

Diagnostic Performance and Clinical Significance of Wells and PERC Scores in Pulmonary Embolism

✉ Efe Kanter¹, ✉ Elif Eryurt Öz E, ✉ Mehmet Göktuğ Efgan¹, ✉ Ecem Ermete Güler¹, ✉ Burak Acar², ✉ Uğur Tavşanoğlu³

¹Department of Emergency Medicine, İzmir Katip Çelebi University Faculty of Medicine, İzmir, Türkiye

²Department of Emergency Medicine, Adıyaman University Training and Research Hospital, Adıyaman, Türkiye

³Department of Emergency Medicine, University of Health Sciences, İstanbul Kanuni Sultan Süleyman Training and Research Hospital, İstanbul, Türkiye

ABSTRACT

Objective: Pulmonary embolism (PE) is a life-threatening emergency requiring rapid diagnosis. This study evaluates the diagnostic performance and distribution of the Wells score and Pulmonary Embolism Rule-Out Criteria (PERC) among emergency department (ED) patients who underwent computed tomography pulmonary angiography (CTPA) for suspected pulmonary embolism (PE), and examines how often confirmed PE occurred in patients classified as low risk by these tools.

Materials and Methods: We conducted a retrospective observational study in the emergency department of a tertiary hospital. Adult patients (≥ 18 years) who underwent computed tomography pulmonary angiography (CTPA) for suspected PE between January and December 2023 and in whom Wells and PERC scores could be retrospectively calculated were included. Diagnostic accuracy was analyzed using receiver operating characteristic (ROC) curves. Since the cohort includes only imaged patients, results apply specifically to CTPA-selected populations.

Results: We included 299 patients, with a mean age of 67.4 ± 16.1 years; 96 (32.1%) had confirmed PE. Among PE-positive cases, 7 (7.3%) had a PERC score of 0, and 42 (43.8%) had Wells < 2 ; 7.3% were low risk by the rules. Wells (2.91 ± 2.21 vs. 1.09 ± 1.48) and PERC (1.60 ± 1.17 vs. 0.82 ± 0.85) scores were significantly higher in PE-positive than PE-negative patients ($p < 0.001$). ROC analysis showed AUC 0.771 for Wells and 0.711 for PERC. Negative predictive values were 89.3% (Wells) and 91.2% (PERC). Higher scores correlated with worse outcomes, including ICU admission and mortality ($p < 0.001$).

Conclusion: Important PEs occurred even in patients classified as low risk, indicating these scores should support but not replace clinical judgment.

Keywords: Diagnostic accuracy, PERC score, pulmonary embolism, Wells score

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INTRODUCTION

Pulmonary embolism (PE) is a life-threatening cardiovascular emergency that often presents with acute dyspnea, chest pain, or hemodynamic instability. Early diagnosis and timely treatment are essential to improve outcomes.^[1,2] Computed tomography pulmonary angiography (CTPA) is the gold standard for diagnosis, but its universal use is limited by radiation exposure, contrast-induced nephropathy, and healthcare costs.^[3,4]

To overcome these challenges, clinical decision rules have been introduced to estimate pre-test probability and guide diagnostic strategies. The Wells score stratifies patients into low, intermediate, and high probability categories based on clinical features and physician judgment. The pulmonary embolism rule-out criteria (PERC), in contrast, is an eight-item checklist designed to exclude PE in patients already considered to be at low risk.^[5-7]

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Address for Correspondence: Uğur Tavşanoğlu, Department of Emergency Medicine, University of Health Sciences, İstanbul Kanuni Sultan Süleyman Training and Research Hospital, İstanbul, Türkiye
E-mail: ugurtavsanoglu@gmail.com **ORCID ID:** 0000-0001-9832-0237

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Although both scores are widely applied, their reliability in real-world emergency department practice remains debated.^[5] Several studies have shown that PE may still occur in patients with a PERC score of zero or a Wells score below two, raising concerns about their absolute safety in excluding the disease.^[5,6,8]

This study aims to assess the diagnostic accuracy of the Wells and PERC scores in a tertiary emergency department. We specifically examine how many patients with confirmed PE would have been misclassified as low risk by these tools. In addition, we investigate whether higher scores correlate with worse clinical outcomes, exploring their potential prognostic as well as diagnostic utility.

MATERIALS and METHODS

Study Design and Setting

This retrospective observational study was conducted in the emergency department (ED) of a tertiary-level academic hospital in Turkey. The ED serves a large urban population and has 24/7 access to advanced imaging modalities and subspecialty consultation. Ethics approval was obtained from the İzmir Katip Çelebi University Clinical Research Ethics Committee (Approval No: 0433, Date: 21.09.2023). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Study Population

The study population consisted of adult patients (≥ 18 years) who presented to the emergency department with clinical suspicion of pulmonary embolism and underwent computed tomography pulmonary angiography (CTPA) for definitive evaluation. Patients were included only if sufficient clinical data were available to retrospectively calculate both Wells and PERC scores. Exclusion criteria were incomplete medical records that prevented score calculation, transfer to another healthcare facility before the diagnostic workup was completed, or loss to follow-up before confirmation of PE status.

Study Protocol

Patients were evaluated per routine ED practice for suspected PE. The decision to obtain CTPA was made by the treating physicians based on clinical assessment and local protocols (symptoms, vital signs, risk factors, pre-test probability, and D-dimer). CTPA served as the reference standard for PE confirmation. Imaging was performed using a multislice CT scanner with intravenous iodinated contrast according to departmental protocols; reports were issued by board-certified radiologists blinded to any retrospective score calculations.

For analysis, Wells and PERC items were abstracted retrospectively from the index ED encounter and scored as originally described. Wells categories were defined as low (<2), intermediate (2–6), and high (>6). PERC was treated two ways: (i) binary rule-out (PERC=0 vs. ≥ 1) and (ii) count of positive items (0–8) for discrimination analyses. If a score component was undocumented, it was considered absent only when clinically implausible to be positive; otherwise, the case was labeled missing for that item and excluded from score calculation.

Clinical outcomes (ED discharge, ward admission, ICU admission, in-hospital death) were assigned from the index hospitalization. No changes to clinical care pathways were introduced by the study.

Data Collection

Data were retrospectively obtained from the hospital's electronic health record system. A standardized abstraction form was used to ensure consistency. Extracted variables included demographic information (age, sex), presenting symptoms (dyspnea, chest pain, syncope), and vital signs at triage, as well as all components required to calculate Wells and PERC scores. Imaging results from CTPA were reviewed to confirm or exclude pulmonary embolism. Clinical outcomes were recorded as discharge from the ED, hospital ward admission, ICU admission, or in-hospital mortality. All data were cross-checked by two independent reviewers to minimize abstraction errors.

Statistical Analysis

All analyses were performed using SPSS version 24.0 (IBM Corp., Armonk, NY, USA). Normality of continuous variables was assessed with the Shapiro–Wilk test. Continuous variables were compared using the Student's t-test or Mann–Whitney U test, depending on distribution. Categorical variables were analyzed with the Chi-square test.

Diagnostic accuracy of the Wells and PERC scores was evaluated by receiver operating characteristic (ROC) curve analysis, with calculation of the area under the curve (AUC) and 95% confidence intervals. For ROC analysis, Wells was treated as a continuous score, while PERC was analyzed both as a binary rule (0 vs. ≥ 1) and as a cumulative score (0–8 items). Optimal cutoff values were determined using the Youden index. Positive predictive value (PPV) and negative predictive value (NPV) were also reported.

The relationship between higher scores and clinical outcomes was tested using Spearman's rank correlation. A two-sided p-value <0.05 was considered statistically significant.

Table 1. Descriptive characteristics of the study population

Parameter	Value	
	n	%
Age (mean±SD)	67.4±16.1	
Pulmonary embolism ratio	96	32.1
Wells score (mean±SD)	1.68±1.94	
Wells subgroup		
<2	210	70.2
2–6	80	26.8
>6	9	3.0
PERC =0	80	26.8
PERC ≥1	219	73.2

SD: Standard deviation; PERC: Pulmonary embolism rule-out criteria

Table 2. Distribution of scores among patients diagnosed with pulmonary embolism

Subgroup	n	%
PERC =0	7/96	7.3
Wells <2	42/96	43.8
PERC =0 and Wells <2 combined	7/96	7.3

Table 3. Comparison of score averages between PE positive and negative groups

Score	PE positive (mean±SD)	PE negative (mean±SD)
Wells score	2.91±2.21	1.09±1.48
PERC score	1.60±1.17	0.82±0.85

PE: Pulmonary embolism

Table 4. ROC analysis of Wells and PERC scores for PE diagnosis

Value	Cut-off	AUC	SE	Youden Index J	p	PPV (%)	NPV (%)	95% CI		Sensitivity	Specificity
								Lower limit	Upper limit		
Wells	1.50	0.771	0.032	0.430	<0.001	48.8	89.3	0.710	0.835	0.84	0.58
PERC	1.00	0.711	0.025	0.286	<0.001	40.6	91.2	0.664	0.763	0.93	0.36

ROC: Receiver operating characteristic; PERC: Pulmonary embolism rule-out criteria; PE: Pulmonary embolism; AUC: Area under curve; SE: Standard error; PPV: Positive predictive value; NPV: Negative predictive value; CI: Confidence interval

RESULTS

A total of 299 patients were included in the analysis. The mean age was 67.4±16.1 years, and pulmonary embolism was confirmed in 96 patients (32.1%). The mean Wells score of the study population was 1.68±1.94. When stratified by Wells subgroups, 70.2% were in the low-risk category (<2), 26.8% in the intermediate-risk group (2–6), and 3.0% in the high-risk group (>6). Overall, 26.8% of patients had a PERC score of 0, while 73.2% had a PERC score ≥1 (Table 1).

Among patients with confirmed PE, 7.3% had a PERC score of 0, and 43.8% had a Wells score <2. The proportion of patients with both PERC =0 and Wells <2 was 7.3% of the PE-positive group (Table 2).

As shown in Table 3, the mean Wells score was significantly higher in patients with PE compared to those without (2.91±2.21 vs. 1.09±1.48, $p<0.001$). Similarly, the mean PERC score was higher among PE-positive patients (1.60±1.17 vs. 0.82±0.85, $p<0.001$).

Diagnostic accuracy analysis demonstrated that the Wells score had an AUC of 0.771 (95% CI: 0.710–0.835, SE =0.032), with an optimal cutoff of 1.50. At this threshold, sensitivity was 0.84, specificity 0.58, PPV 48.8%, and NPV 89.3%. The PERC score yielded an AUC of 0.711 (95% CI: 0.664–0.763, SE =0.025), with an optimal cutoff of 1.00, corresponding to a sensitivity of 0.93, specificity 0.36, PPV 40.6%, and NPV 91.2% (Table 4). The ROC curves for both scores are presented in Figure 1.

When clinical outcomes were considered, patients who were discharged had mean Wells and PERC scores of 0.90±1.24 and 0.60±0.63, respectively. Patients admitted to the ward had mean Wells and PERC scores of 2.00±1.99 and 1.38±1.06, while those admitted to the ICU had mean scores of 2.35±2.34 and 1.32±1.15. Deceased patients had the highest mean scores, with Wells at 3.14±1.91 and PERC at 2.14±1.57. Both associations were statistically significant ($p<0.001$) (Table 5).

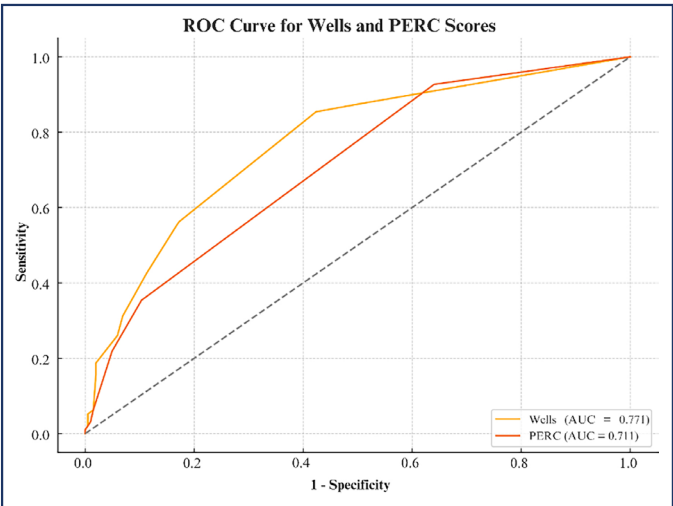


Figure 1. ROC curve for wells and PERC scores
The ROC curve demonstrates the diagnostic performance of the Wells and PERC scores in predicting pulmonary embolism. The Wells score shows an AUC of 0.771, while the PERC score shows an AUC of 0.711. ROC: Receiver operating characteristic; PERC: Pulmonary embolism rule-out criteria; AUC: Area under curve

DISCUSSION

In this single-center ED cohort, we found that both Wells and PERC achieved respectable discrimination (AUC 0.771 and 0.711, respectively) and high NPVs, yet a non-trivial fraction of PE cases fell into categories typically regarded as “low risk.” Notably, 7.3% of PE-positive patients were PERC-negative, and 43.8% had Wells <2, with 7.3% meeting both thresholds. These data underscore that clinical decision rules (CDRs) should inform, but not replace, physician judgment, particularly in older or comorbid patients. Importantly, these findings reflect performance within a CTPA-selected cohort and should not be generalized to all patients presenting with suspected PE.

Our results align with, yet are more conservative than, classic validation work showing that PERC can be safe when it is applied strictly to truly low-risk patients. In the PROPER randomized trial, a PERC-based strategy in low-risk ED patients was non-inferior to conventional testing and did not increase 3-month thromboembolic events, supporting selective imaging reduction.^[9] Early prospective, multicenter evaluation likewise demonstrated high sensitivity of the PERC rule when used in its intended context.^[10] However, because PERC is explicitly designed for very low-risk patients before imaging is considered, applying it retrospectively to a higher-risk, already-imaged cohort—such as ours—naturally results in a higher apparent miss rate.

Table 5. Wells and PERC score averages by clinical outcome		
Outcome	Wells score (mean±SD)	PERC score (mean±SD)
Discharged	0.90±1.24	0.60±0.63
Ward	2.00±1.99	1.38±1.06
ICU	2.35±2.34	1.32±1.15
Deceased	3.14±1.91	2.14±1.57
p	<0.001*	<0.001*

*: Analyzed using Spearman rank correlation. PERC: Pulmonary embolism rule-out criteria; SD: Standard deviation; ICU: Intensive care unit

At the same time, several real-world analyses caution that “PERC-negative” does not equal “PE impossible.” In UK and European contexts, retrospective validations have reported meaningful miss rates among PERC-negative patients adjudged “PE unlikely,” with one study estimating that PERC may still miss ~8% in such cohorts^[11] and another finding that combining Wells <2 with PERC =0 did not eliminate events.^[8] Our finding that 7.3% of confirmed PE cases were PERC-negative is consistent with this more cautious view when selection is imperfect or baseline risk is higher.^[8,11] This further reinforces that low scores reduce—but do not eliminate—the likelihood of clinically important PE.

Wells performed better than PERC for discrimination in our dataset, which echoes the broader literature: Wells formalizes pre-test probability and has repeatedly shown robust performance across risk strata, especially when coupled to D-dimer strategies.^[12,13] Yet, its partially subjective “gestalt” element introduces inter-clinician variability, an issue that may be amplified in older patients or those with atypical presentations, as in our cohort.^[12,13] Even so, our findings indicate that neither Wells nor PERC, when used alone, can safely exclude PE in all patients who undergo CTPA.

A practical way to limit imaging without sacrificing safety is to combine clinical probability with D-dimer thresholds that adapt to pre-test probability. The PEGeD approach (probability-adjusted D-dimer) substantially reduces imaging while preserving low failure rates and represents a natural complement to Wells-based triage.^[14] In settings with very low pre-test probability, PERC can still serve as a front-end gatekeeper; if PERC is positive or the clinical probability is not clearly low, probability-adjusted D-dimer strategies are preferable to “CT-first.”^[9,14] Our results support this tiered diagnostic framework, emphasizing that decision rules should function as adjuncts within a broader clinical algorithm rather than as absolute exclusion tools.

Large, real-world datasets also suggest that PERC is safest when applied exactly as intended. In the RIETE registry analysis, PERC is framed as a pathway to exclude PE without D-dimer when pre-test probability is <15%, emphasizing that misapplication outside this envelope can erode performance.^[15] This message resonates with our observation that even “low-risk” labels do not guarantee absence of disease.^[15] Thus, the safest use of PERC is within strictly defined low-risk populations, not within cohorts already selected for imaging, such as ours.

Pandemic-era evidence adds nuance. In a *Journal of Emergency Medicine* study focused on the COVID-19 period, PERC sensitivity and NPV remained high and did not differ significantly by COVID status, but specificity was very low and overall diagnostic concordance with CTPA was limited, cautioning against relying on PERC as a solitary test during viral surges.^[16] Our cohort may mirror such “higher baseline risk” contexts where PERC’s role narrows to a screening adjunct rather than a stand-alone rule-out.^[16] This contextual limitation is important, as pre-test probability shifts dramatically in such populations.

Beyond PERC, COVID-era work evaluating YEARS and age-adjusted Wells thresholds raises further concerns. In a COVID-19 cohort, using AADD-Wells or YEARS would have produced substantial miss rates (11.4% and 7.1%, respectively), and follow-up VTE occurred even after negative CTPA, likely reflecting both rule failure and *de novo* thrombosis in hyperinflammatory states. Mechanistic explanations like local pulmonary thrombosis and persistent coagulopathy help explain why classical algorithms may underperform in this phenotype.^[17] These findings further highlight that clinical rules must be applied within the context of evolving patient physiology and disease patterns.

Finally, syntheses that pair PERC with D-dimer reiterate a practical middle path: PERC can safely avert testing in carefully selected, truly low-risk patients, while probability-adjusted D-dimer and disciplined imaging thresholds help curb overuse elsewhere^[18], dovetailing with results of PROPER^[9] and early PERC validations.^[10] Our findings fit this evidence-based pragmatism: both scores were “good but not perfect,” and their safest use is as guardrails around clinical reasoning, not as absolute gates.^[9,10,18] In acute respiratory distress syndrome, the Berlin definition similarly illustrates how standardized criteria can improve risk stratification and guide ventilatory management in critically ill patients.^[19] Ultimately, our analysis supports a nuanced, clinically integrated use of decision rules—never

as solitary exclusion mechanisms, but as structured aids within a comprehensive diagnostic process.

Study Limitations

As with prior retrospective and single-center analyses, our design risks selection and information bias and may over-represent older or comorbid patients. We did not model biomarker-integrated algorithms (e.g., PEGeD^[14]) directly, and we did not stratify PE by clot burden, which could influence “miss” severity. These constraints mirror caveats frequently noted in the validation literature.^[11–13] Additionally, because our study included only patients who underwent CTPA, the findings cannot be generalized to all emergency department patients presenting with suspected PE.

Clinical Implications

Wells and PERC remain valuable tools for guiding the initial evaluation of suspected PE, but their limitations highlight the need for careful application. Both scores showed high NPVs in our cohort, yet clinically important PEs occurred among patients categorized as low risk. This emphasizes that neither should be used in isolation to exclude PE.

In practice, PERC should be reserved for patients with a clearly low pre-test probability, while Wells can guide risk stratification across a broader spectrum. Integrating these rules with probability-adjusted D-dimer strategies can reduce unnecessary imaging while maintaining safety. In older or comorbid patients, where miss rates are higher, clinical judgment and follow-up remain essential. Pediatric cohorts with cardiovascular system–associated tracheobronchial compression likewise show that complex cardiorespiratory interactions require multimodal, individualized assessment beyond rigid algorithms.^[20]

CONCLUSION

In this real-world ED cohort, both Wells and PERC demonstrated high negative predictive values but failed to completely exclude pulmonary embolism in patients classified as low risk. Importantly, because the cohort consisted only of patients who underwent CTPA, these findings should not be generalized to all patients evaluated for suspected PE. Our findings reinforce that these rules are valuable adjuncts but should not be used as stand-alone exclusion tools, particularly in older or comorbid patients. The safest strategy is to integrate Wells and PERC with probability-adjusted D-dimer thresholds and clinical judgment to achieve diagnostic accuracy while minimizing unnecessary imaging.

Disclosures

Ethics Committee Approval: The study was approved by the İzmir Katip Çelebi University Clinical Research Ethics Committee (No: 0433, Date: 21/09/2023).

Informed Consent: Due to the retrospective design of the study, the requirement for informed consent was waived by the ethics committee.

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