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Review of Different Scoring Systems in Assessing the Clinical Probability of Pulmonary Embolism

Ajala Aisha Oluwabunmi [a*] and Negedu John [b]

[a] Department of Internal Medicine University of Port Harcourt Teaching Hospital, Port Harcourt, Nigeria.
[b] China Medical University, Liaoning province, China.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Pulmonary embolism remains to be fatal and measures should therefore be taken early enough. It remains one of the most challenging diagnoses in emergency medicine. A mini-review of the scoring criteria for pulmonary embolism in clinical assessments was carried out. The five strategies discussed include; the revised Wells' criteria, the revised Geneva score, the YEAR algorithm for pulmonary embolism, Pulmonary Embolism Rule Out Criteria and 4-Level Pulmonary Embolism Clinical Probability Score (4PEPS) All these strategies have advantages and disadvantages. They are also best applicable in different situations. Considering that PE is fatal, these methods are all crucial in determining the probability of PE. Doctors should be able to think through each individual patient.

Keywords: Pulmonary embolism; testing criteria; 4PEPS.

**Corresponding author: E-mail: ajalabunmi@gmail.com;*

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1. INTRODUCTION

Acute pulmonary embolism (PE) constitutes one of the “big three” cardiovascular killers, along with myocardial infarction and stroke. “Pulmonary Embolism accounts for several hundred thousand deaths annually in the United States and afflicts millions of individuals worldwide. The case fatality rate for PE is approximately 15% and this exceeds the mortality rate for acute myocardial infarction” [1]. “Pulmonary Embolism is the leading cause of lost disability-adjusted life-years [DALYs] lost in low- and middle-income countries and the second leading cause in high-income countries. A recent study involving 35.4 million hospitalized patients [>48 hours] found that more than half of hospitalized patients are at risk of VTE development” [2]. “The true incidence of PE remains unknown as sudden death before clinical presentation is common [up to 25%] and nearly half of all cases are not diagnosed” [3]. “Historically, the gold standard of diagnosis was pulmonary angiography but this was associated with a 6.5% rate of adverse events including 0.2% chance of death, leading to the development of less-invasive testing” [4]. “Multi-detector CT Pulmonary Angiogram or Ventilation/perfusion scanning are therefore warranted to confirm the diagnosis but the issue of costs, exposure to radiation, risk of contrast-induced nephropathy, over-diagnosis and lack of availability in resource poor setting make them less desirable as a first line test. This has led to the recommendation to start the diagnostic management of suspected acute PE with Clinical Pre-test probability tests” [5]. Clinical probability assessment has become a keystone of the PE diagnostic process, It is the first step of the currently recommended diagnostic strategies with a view to rule out PE with confidence in case of a negative test. Several clinical probability tests have therefore been proposed to reduce PE over-testing and overdiagnosis. This article aims to review the different scoring systems for determining the pre-test probability for pulmonary embolism.

2. REVISED WELLS CRITERIA

“The Revised Wells Criteria provides a pre-test probability of PE” [6]. “It is the most widely used pre-test probability score in testing PE. The Wells score include six explicit criteria and one subjective criterion” [7]. A wells score reflects the risk of developing PE and is calculated based on various factors. Some of these factors include; Clinical symptoms of DVT (leg swelling, pain with palpation), other diagnosis less likely than pulmonary embolism, heart rate >100, immobilization (≥3 days) or surgery in the previous four weeks previous DVT/PE, haemoptysis and malignancy. Each of these symptoms and risk factors is assigned a point value. The doctor adds up the points and uses the final score to decide whether they will proceed with further diagnostic testing.

In the two -tier model: If considered unlikely, a negative D-dimer rule is applied to rule out PE, if it is likely, a CTPA should be considered. In a three- tier model, the pulmonary embolism rule-out criteria 9PERC) or a D-dimer can be considered for low-risk patients, for moderate risk one may consider a CT pulmonary angiography or a D-dimer, and for a high risk, D-dimer is not recommended. “The performances of the original and simplified Wells scores were compared in six prospective outcome studies and both scores were found to have similar performances in the diagnostic management of patients with clinically suspected acute PE when combined with quantitative age-adjusted D-dimer testing. The age-adjusted D-dimer positivity threshold defined as a patient's age multiplied by 10 µg/L in those aged ≥ 51 years” [8].

Table 1. Original and simplified Wells criteria

Variable	Original	Simplified
Clinical symptoms of DVT (leg swelling, pain with palpation)	3.0	1.0
Other diagnosis less likely than pulmonary embolism	3.0	1.0
Heart rate > 100	1.5	1.0
Immobilization (≥3 days) or surgery in the previous four weeks	1.5	1.0
Previous DVT/PE	1.5	1.0
Haemoptysis	1.0	1.0
Malignancy	1.0	1.0

Table 2. Two-tier or three-tier for interpretation of the Wells' score

Probability	Score
Three tier model clinical probability assessment [Wells criteria]	
High	>6.0
Moderate	2.0 to 6.0
Low	<2.0
Two tier clinical probability assessment (Wells criteria)	
PE likely	>4.0
PE unlikely	≤4.0
Simplified Wells Criteria	
PE likely	>1.0
PE unlikely	≤1.0

In the revised Wells criteria, a clinician decides whether an individual is more likely to have an alternative diagnosis. The ability to predict the probability of PE using this technique can help clinicians treat the disease before it worsens and helps patients live healthy lives [9]. PE has proven to be fatal meaning that it is best to detect it early enough and effectively treat it so as to reduce comorbidities. Wells' criteria can be applied in primary care centres where there is negligible availability of radiological tools. Therefore, it is an effective tool in conducting diagnosis of poor patients in less inaccessible areas. The rules of Wells' Criteria perform well in younger patients who do not have comorbidities or history of venous thromboembolism [10]. "Wells' criteria have a moderate to substantial interrater agreement and also indicates a reliable risk stratify pretest probability in patients suspected to have pulmonary embolism" [11].

Considering that the Wells' score is dependent on prediction based on a patient's information, its accuracy may be affected if the patient's history and symptoms are not accurately recorded [12]. The fact that Wells' criteria requires further diagnostic tests to be conducted to confirm the diagnosis confirms its ineffectiveness [9]. "A physician has to determine whether an alternative diagnosis is more likely than PE. This makes it subjective meaning that it cannot be standardized. The predictive value of this criterion is primarily based on its subjective component" [13].Therefore, it cannot be termed as fully reliable. Also, beginning prophylactic treatments early could risk a patient having adverse effects. The Wells' score is not effective in diagnosing PE among pregnant and postpartum population[14]. The Wells score should not be used among patients with dyspnoea or chest pain. One must first have a clinical suspicion of PE.

3. REVISED GENEVA SCORE

"The Revised Geneva Score is a clinical prediction rule which determines the probability test of PE based on a patient's factors. Like the revised Wells' criteria, the revised Geneva score applies prediction rule in the diagnosis of pulmonary embolism" [15]. "The two clinical decision rules are the best validated and therefore the most used. It is a simple score that is entirely based on clinical variables and does not include a physician's implicit judgement"[16]. The Geneva score is based on eight objective variables. They include; age older than 65 years, previous deep venous thrombosis or pulmonary embolism, surgery or fracture within a month, active malignant condition, unilateral lower limb pain, haemoptysis, heart rate of 75 to 94 beats/min or 95 beats/min or more, and pain on lower-limb deep venous palpation and unilateral edema. Each point is given points based on a patient.

"The scores obtained on each factor relate to the probability of PE. It is either, low, intermediate or high. The probabilities are then used to determine the need for and nature of further diagnostic measures such as D-dimer, CT pulmonary angiography or ventilation/perfusion scanning, to confirm or exclude PE. The diagnostic accuracy of the 2 versions of the Geneva score has been evaluated and implies that simplification of the revised Geneva score does not lead to a decrease in diagnostic accuracy and clinical utility" [17]. "Utilizing the simplified Geneva score, the likelihood of a patient having PE with a score of less than 2 and a normal D-dimer is 3%" [18].

Table 3. The Geneva score criteria

Variable	Revised	Simplified
Age >65 years	1	1
Previous DVT or PE	3	1
Surgery [under general anaesthesia] or fracture [of the lower limbs] within 1month	2	1
Active malignant condition [solid or hematologic, currently active or considered cured <1 year]	2	1
Unilateral lower-limb pain	3	1
Hemoptysis	2	1
Heart rate 75–94 beats min^{-1}	3	1
Heart rate >94 beats min^{-1}	5	2

Table 4. Interpretation of the Geneva score using a two-tier or three-tier model

Clinical Probability	Original Geneva Score	Simplified Geneva Score
Three-tier model		
Low	0 – 3 [8%]	0 - 1
Intermediate	4 -10 [29%]	2 -4
High	≥ 11 [74%]	≥ 5
Two-tier model		
PE likely	0 -5	0-2
PE unlikely	≥6	≥3

"The Geneva score criteria incudes four variables that are not included in the wells rule. They include; age over 65 years, unilateral lower-limb pain, heart rate 75–94 beats per minute or more than 94 beats per minute, and pain on lower-limb deep venous palpation and unilateral edema. It is therefore completely explicit. A study by Le Gal et al. confirmed that the revised Geneva score is entirely standardized and is based on major clinical variables" [16]. Therefore, unlike the revised wells criteria, this technique is based on clinical variables and not a clinician's judgement. It is considered relevant and easy to compute. The diagnosis of PE during pregnancy could be challenging [19]. This is because its symptoms mimic those of pregnancy [shortness of breath, chest pain, tachycardia]. Like Wells' score, the revised Geneva score has limited use in testing PE among pregnant women.

4. YEARS ALGORITHM FOR PULMONARY EMBOLISM

The YEARS algorithm was developed to increase the results of non-invasive testing among non-pregnant patients [20]. It incorporates differential D-dimer cut-off values and it is designed to be fast. And compatible with clinical practice. The YEARS algorithm measures three main variables of the wells score [clinical signs of deep vein thrombosis [DVT], haemoptysis, and PE most likely diagnosis] which are used along with differential D-dimer cut off values [21]. The three variables are also referred to as the YEARS items. The Fig. 1 shows the YEARS diagnostic algorithm.

Unlike the Wells score, the YEARS score can be easily remembered because it only has three items [22]. In the case where there are no YEARS items, a D-dimer threshold of 1000 ng/ml can be used to exclude PE. When there are one or more YEARS items, a D-dimer threshold of 500 ng/ml is used. Van der Pol et al. conducted a study to determine whether the YEARS diagnostic algorithm is associated with shorter visits to the emergency department and any associated cost savings. They determine that the YEARS algorithm was mainly designed to help simplify the diagnostic workup of suspected PE. It was associated with a shorter time visit to the emergency department. The authors add that the strategy enabled the treatment of PE 53 minutes earlier [23].

Unlike most methods, the YEARS algorithm is considered reliable in excluding PE among pregnant patients [24]. It reduces the application of reduce the use of computed tomography pulmonary angiography [CTPA]. In the study conducted by Langlois et al., the YEARS algorithm safely excluded PE without exposing them to radiation. Out of the 371 women

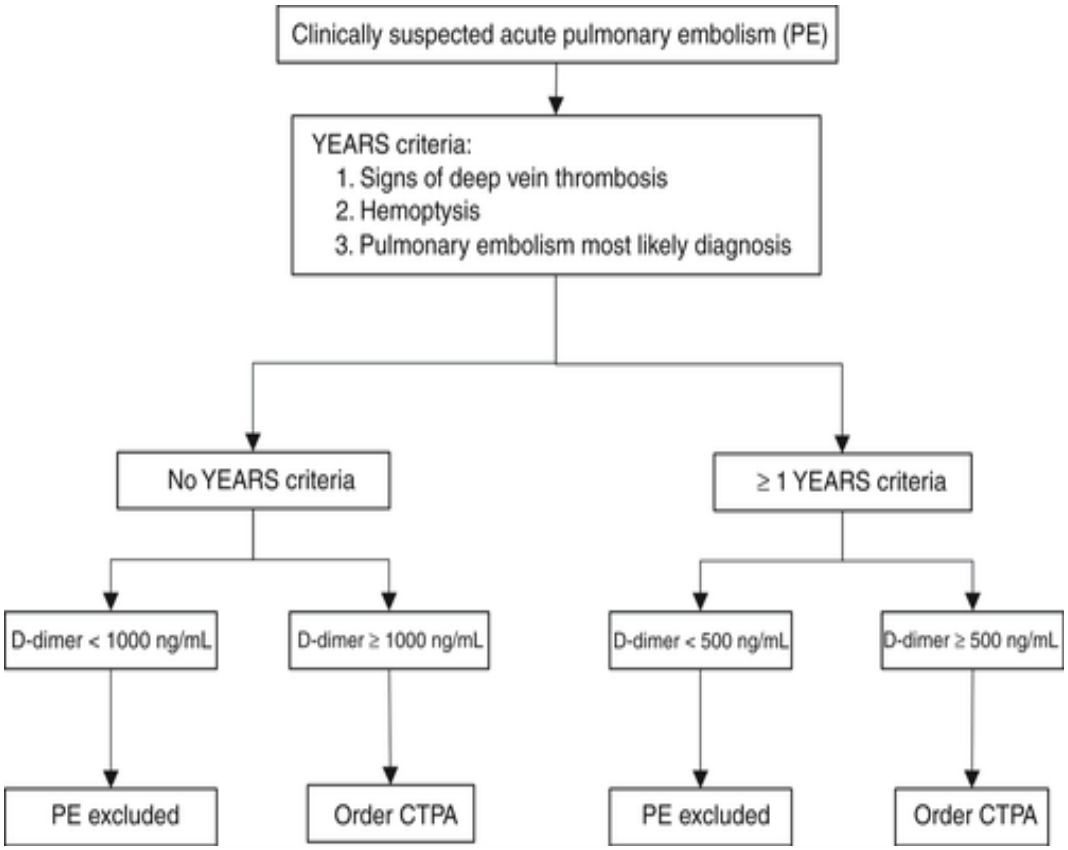

Fig. 1. YEARS diagnostic algorithm

involved, 6.5% had PE and the YEARS algorithm didn't miss. The YEARS algorithm is more efficient and less complex when compared to other tools used in diagnosing PE. This makes it more useful in clinical practice [24]. Luu et al, conducted a systematic study to identify the role of YEAR algorithm in excluding PE among patients suspected to have COVID-19 [25]. The authors noted the importance of having a PE diagnosis as soon as possible to avoid further respiratory deterioration. All patients were screened based on the YEARS algorithm and they managed to rule out PE in over 25% of the total number of patients who were screened. The authors concluded that the YEARS algorithm is a feasible approach in ensuring early detection of PE to reduces morbidity and mortality rates among COVID-19 patients.

5. PERC RULE OUT CRITERIA [PULMONARY EMBOLISM RULE OUT CRITERIA]

This criterion is mainly prescribed if a patient is at low risk [10]. This is mainly due to its high sensitivity and a low negative likelihood ratio [26]. It follows eight objective criteria to determine the possibility of PE. These variables include; younger than 50 years, pulse <100 beats/min, SaO_2 >94%, no previous venous thromboembolism, no recent surgery, no unilateral limb swelling, no haemoptysis, and no estrogen use. These eight criteria help in the identifying people at low risk whose further testing could be associated with an unfavourable risk benefit ratio [27].

In the PERC rule, all variables must get a "no" for the test to be considered negative. When the score is zero, there is no need for further workup since the chance of their being PE is less than 2%. However, if only one variable is positive, the diagnosis of PE cannot be ruled out. And the diagnostic process must continue. The strategy is not meant for risk stratification. A patient is considered to be low risk if their pre-test probability is less than the test threshold for pulmonary embolism [28]. Patients with a pre-test probability that is lower than the test threshold should not be subjected to further diagnostic testing. They may even be harmed in the process.

Table 5. Perc rule out criteria

Variable	Absent	Present
Age > 50 years	No (0)	+ 1 point
Heart rate > 100	No (0)	+ 1 point
SaO2 < 95%	No (0)	+ 1 point
Unilateral leg swelling	No (0)	+ 1 point
Hemoptysis	No (0)	+ 1 point
Recent trauma or surgery	No (0)	+ 1 point
History of PE or DVT	No (0)	+ 1 point
No estrogen use	No (0)	+ 1 point

Table 6. The 4-level pulmonary embolism clinical probability score (4PEPS)

Variable		Points
Age, years	<50	-2
	50-64	-1
	>64	0
Sex	Female	0
	Male	2
Chronic respiratory disease	No	0
	Yes	-1
Heart rate <80	No	0
	Yes	-1
Chest pain AND acute dyspnoea	No	0
	Yes	1
Current estrogen use	No	0
	Yes	2
Prior history of VTE	No	0
	Yes	2
Syncope	No	0
	Yes	2
Immobility within the last four weeks*	No	0
	Yes	2
O_2 saturation <95%	No	0
	Yes	3
Calf pain and/or unilateral lower limb edema	No	0
	Yes	3
PE is the most likely diagnosis	No	0
	Yes	5

Table 7. interpreting the 4-level pulmonary embolism clinical probability score [4PEPS]

4PEPS Score for PE	Clinical probability of PE	PE diagnosis
<0	Very low CPP (<2%)	PE can be ruled out
0-5	Low CPP (2-20%)	PE can be ruled out if D-dimer level <1.0 µg/mL
6-12	Moderate CPP (20-65%)	PE can be ruled out if D-dimer level <0.5 µg/mL OR < [age x 0.01] µg/mL
≥13	High CPP (>65%)	PE cannot be ruled out without imaging testing

The application of the PERC rule requires a clinical suspicion of less than 15%. It can therefore be excluded if that is not the case or when the eight criteria are not met. Also, patients with the following characteristics should not be subjected to the PERC rule; known thrombophilia, transient tachycardia, strong family history of thrombosis, massively obese

patients in whom unilateral leg swelling could not be assessed, concurrent beta-blocker use [could blunt reflex tachycardia], patients with amputations, and Patients with baseline SaO2 of < 95% [29].

The application of PERC can be considered as a way of reducing irradiative imaging studies, decrease the length of stay in emergency departments adverse effects that result from diagnostic and intervention measures [29]. The Pulmonary Embolism Rule-out Criteria is without doubt an effective strategy whose usefulness has been demonstrated in various observational studies. However, inadequate prospective randomized trials have prevented its adoption. Kline et al. conducted a study on the application of PERC rule among children being evaluated for pulmonary embolism. They noted that PERC predicts a low probability of PE among adults [28]. They examine the accuracy in previous tests done using the PERC rule on children. Based on their study, the authors determined that the PERC rule was negative in 31%. The tests also indicated good diagnostic accuracy in general.

Hugli et al. conducted a study aimed at validating the application of the PERC rule alone to exclude PE without further testing [30]. The authors also considered a combination of the PERC rule and the revised Geneva score. Based on their findings, the PERC rule cannot safely rule out PE without conducting additional testing. This is the case even when the strategy is combined with the revised Geneva score. The PERC rule out criteria is considered inadequate in pregnancy [31] and postpartum status. It is more likely to miss small and distal PE. Despite being widely used, and considered safe, the validity of the PERC rule is still controversial. For example, European physicians have been reluctant to apply the rule in excluding PE among patients [32]. Kline et al conducted a study from which they reported that the PERC rule [combined with a low clinical probability assesses by physician's gestalt] was safe to be applied even in Europe.

6. 4-LEVEL PULMONARY EMBOLISM CLINICAL PROBABILITY SCORE (4PEPS)

The 4-level pulmonary embolism clinical probability score (4PEPS) is used to rule out PE based on clinical criteria and optimized D-dimer measurements. This means that this technique helps decrease image testing for suspected PE in patients. The 4PEPS was devised to validate a pre-test probability score that would safely reduce imaging testing by combining the previous strategies [33].

Roy et al. conducted a study to derive and validate a new 4-level pre-test probability rule (4-Level Pulmonary Embolism Clinical Probability Score, 4PEP). Based on their results, it was clear that the 4PEPS strategy leads to a significant and safe reduction in image testing among patients with suspected PE. The authors note that several strategies [wells score, revised Geneva score, Pulmonary Embolism Rule-out Criteria (PERC) and YEARS algorithm] have been proposed to aid the reduction PE over testing and overdiagnosis [33]. They have been successful in ensuring safety and efficacy. However, these strategies are based on different models in assessing clinical pretest probability. This means that it is hard to combine them hence risking their misuse in clinical practice. 4PEPS is an integration of the four methods. The authors aim to determine the efficacy of the new strategy. They determined that the application of 4PEPS leads to a reduction in diagnostic failure and a reduction in imaging testing.

7. CONCLUSION

Pulmonary embolism remains to be fatal and measures should therefore be taken early enough. It remains one of the most challenging diagnoses in emergency medicine. It may also be quite elusive. The five strategies discussed include; the revised Wells' criteria, the revised Geneva score, the YEAR algorithm for pulmonary embolism, Pulmonary Embolism Rule Out Criteria and 4-Level Pulmonary Embolism Clinical Probability Score (4PEPS) All these strategies have advantages and disadvantages. They are also best applicable in different situations. Considering that PE is fatal, these methods are all crucial in determining the probability of PE. The application of these tools does not mean that one should conduct further diagnostic testing. For example, a positive PERC does not necessarily mean that one should order a D-dimer. A high-risk score on the Wells' tool does not mean that one must conduct a CTPA. Doctors should be able to think through each individual patient. With these tools, they could find a balance on PE.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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