AUCTORES
Globalize your Research

Journal of Clinical Research and Reports
Ashley Sundin *

Open Access

Research Article

Pulmonary Embolism as A Cardiovascular Emergency: Optimizing Early Diagnosis and Management in The Emergency Department

Ashley Sundin[1]*, Dilpat Kumar [2], Manar Jbara [2]

[1]East Tennessee State University, Department of Internal Medicine.

[2]East Tennessee State University, Division of Cardiology, Department of Internal Medicine.

***Corresponding Author:** Ashley Sundin., East Tennessee State University, Department of Internal Medicine.

Received date: October 03, 2025; **Accepted date:** October 15, 2025; **Published date:** October 21, 2025

Citation: Ashley Sundin, Dilpat Kumar, Manar Jbara, (2025), Pulmonary Embolism as A Cardiovascular Emergency: Optimizing Early Diagnosis and Management in The Emergency Department, *J Clinical Research and Reports,* 21(3); **DOI:**10.31579/2690-1919/563

Abstract

Background/Objectives:

Pulmonary embolism (PE) is the third leading cause of cardiovascular mortality and presents significant diagnostic and therapeutic challenges in the emergency department. Utilizing appropriate and accurate screening and risk stratification tools optimizes clinical decision making and patient outcomes. This review seeks to discuss current evidence on the diagnosis, risk stratification, and evolving management strategies for pulmonary embolism, with a focus on advanced therapeutic intervention and its implications for emergency practice.

Methods: We reviewed current literature regarding the epidemiology, diagnosis, risk stratification, and management of PE, with a focus on clinical decision tools and advanced therapeutic interventions. Specific attention was given to diagnostic algorithms, and guidelines regarding risk stratification methods as well as treatment options including catheter-directed thrombolysis (CDT), mechanical thrombectomy, systemic thrombolysis, and ultrasound-assisted thrombolysis (USAT). The literature search was performed using the database PubMed with keywords to include "pulmonary embolism," "catheter-directed thrombolysis,", "ultrasound-assisted thrombolysis," "mechanical thrombectomy," "systemic thrombolysis," and "clinical decision support.". Inclusion criteria included peer-reviewed articles, randomized controlled trials, observational studies, and major guidelines focused on adult patients with acute PE. Exclusion criteria included non-English language publications, case reports, and studies involving pediatric populations. This approach was designed to ensure a thorough and reproducible synthesis of current evidence.

Results: Accurate utilization of risk stratification tools has been shown to improve patient-specific treatment and provide a better insight into patient outcomes. Interventional therapies such as CDT and USAT have demonstrated reduced mortality and morbidity in high- and intermediate-risk PE patients when compared to systemic anticoagulation alone. There is also future discussion on how to improve risk stratification to continue to reduce patient mortality and morbidity, as well as reduce the risk of sequelae and side effects.

Conclusion: This review article highlights the evolving landscape of PE diagnosis and management driven by advances in risk-stratification tools and interventional therapies. By discussing current evidence, we underscore the importance of accurate risk stratification and the judicious use of different treatment modalities. We also discuss ongoing research focused on refining treatment algorithms, improving the accuracy of clinical decision-making, comparing new and more mature treatment therapies, and preventing long-term complications. The ultimate goal of this review article to provide further discussion on PE to improve patient outcomes.

Keywords: pulmonary embolism; risk stratification; catheter-directed thrombolysis; mechanical thrombectomy; systemic thrombolysis; ultrasound-assisted thrombolysis

1.Introduction

Pulmonary embolism (PE) is a common and potentially life-threatening cardiovascular emergency, ranking as the third leading cause of cardiovascular mortality worldwide [1]. It is frequently encountered in the Emergency Department (ED), where timely recognition and management are critical. PE typically arises when a part of a thrombus from a deep vein in the lower extremities enters the pulmonary circulation and obstructs the pulmonary arteries. Less commonly, PE may occur from embolizing other materials, such as air, fat, or tumor cells [2]. Risk factors for PE are numerous and well-established. They include a history of venous thromboembolism (VTE), recent prolonged immobilization such as hospitalization, obesity, the use of oral contraception, postpartum period, lower extremity surgery, malignancy, and thrombophilias [3]. Despite known risk factors, the clinical presentation of PE is notoriously variable and nonspecific, ranging from mild dyspnea to catastrophic hemodynamic collapse [4]. This wide variation in presentation leads to diagnostic uncertainty, causing PE to be both undiagnosed and over investigated. This unresolved challenge of underdiagnosis can lead to potentially fatal consequences, while over investigation can give rise to unnecessary imaging, increased healthcare costs, and additional burden on an already overextended ED [5]. Despite its high clinical burden, therapeutic advances for PE have previously lagged compared to other cardiovascular emergencies, such as myocardial infarction (MI) and stroke, the first and second leading causes of cardiovascular death, respectively. Historically, treatment has been limited to anticoagulation alone for more hemodynamically stable patients or systemic thrombolytic therapy for life-threatening PE. This has left a critical gap in the availability of effective, targeted, and safer therapies for patients who fall between these extremes of severity. However, in recent years, there has been a surge of renewed interest in developing safer and more effective interventions, such as ultrasound-assisted catheter-directed thrombolysis (USCDT) and mechanical thrombectomy, with the goal of improving outcomes while minimizing complications in these intermediate-risk patients [6]. This review addresses this therapeutic gap by examining the expanding role of interventional therapies for acute PE management in the ED. We will evaluate both traditional and emerging therapies, highlight the potential of emerging therapies to bridge the current treatment void, and explore how these newer treatment options may be incorporated into contemporary cardiovascular emergency care. Additionally, we will explore future directions and implementation strategies for optimizing PE management across varying risk stratifications.

2. Clinical Decision Rules in Pulmonary Embolism Diagnosis

: The annual incidence rate of PE in the U.S. is approximately 1.15 cases per 1,000 persons, with PE accounting for about 0.16% of all emergency department visits, with the incidence rising every year [7][8]. With PE having an increased burden of morbidity and mortality worldwide, early identification of the severity of PE on initial presentation is vital to therapy-directed treatment options. There have been several evidence-based clinical decision support systems (CDSS) that have been developed to assist in the determination of PE, including the Wells Criteria, Revised Geneva Score, and the Pulmonary Embolism Rule-Out Criteria (PERC) [9]. The Wells score remains one of the most widely used tools, stratifying patients into low, intermediate, or high probability categories based on clinical criteria. When combined with D-dimer testing, the Wells score can safely rule out PE in many patients without requiring imaging [10]. However, the subjectivity and interobserver variability associated with the clinician's assessment of whether a PE is the most likely diagnosis limit the Wells score and should be accounted for when utilizing this CDSS. Similarly, the revised Geneva score is another scoring system in assisting with the pretest probability of PE, similar to the Wells score, however, relying purely on objective clinical variables [11]. In low-risk patients, pre-test probability (≤15%), the Pulmonary Embolism Rule-Out Criteria (PERC) can be employed to safely discharge patients without further testing if all criteria are negative [12][13]. As with the Wells score, the PERC rule does incorporate physicians' pre-test probability, which may lead to reduced specificity of these CDSS in patients with multiple comorbidities, leading to diagnostic uncertainty and potential overuse of imaging in certain populations. More recently, the YEARS algorithm has been introduced, which reduces unnecessary imaging by adjusting D-dimer thresholds based on clinical suspicion and has been shown to reduce imaging in special populations such as pregnant patients, where minimizing radiation exposure is critical[14]. There have been studies to show that the YEARs criteria have also shown superior efficacy in safely reducing imaging utilization and maintaining diagnostic accuracy compared to the previous Wells criteria [15]. In parallel with clinical scoring tools, imaging plays a central role in confirming or excluding PE. Computed tomography pulmonary angiography (CTPA) is the preferred first-line imaging modality due to its high sensitivity and specificity, as well as its ability to provide additional information about possible right ventricular dysfunction. In patients with renal insufficiency, contrast allergies, or other contraindications to CTPA, ventilation-perfusion (V/Q) scintigraphy offers a viable alternative. Although less specific than CTPA, a normal V/Q scan has a high negative predictive value and is particularly useful in patients who are pregnant or have chronic pulmonary disease. Additionally, chest graph can provide a valuable initial imaging tool, particularly in patients with nonspecific symptoms. It can assist in excluding alternative causes of dyspnea or chest pain, such as pneumonia and pneumothorax. It also may identify classic but rare signs of PE such as Hampton's hump or Westermark's sign. A D-dimer is a blood test that specifically measures the fibrin degradation products that are released when a blood clot is broken down in the body. It is typically used in patients with low pre-test probability, where a negative result can reliably exclude pulmonary embolism without the need for imaging. Patients in a high-risk category or who have a high clinical suspicion for PE should receive imaging instead of the D-dimer test because D-dimer testing cannot confirm an active clot and can be elevated in a myriad of other conditions. Additionally, patients who are elderly, have malignancy, liver disease, are pregnant, have a chronic inflammatory state, or have been hospitalized for a significant amount of time will have baseline elevations in their D-dimer levels. These limitations should be taken into account when considering ordering D-dimers in the aforementioned patient population and are the limitations of this blood test. In moderate-risk patients, one can either obtain a D-dimer (a negative D-dimer would rule out PE) or go straight to imaging if clinical suspicion remains high [16]. Gold standard use of the D-dimer test should be used in conjunction with CDSS, as described above, such as the YEARs criteria to best identify possible PE.

3. Risk Stratification

Once PE is suspected or identified, immediate risk stratification to guide treatment by identifying patients most likely to experience adverse outcomes. The most widely adopted classification systems for determining the severity of pulmonary embolism (PE) are those established by the American Heart Association (AHA) and the European Society of Cardiology (ESC) [17] [18]. These two systems, which share many similarities, categorize PE severity into three primary levels: massive, submassive, and nonmassvive, determined by the AHA, and high-risk, intermediate-risk, and low-risk PE defined by the ESC (Table 1).

AHA Classification	ESC Classification	Defining Features
Massive	High-risk	- Presence of hypotension (systolic BP <90vmm HG, or a drop of >40mm HG for at least 15minutes - Requirement of vasopressor support
Submassive	Intermediate high-risk	Right ventricular dysfunction and injury
	Intermediate low-risk	Right ventricular dysfunction OR injury
Nonmassive	Low risk	Does not meet criteria for massive (high-risk) or submassive (intermediate-risk)

Table 1: Highlights the two PE classification systems (AHA and ESC).

These categories are determined based on hemodynamic effects and the short-term prognosis of the patient. Management strategies are then decided upon, tailored to the severity of PE based on risk and benefits to best decrease mortality and morbidity in patients presenting with PE. The first category is termed massive (high-risk) PE as defined by the AHA/ESC, respectively. Massive (high-risk) PE has traditionally been defined by the basis of angiographic burden of the emboli by use of the Miller index, however, most recent registry data now support the presence of circulatory arrest or hypotension as defining criteria in the diagnosis of massive (high-risk) PE [18][19]. Further definition of hypotension can be described as a systolic blood pressure <90 mm Hg, a drop of >40 mm Hg for at least 15 minutes, or need for vasopressor support, which identifies these patients [20]. These patients have approximately 65% 30-day mortality [21]. The next category is submissive (intermediate risk), which the AHA defines as a normotensive patient with evidence of right ventricular (RV) strain or myocardial ischemia (MI). The ECS has a broader definition that also incorporates the use of the simplified Pulmonary Embolism Severity Index (sPESI) for PE-related 30-day mortality. Patients with a sPESI score of 1 or greater are then subdivided into two subgroups according to whether the patients have both RV dysfunction and RV injury (intermediate risk-high) or only one of neither of these findings (intermediate risk-low) [22]. RV strain does encompass RV dysfunction as evidenced on transthoracic echocardiography (TTE), RV dilation (RV/LV ratio .0.9) via contrast topography (CT) or TTE, and RV pressure overload and injury secondary to elevated biomarkers such as biomarkers such as troponin and brain natriuretic peptide (BNP) [18-,21]. Clot burden viewed on CT scan does not predict overall mortality in patients with submassive (intermediate risk) PE [22]. MI is often assessed by an electrocardiogram (ECG). This group of patients accounts for approximately 35-55% of hospitalized patients [18]. Nonmassive (low-risk) PE is defined as patients with PE who do not meet the criteria for massive (high-risk) or submassive (intermediate-risk) PE. This group of patients accounts for approximately 40-60% of hospitalized patients with PE and has an average mortality of approximately 1% in one month [23]. Though there are limitations to risk stratification, such as PE severity varying over time with unique patient presentations and histories, it is a useful tool that has been validated by multiple studies [18] [19]. Additionally, risk stratification allows providers to decrease overall mortality and morbidity of PE in patients while also reducing the risk associated with different therapy modalities.

4. Clinical Treatments and Outcomes

Historically, PE has mainly been treated with anticoagulation (AC), mainly Heparin, especially in more hemodynamically stable patients; however, there have been several novel treatment modalities created in recent years. These new treatment modalities have aimed at reducing the duration of anticoagulation needed and improving outcomes from the sequelae of high-risk and intermediate-risk PE. Current guidelines still recommend therapeutic anticoagulation with subcutaneous low molecular weight heparin (LMWH), intravenous or subcutaneous unfractionated heparin (UFH), weight-based subcutaneous UFG, or subcutaneous fondaparinux should be administered to patients with confirmed PE and no contraindications to AC [1]. Additionally, therapeutic anticoagulation should be given to patients during the diagnostic work-up with intermediate or high clinical probability of PE with no contraindications to AC [1]. Management strategies have evolved to include a range of advanced interventional therapies such as systemic thrombolysis, catheter-directed thrombolysis (CDT), mechanical thrombectomy, and ultrasound-assisted thrombolysis (e.g., EKOS)[24]. Patients with massive or submassive PE who have hemodynamic compromise and/or have cardiogenic shock may also benefit from additional techniques such as invasive hemodynamic support devices, such as extracorporeal membrane oxygenation (ECMO) or isolated percutaneous RV support in conjunction with treatment modalities [25-27]. CDT technique involves delivering thrombolytic agents directly to the clot through a multi-side hole infusion catheter, typically reserved for cases of massive or submassive PE where systemic thrombolysis may lead to increased risk of major and intracranial bleeding. By localizing the thrombolytic action, CDT offers an advantage in terms of reducing the systemic bleeding risk. CDT has reported a significantly lower total dose of thrombolytic agents by approximately 25% of what is usually given systemically [28]. Ultrasound-Assisted Thrombolysis (USAT) with the EKOSonic endovascular system (EKOS Corp, Bothell, WA) combines the use of low-frequency ultrasound waves with thrombolytic agents, which enhances the ability of the clot-dissolving drugs to penetrate the thrombus [29]. The EKOS catheter has two lumens, with one lumen holding a filament with multiple ultrasound transducers that emit high-frequency, low-energy ultrasound. The second lumen releases local thrombolytic delivery through multiple ports along the length. The low-energy ultrasound breaks down fibrin strands, leading to a more effective thrombolysis at lower doses. The primary proposed advantage of EKOS over CDT is its potential for more effective penetration of the thrombolytic agent over a shorter duration of time [30]. Though this benefit remains theoretical, as it has not yet been confirmed by a randomized controlled trial (RCT) [31]. Ultrasound-assisted thrombolysis can be used for patients with intermediate-risk PE, offering a less invasive alternative to mechanical thrombectomy or systemic thrombolysis. Both USAT and CDT are more recent additions in the therapeutic toolbox that physicians can use in the treatment of patients with submassive (intermediate-risk) PE. While both modalities aim to deliver targeted thrombolytic therapy for pulmonary embolism, they differ in the mechanism of action, treatment duration, and thrombolytic dosing (Table 2).

Feature	EKOS (USAT)	Standard CDT
Mechanism	Delivers thrombolytics with high-frequency ultrasound to enhance drug penetration and clot dissolution	Infused thrombolytics directly through catheter without ultrasound
Infusion Time	Typically 6-12 hours	Typically 12-24 hours
Thrombolytic Dose	Typically requires less compared to standard CDT	Tends to require a higher dose of thrombolytics compared to EKOS but less than systemic thrombolytics used for traditional PE management.
Efficacy	Suggested improved clot resolution in obervational studies	Effective in reducing RV dysfunction and clot burden
Saftey Profile	Potentially lower bleeding risk (due to lower dose and time)	Considered favorable with a lower risk of major bleeding compared to systemic thrombolysis.
Clinical Evidence	Supported by observational and registry data	Supported by oberservational studies but also lack large RCTs
FDA Clearance	Yes	Yes

Table 2: Comparison between EKOS (USAT) and Standard CDT in the treatment of submassive (intermediate-risk) PE.

Mechanical thrombectomy or embolectomy is becoming increasingly recognized as a viable option for patients with massive (high-risk) and submassive (intermediate-risk) PE especially when rapid clot removal is needed and thrombolytics are contraindicated. There are several different types of catheters and techniques used; however, the general idea is that mechanical thrombectomy physically removes the embolus using specialized devices, improving both right ventricular function and overall hemodynamic stability [32]. Usually, a pre-procedural CT scan is ordered, which assists in guiding the catheter. This treatment is often used in combination with other therapies, such as CDT, in severe cases [18]. Devices such as FlowTriever and Indigo have been the topic of recent studies, which showed increased safety and hemodynamic improvements. Notably, the FLARE trial evaluated the FlowTriever device in patients with submassive (intermediate-risk) PE and showed significant improvements in patients' RV/LV ratio and low major bleeding rates [33]. More recently, the PEERLESS trial, a RCT, compared mechanical thrombectomy to CDT in intermediate-high risk PE and found comparable improvement in RV function with a trend towards fewer bleeding complications in the thrombectomy group [34]. These studies have shown support in mechanical thrombectomy as a viable alternative to systemic anticoagulation and CDT however, long-term outcomes and broader clinical adoption will require further validation. Systemic Thrombolysis therapy remains a cornerstone for massive (high-risk) PE management, particularly in cases with hemodynamic compromise. These medications actively promote clot degradation and reduce right heart strain [35]. While this approach has a proven benefit in reducing mortality and improving clinical outcomes, it carries a significant risk of bleeding, particularly in patients with contraindications, such as active bleeding or recent surgery [36]. However, systemic thrombolysis has failed to show a mortality benefit in patients with submassive (intermediate-risk) PE, as shown in the PEITHO trial, which revealed an increased risk of major bleeding in this treatment arm [37]. These findings highlight the importance of accurate PE classification to determine appropriate management and interventional therapy. Patients with massive PE (high-risk) with significant right ventricular strain and hemodynamic compromise may benefit from a more invasive procedure, such as ECMO in conjunction with other treatment modalities. These patients are at a significantly higher risk for cardiac arrest, and some observational studies have shown benefit in starting ECMO as a bridging therapy in these patients [38]. However, with ECMO being an advanced interventional therapy, it may not be universally accessible due to cost constraints, specialized equipment requirements, and limited availability in non-tertiary centers [39]. Ultimately, treatment decisions should involve a multidisciplinary approach, with patient history and objective information contributing to the overall decision for treatment of PE. By focusing on individualized care, physicians can minimize complications while improving the chances of recovery and reducing mortality in patients with pulmonary embolism.

5. Patient Outcomes

Pulmonary embolism management has evolved significantly, with a strong emphasis on early diagnosis, risk stratification, and individualized treatment approaches. The variety of treatment modalities, including systemic thrombolysis, CDT, mechanical thrombectomy, and USAT, has allowed for more tailored care aimed at improving outcomes, minimizing complications, and preventing long-term sequelae like chronic thromboembolic pulmonary hypertension (CTEPH) or recurrent PE from deep venous thromboembolism (DVT). Preventing CTEPH remains a critical goal in post-PE care. Current strategies include the early initiation and appropriate duration of anticoagulation, often with direct oral anticoagulants (DOACs) as well as close follow-up. Additionally, TTE and ventilation-perfusion (V/Q) scans can be used post-PE to monitor for persistent pulmonary hypertension or unresolved thromboembolic burden. However, there still remains evidence gaps in duration of surveillance intervals, duration of follow-up imaging, and long-term anticoagulation strategies in patients at higher risk for CTEPH. High-risk patients may benefit from prompt, aggressive interventions such as systemic thrombolysis or mechanical thrombectomy, which can dramatically reduce mortality by rapidly reversing hemodynamic compromise compared to just AC if implemented early [36]. However, the bleeding risks associated with systemic thrombolysis, especially intracranial hemorrhage, necessitate careful patient selection. Intermediate-risk patients, the goal is often to avert hemodynamic collapse and death resulting from progressive right-sided heart failure. This group can benefit from catheter-directed therapies, including USAT, which deliver lower doses of thrombolytics directly to the clot. This approach improves right ventricular function and reduces clot burden with fewer bleeding complications compared to systemic thrombolysis. Non-massive PE patients typically achieve excellent outcomes with anticoagulation alone, and many can even be safely managed as outpatients [38]. This patient-centered approach minimizes hospitalization, reduces costs, and maintains high safety profiles. Another goal of modern PE management is the prevention of CTEPH, a debilitating long-term complication of unresolved PE characterized by persistent pulmonary artery obstruction and pulmonary hypertension, prevention of recurrent PE, and reintroduction of exercise. Early and effective clot resolution is key to minimizing these risks. Permanent or temporary Inferior Vena Cava (IVC) filters are also a treatment modality utilized in recent years for the prevention of recurrent PE in patients with known DVT where systemic AC is contraindicated [41-43]. Furthermore, the CDSS such as the PERC rule, Wells score, and the YEARS algorithm assist in identifying patients who can avoid unnecessary imaging or treatment, thus sparing them from potential procedural risks and radiation exposure. The precision in risk stratification, ensuring the right therapy is used for the right patient at the right time, enhances survival and significantly reduces the occurrence of treatment-related complications.

6. Future of PE Risk Stratification and Therapeutic Modalities

One major future direction is the continued refinement of risk stratification models. Artificial intelligence (AI) and machine learning algorithms are beginning to play a role in predicting PE risk, which could include a more accurate risk stratification system, determining severity, and guiding diagnostic and therapeutic decisions. Future studies are needed to identify where risk stratification can be improved upon and how to better categorize treatment plans for patients to reduce mortality and morbidity [44]. Additionally, current and future studies such as the HI-PEITHO trial, a large multicenter RCT, aims to address the gap in treatment options for submassive (intermediate-risk) patients by comparing USAT plus anticoagulation to anticoagulation alone. The findings of this study will be pivotal in determining treatment options for these patients and also on the therapeutic advantages that USAT may or may not provide [45].As data continue to support the safety and effectiveness of catheter-directed thrombolysis and mechanical thrombectomy, these modalities are expected to become the standard of care for intermediate-risk PE. Future devices may offer even more precise clot targeting, improved ease of use, and further reduced doses of thrombolytic agents. Combination strategies, such as low-dose systemic thrombolysis followed by catheter-based clot disruption, are being explored to optimize outcomes while preserving safety. Additional studies are also needed to determine the benefit of USAT and CDT in patients with high-risk or intermediate-risk PE to create a unified guideline and reduce the risk of sequelae or side effects of therapeutic modalities.

7. Conclusion

PE is a cardiovascular emergency that remains a significant mortality in patients who present to the ED. To reduce the risk of mortality and optimize patient outcomes, PE requires prompt diagnosis, accurate risk stratification, and tailored therapeutic strategies. PE has a wide variety of presentations, ranging from sudden cardiac death to asymptomatic, making it a difficult diagnosis to determine with just clinical gestalt. Clinical decision tools such as the Wells score, revised Geneva score, PERC, and the YEARS algorithm have become regular practice in improving diagnostic efficiency while minimizing unnecessary testing. Risk stratification not only guides immediate management but also determines long-term prognosis. This allows physicians to select appropriate therapies, from AC to advanced interventions like CDT, mechanical thrombectomy, and USAT. For clinicians, a practical takeaway is the importance of integrating validated clinical decision tools with imaging and biomarker data to tailor diagnostic and therapeutic strategies to better treat patients presenting with a possible PE. Current guidelines still recommend treating patients with confirmed PE with systemic thrombolytics unless there is otherwise a contraindication for AC. Mechanical thrombectomy may be considered in patients with contraindications to thrombolysis, while CDT/USAT may have more benefit in patients with right ventricular dysfunction and evidence of myocardial injury. Clinicians should have a discussion with hospital leadership to determine what treatment options are available at their facility and whether there are appropriate resources, expertise, and protocols in place to safely implement them. Advancements in treatment modalities have significantly improved survival and reduced morbidity, especially through individualized care approaches that balance efficacy with the minimization of bleeding risks. Modern management strategies have also placed a new emphasis on the prevention of CTEPH, recurrent PE, and earlier initiation of exercise therapy. Looking forward, the future of PE management lies in further studies exploring more accurate risk stratification and in the expanding role of CDT, USAT, and developing safer pharmacologic agents. By continuing to evolve in response to emerging technologies and research, emergency medicine physicians and interventional cardiologists will be increasingly equipped to provide the right care for the right patient at the right time, ultimately reducing mortality and improving quality of life for patients with pulmonary embolism.

References

1. Giri, J., Sista, A. K., Weinberg, I., Kearon, C., Kumbhani, D. J., et al. (2019). Interventional Therapies for Acute Pulmonary Embolism: Current Status and Principles for the Development of Novel Evidence: A Scientific Statement from the American Heart Association. Circulation, 140(20), e774–e801.
2. Vyas V, Sankari A, Goyal A. Acute Pulmonary Embolism. 2024. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan-.
3. Westafer, L. M., Long, B., & Gottlieb, M. (2023). Managing Pulmonary Embolism. Annals of emergency medicine, 82(3), 394–402.
4. Morrone, D., & Morrone, V. (2018). Acute Pulmonary Embolism: Focus on the Clinical Picture. *Korean circulation journal*, 48(5), 365–381.
5. Monteleone, P., Lou, Y., Klein, A. J., Maholic, R. L., Hollenbeck, S. T., et al. (2024). Modern treatment of pulmonary embolism (USCDT vs MT): Results from a real-world, big data analysis (REAL-PE). *Journal of the Society for Cardiovascular Angiography & Interventions*, 3(1),
6. Kline, J.A. · Garrett, J.S. · Sarmiento, E.J. · et al. (2020). Over-testing for suspected pulmonary embolism in American emergency departments: the continuing epidemic. *Circ Cardiovasc Qual Outcomes*.; 13, e005753
7. Gottlieb, M., Moyer, E., & Bernard, K. (2024). Epidemiology of pulmonary embolism diagnosis and management among United States emergency departments over an eight-year period. *The American Journal of Emergency Medicine*, 85, 158–162.
8. Hsu, S. H., Ko, C. H., Chou, E. H., Herrala, J., Lu, T. C., et al. (2023). Pulmonary embolism in United States emergency departments, 2010-2018. *Scientific reports*, 13(1), 9070.
9. Medson, K., Yu, J., Liwenborg, L., Lindholm, P., & Westerlund, E. (2022). Comparing 'clinical hunch' against clinical decision support systems (PERC rule, wells score, revised Geneva score and YEARS criteria) in the diagnosis of acute pulmonary embolism. *BMC pulmonary medicine*, 22(1), 432.
10. UpToDate. (n.d.). Pulmonary embolism: Clinical presentation and diagnosis. Retrieved April 26, 2025, from https://www.uptodate.com/contents/pulmonary-embolism-clinical-presentation-and-diagnosis
11. (2025). Elsevier. (n.d.). Geneva score. ScienceDirect Topics.
12. (2020). Evidence review for the use of the pulmonary embolism rule-out criteria for diagnosis of pulmonary embolism: Venous thromboembolic diseases: diagnosis, management and thrombophilia testing: Evidence review B. London: National Institute for Health and Care Excellence (NICE);. (NICE Guideline, No. 158.)

13. Jones, N. R., & Round, T. (2021). Venous thromboembolism management and the new NICE guidance: what the busy GP needs to know. The British journal of general practice : *the journal of the Royal College of General Practitioners*, 71(709), 379–380.
14. Kearon, C., de Wit, K., Parpia, S., Schulman, S., Afilalo, M., et al. (2019). Diagnosis of pulmonary embolism with D-dimer adjusted to clinical probability. *New England Journal of Medicine*, 381(22), 2125–2134.
15. Stals MAM, Takada T, Kraaijpoel N, et al. (2022). Safety and efficiency of diagnostic strategies for ruling out pulmonary embolism in clinically relevant patient subgroups: a systematic review and individual-patient data meta-analysis. *Ann Intern Med*; 175:244–255.
16. Bounds EJ, Kok SJ. D Dimer. (2023). In: StatPearls [Internet]. Treasure Island (FL): *StatPearls Publishing*; 2025.
17. Konstantinides, S. V., Meyer, G., Becattini, C., Bueno, H., Geersing, G.-J., et al., ... ESC Scientific Document Group. (2020). 2019 ESC guidelines for the diagnosis and management of acute pulmonary embolism developed in collaboration with the European Respiratory Society (ERS): The Task Force for the Diagnosis and Management of Acute Pulmonary Embolism of the European Society of Cardiology (ESC). *European Heart Journal*, 41(4), 543–603.
18. Jaff MR, McMurtry MS, Archer SL, Cushman M, Goldenberg N, et al. (2012). on behalf of the American Heart Association Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation; American Heart Association Council on Peripheral Vascular Disease; American Heart Association Council on Arteriosclerosis, Thrombosis and Vascular Biology. Management of massive and submassive pulmonary embolism, iliofemoral deep vein thrombosis, and chronic thromboembolic pulmonary hypertension: a scientific statement from the American Heart Association [published corrections appear in Circulation.. *Circulation*.;123:1788–1830.
19. Miller, G. A., Sutton, G. C., Kerr, I. H., Gibson, R. V., & Honey, M. (1971). Comparison of streptokinase and heparin in treatment of isolated acute massive pulmonary embolism. *British medical journal*, 2(5763), 681–684.
20. Russell, C., Keshavamurthy, S., & Saha, S. (2022). Classification and Stratification of Pulmonary Embolisms. *The International journal of angiology : official publication of the International College of Angiology, Inc*, 31(3), 162–165.
21. Frémont B, Pacouret G, Jacobi D, Puglisi R, Charbonnier B, de Labriolle A. (2008). Prognostic value of echocardiographic right/left ventricular end-diastolic diameter ratio in patients with acute pulmonary embolism: results from a monocenter registry of 1,416 patients. *Chest*.;133:358–362.
22. Meinel FG, Nance JW, Schoepf UJ, Hoffmann VS, Thierfelder KM, et al. (2015). Predictive value of computed tomography in acute pulmonary embolism: systematic review and meta-analysis. *Am J Med*.; 128:747–59. e2.
23. Jiménez D, Kopecna D, Tapson V, Briese B, Schreiber D, et al. (2014). Derivation and validation of multimarker prognostication for normotensive patients with acute symptomatic pulmonary embolism. *Am J Respir Crit Care Med*.; 189:718–726.
24. Bock, J. S. (2023). Treating pulmonary embolism with the EKOS™ endovascular system: A clinician's perspective. Endovascular Today.
25. Elder, M., Blank, N., Shemesh, A., Pahuja, M., Kaki, A., et al. (2018). Mechanical Circulatory Support for High-Risk Pulmonary Embolism. *Interventional cardiology clinics*, 7(1), 119–128.
26. Ain, D. L., Albaghdadi, M., Giri, J., Abtahian, F., Jaff, M. R., et al. (2018). Extra-corporeal membrane oxygenation and outcomes in massive pulmonary embolism: Two eras at an urban tertiary care hospital. *Vascular medicine (London, England)*, 23(1), 60–64.
27. DeFilippis, E. M., Topkara, V. K., Kirtane, A. J., Takeda, K., Naka, Y., et al. (2022). Mechanical Circulatory Support for Right Ventricular Failure. *Cardiac failure review*, 8, e14.
28. Kucher N, Boekstegers P, Müller OJ, Kupatt C, Beyer-Westendorf J, et al, (2014). controlled trial of ultrasound-assisted catheter-directed thrombolysis for acute intermediate-risk pulmonary embolism. *Circulation*.;129:479–486.
29. Boston Scientific. (n.d.). EKOS™ Endovascular System.
30. Piazza, G., Hohlfelder, B., Jaff, M. R., Ouriel, K., Engelhardt, T. C., et al. (2015). A Prospective, Single-Arm, Multicenter Trial of Ultrasound-Facilitated, Catheter-Directed, Low-Dose Fibrinolysis for Acute Massive and Submassive Pulmonary Embolism: The SEATTLE II Study. *JACC. Cardiovascular interventions*, 8(10), 1382–1392.
31. Lin, P. H., Annambhotla, S., Bechara, C. F., Athamneh, H., Weakley, S. M., et al. (2009). Comparison of percutaneous ultrasound-accelerated thrombolysis versus catheter-directed thrombolysis in patients with acute massive pulmonary embolism. *Vascular*, 17 Suppl 3, S137–S147.
32. Lauder, L., Pérez Navarro, P., Götzinger, F., Ewen, S., Al Ghorani, H., Haring, B., Lepper, P. M., Kulenthiran, S., Böhm, M., Link, A., Scheller, B., & Mahfoud, F. (2023). Mechanical thrombectomy in intermediate- and high-risk acute pulmonary embolism: hemodynamic outcomes at three months. *Respiratory research*, 24(1), 257.
33. Tu, T., Toma, C., Tapson, V. F., Adams, C., Jaber, W. A., et al. (2019). A prospective, single-arm, multicenter trial of catheter-directed mechanical thrombectomy for intermediate-risk acute pulmonary embolism: The FLARE study. *JACC: Cardiovascular Interventions*, 12(9), 859–869.
34. Jaber, W. A., Gonsalves, C. F., Stortecky, S., Horr, S., Pappas, O., et al. (2025). Large bore mechanical thrombectomy versus catheter directed thrombolysis in the management of intermediate risk pulmonary embolism: Primary results of the PEERLESS randomized controlled trial. *Circulation*, 151(5), 260–273.
35. Goldhaber SZ, Come PC, Lee RT, Braunwald E, Parker JA, et al. (1993). Alteplase versus heparin in acute pulmonary embolism: randomised trial assessing right-ventricular function and pulmonary perfusion. *Lancet*.; 341: 507–511.
36. U.S. Food and Drug Administration. (2015). Activase (alteplase) prescribing information.
37. Meyer, G., Vicaut, E., Danays, T., Agnelli, G., Becattini, C., et al. (2014). Fibrinolysis for patients with intermediate risk pulmonary embolism. *The New England Journal of Medicine*, 370(15), 1402–1411.
38. de Perrot, M., Mai, G., & Raphael, J. (2024). Circulatory extracorporeal membrane oxygenation support for high risk pulmonary embolism. *Journal of Pulmonary Circulation* (in press).
39. Oude Lansink-Hartgring A, van Minnen O, Vermeulen KM, van den Bergh WM (2021). Dutch Extracorporeal Life Support

Study Group. Hospital Costs of Extracorporeal Membrane Oxygenation in Adults: A Systematic Review. *Pharmacoecon Open*.;5(4):613-623.
40. Aujesky, D., Roy, P. M., Verschuren, F., Righini, M., Osterwalder, J., et al. (2011). Outpatient versus inpatient treatment for patients with acute pulmonary embolism: an international, open-label, randomised, non-inferiority trial. *Lancet (London, England),* 378(9785), 41–48.
41. Stein PD, Kayali F, Olson RE. (2004). Twenty-one-year trends in the use of inferior vena cava filters. *Arch Intern Med*; 164: 1541–1545.
42. Jaff MR, Goldhaber SZ, Tapson VF. (2005). High utilization rate of vena cava filters in deep vein thrombosis. *Thromb Haemost*.; 93: 1117–1119.
43. Muneeb A, Dhamoon AS. (2025). Inferior Vena Cava Filter. [Updated 2023 Aug 8]. In: StatPearls [Internet]. Treasure Island (FL): *StatPearls Publishing*
44. Franchin, L., & Iannaccone, M. (2025). Limitations and Future Perspectives on Pulmonary Embolism: So Far, So Good. Interventional cardiology (London, England), 20, e11.
45. Klok, F. A., Konstantinides, S. V., Jaff, M. R., Rosenfield, K., Barco, S., Sista, A., … Boston Scientific Clinical Study Group. (2022). Ultrasound-facilitated, catheter directed thrombolysis versus anticoagulation alone for acute intermediate–high risk pulmonary embolism: Rationale and design of the HI PEITHO study. *American Heart Journal*, 251, 43–53.

DOI:10.31579/2690-1919/563