACs

in anticoagulation therapy for most patients without contraindications. Conditional recommendations, based on individual patient factors and emerging evidence, guide the use of catheter-directed therapies and the consideration of outpatient management for low-risk patients.

73.5 Conclusion

The management of PE in the ICU requires a multifaceted approach that encompasses timely diagnosis, accurate risk stratification, and the implementation of appropriate therapeutic interventions. Incorporating age-adjusted D-dimer cut-offs and clinical prediction rules enhances diagnostic accuracy while reducing unnecessary imaging. Risk stratification models like PESI and sPESI inform treatment decisions and help identify patients suitable for outpatient management. Advanced interventional therapies and the formation of multidisciplinary teams, such as PERT, enhance the care of high-risk patients. Special considerations for pregnancy and the emphasis on long-term follow-up address the unique needs of specific patient populations and potential chronic complications. Adherence to evidence-based guidelines ensures optimal outcomes, improves resource utilization, and advances the standard of care for patients with PE in the ICU setting.

Algorithm 73.1: Approach to pulmonary embolism (PE) in the ICU



Bibliography

1. Erythropoulou-Kaltsidou A, Alkagiet S, Tziomalos K. New guidelines for the diagnosis and management of pulmonary embolism: key changes. World J Cardiol. 2020;12(5):161–6.
2. Ortel TL, Neumann I, Ageno W, Beyth R, Clark NP, Cuker A, et al. American Society of Hematology 2020 guidelines for management of venous thromboembolism: treatment of deep vein thrombosis and pulmonary embolism. Blood Adv. 2020;4(19):4693–738.
3. Konstantinides SV, Meyer G, Becattini C, Bueno H, Geersing GJ, Harjola VP, et al. ESC guidelines for the diagnosis and management of acute pulmonary embolism developed in collaboration with the European Respiratory Society (ERS). Eur Heart J. 2020;41(4):543–603.
4. Kahn SR, de Wit K. Pulmonary embolism. N Engl J Med. 2022;387(1):45–57.
5. Jaff MR, McMurtry MS, Archer SL, Cushman M, Goldenberg N, Goldhaber SZ, et al. Management of massive and submassive pulmonary embolism, iliofemoral deep vein thrombosis, and chronic thromboembolic pulmonary hypertension: a scientific statement from the American Heart Association. Circulation. 2011;123(16):1788–830.
6. Stevens SM, Woller SC, Kreuziger LB, Bounameaux H, Doerschug K, Geersing GJ, et al. Antithrombotic therapy for VTE disease: second update of the CHEST guideline and expert panel report. Chest. 2021;160(6):e545–608.