Clinical probability of pulmonary embolism: Comparison of different scoring systems

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Abstract Pulmonary embolism is one of the greatest diagnostic challenges in emergency medicine and clinical probability assessment is a fundamental step in its diagnosis.

Aim: To evaluate the role of estimating clinical probability of pulmonary embolism and to compare between different pre-test probability scoring systems as regards their sensitivity and specificity.

Patients and methods: We used seven scoring systems (original Geneva score, revised Geneva score, simplified Geneva score, Wells score, simplified Wells score, simplified Charlotte rule, Pisa model) to assess the clinical probability of PE in 41 patients with suspected pulmonary embolism for whom the final diagnosis was based on multislice CT pulmonary angiography (CTPA).

Results: Twenty-four patients (58.5%) had pulmonary embolism. The scores with the strongest correlation with the result of CTPA were the Pisa model (P < 0.001) followed by the original Geneva score and the Wells score (P < 0.01). Simplified Wells score had the highest sensitivity (0.92), Pisa model had the highest specificity (0.82) and the highest overall accuracy (0.76).

Conclusion: For most patients, clinical probability assessment is an easy and effective way to decide which patient should undergo further investigations. Among the studied seven scores, the Pisa model has the best correlation with the CTPA results and it has a good sensitivity, specificity, positive and negative predictive values and the highest overall accuracy.

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Introduction

Suspected acute pulmonary embolism (PE) is a common cause for acute hospital attendance and admission. Clinical assessment is necessary to estimate a pre-test probability of PE and determine what (if any) diagnostic testing is required. Clinical assessment may be used in an unstructured manner to generate a pre-test estimate of probability or may be used in a formal clinical probability score to categorize patients into (typically) low, intermediate or high-risk groups [1].
The main challenge in the diagnostic workup of patients with clinically suspected pulmonary embolism is to accurately and rapidly distinguish the approximately 25% of patients who have the disease and require anticoagulant treatment from the 75% who do not [2,3].

Aim

The aim of this study was to evaluate the role of estimating clinical probability of pulmonary embolism and to compare between different pre-test probability scoring systems as regards their sensitivity and specificity.

Patients and methods

The present study included 41 patients with suspected pulmonary embolism admitted to chest department, Menoufiya University hospitals in the period from February 2011 to April 2012. After having an informed consent from the patients, they underwent history taking, clinical examination, radiographic examination of the chest (P-A view), ECG, echocardiography and arterial blood gases. Multislice CT angiography of the chest was used to confirm or exclude the diagnosis of PE.

Different probability scores for pulmonary embolism were calculated for each patient.

*The original Geneva score (Wicki criteria): [4]*

*The revised Geneva score: [5]*

*The simplified Geneva score [6]*

*Wells score: [7]*

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### Table 1 The original Geneva score.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
</tr>
<tr>
<td>60–79 years</td>
<td>1</td>
</tr>
<tr>
<td>80+ years</td>
<td>2</td>
</tr>
<tr>
<td>Previous venous thromboembolism</td>
<td></td>
</tr>
<tr>
<td>Previous DVT or PE</td>
<td>2</td>
</tr>
<tr>
<td>Previous surgery</td>
<td></td>
</tr>
<tr>
<td>Recent surgery within 4 weeks</td>
<td>3</td>
</tr>
<tr>
<td>Heart rate</td>
<td></td>
</tr>
<tr>
<td>Heart rate &gt; 100 beats per minute</td>
<td>1</td>
</tr>
<tr>
<td>$\text{PaCO}_2$ (partial pressure of $\text{CO}_2$ in arterial blood) ≤ 35 mm Hg</td>
<td>2</td>
</tr>
<tr>
<td>35–39 mm Hg</td>
<td>1</td>
</tr>
<tr>
<td>$\text{PaO}_2$ (partial pressure of $\text{O}_2$ in arterial blood) &lt; 49 mm Hg</td>
<td>4</td>
</tr>
<tr>
<td>49–59 mm Hg</td>
<td>3</td>
</tr>
<tr>
<td>60–71 mm Hg</td>
<td>2</td>
</tr>
<tr>
<td>72–82 mm Hg</td>
<td>1</td>
</tr>
<tr>
<td>Chest X-ray findings</td>
<td></td>
</tr>
<tr>
<td>Band atelectasis</td>
<td>1</td>
</tr>
<tr>
<td>Elevation of hemidiaphragm</td>
<td>1</td>
</tr>
</tbody>
</table>

< 5 Points indicates a low probability of PE.

5–8 Points indicates a moderate probability of PE.

> 8 Points indicates a high probability of PE.

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### Table 2 The revised Geneva score.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 65 years or over</td>
<td>1</td>
</tr>
<tr>
<td>Previous DVT or PE</td>
<td>3</td>
</tr>
<tr>
<td>Surgery or fracture within 1 month</td>
<td>2</td>
</tr>
<tr>
<td>Active malignant condition</td>
<td>2</td>
</tr>
<tr>
<td>Unilateral lower limb pain</td>
<td>3</td>
</tr>
<tr>
<td>Haemoptysis</td>
<td>2</td>
</tr>
<tr>
<td>Heart rate 75–94 beats per minute</td>
<td>3</td>
</tr>
<tr>
<td>Heart rate 95 or more beats per minute</td>
<td>5</td>
</tr>
<tr>
<td>Pain on deep palpation of lower limb and unilateral edema</td>
<td>4</td>
</tr>
</tbody>
</table>

0–3 Points indicates low probability.

4–10 Points indicates intermediate probability.

11 Points or more indicates high probability.

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Simplified Wells score [6]

As the simplified Geneva score, the simplified Wells scoring system replaced the weighted scores for each parameter with a 1 point score for each parameter present. PE is considered unlikely if the score is ≤ 1 and is likely if the score is > 1 (Table 1–4).

Simplified Charlotte rule [8]

If any two boxes are checked the patient is considered high risk.

- Age > 50.
- HR > systolic blood pressure (SBP).
- Surgery in the past month.
- Unilateral leg swelling.
- Hemoptysis.
- Unexplained room air pulse oximetry < 95%.

Pisa model: [9]

The model includes 10 variables positively associated with PE and six variables negatively associated with PE. Positive variables are older age (57–67 years, 68–74 years, 75 years and older), male gender, immobilization, history of deep venous thrombosis, sudden onset of dyspnea, chest pain, fainting or syncope, hemoptysis, unilateral leg swelling, and ECG with acute cor pulmonale. Negative variables are history of cardiovascular disease, history of pulmonary disease, orthopnea, fever > 38°C (100.4°F), wheezes, and crackles. Two calculators based on the Pisa model are available online. One calculator model uses chest X-ray findings (Pisa model 1) [10] or [11]. The other model does not need chest X-ray findings (Pisa model 2) (we used this model) [12] or [13], the score is calculated as a percentage and the probability of PE is classified as follows:

- Slight risk if score ≤ 10, moderate risk if score = 11–50, substantial risk if score = 51–80 and high risk if score ≥ 80.

Statistical analysis

Data were analyzed using SPSS 16, Spearman’s correlation was used for non parametric data. Sensitivity is defined as the proportion of patients classified as having PE among those...
with angiographically proven PE. Specificity is the proportion of patients classified as not having PE among those in whom the disease was excluded. Positive predictive value is the proportion of patients with confirmed PE among those classified as having PE. Negative predictive value is the proportion of patients without PE among those classified as not having PE. Accuracy is the proportion of patients truly diagnosed as having PE plus the patients truly diagnosed as not having PE among the total patients.

**Results**

See Table 5–7.

**Discussion**

Diagnosing pulmonary embolism can be difficult. Problems may arise not only because symptoms and signs can be non-specific or occult, but because in assessing the accuracy of any diagnostic test for PE there is no universally accepted reference standard [14]. Both underdiagnosis and overdiagnosis are associated with substantial morbidity and mortality rates. Untreated pulmonary embolism can be fatal [15,16], and overtreatment exposes the patient who does not have pulmonary embolism to an unjustified risk for major bleeding [17]. The BTS guidelines for the management of suspected acute pulmonary embolism in 2003 recommended that all patients with...
possible PE should have clinical probability assessed and documented [18].

So, in this study, we tried to study different clinical probability scores of pulmonary embolism and to assess their role in detection or exclusion of PE. We included 41 patients with suspected acute PE. The final diagnosis as regarding presence or absence of PE was based on the result of multislice CT pulmonary angiography (CTPA). Twenty-four patients (58.5%) had pulmonary embolism and 17 patients (41.5%) had negative multislice CTPA. The BTS guidelines for the management of suspected acute pulmonary embolism in 2003 stated that patients with a good quality negative CTPA do not require further investigation or treatment for PE and they ranked that absence of PE was based on the result of multislice CT pulmonary angiography. We included 41 patients with suspected acute PE. The final diagnosis as regarding presence or absence of PE was based on the result of multislice CT pulmonary angiography (CTPA). Twenty-four patients (58.5%) had pulmonary embolism and 17 patients (41.5%) had negative multislice CTPA. The BTS guidelines for the management of suspected acute pulmonary embolism in 2003 stated that patients with a good quality negative CTPA do not require further investigation or treatment for PE and they ranked that absence of PE was based on the result of multislice CT pulmonary angiography.

We used seven scoring systems to assess the clinical probability of PE in the studied patients. The scores with the strongest correlation with the results of CTPA were the Pisa model (P < 0.001) followed by the original Geneva score and the Wells score (P < 0.01).

The Pisa model was developed from a database of 1100 patients with suspected pulmonary embolism, of whom 440 had the disease confirmed by angiography or autopsy findings. It was validated in an independent sample of 400 patients with suspected pulmonary embolism. Easy-to-use software was developed for computing the clinical probability. The website describes two prediction models for pulmonary embolism that have been developed at the Institute of Clinical Physiology, National Research Council, Pisa, Italy [9,19]. If a chest radiograph is available and the physician is familiar with the interpretation of it, Pisa model 1 (PM1) is used. If a chest radiograph is not available, Pisa model 2 (PM2) is used. Both models provide on-line computation of the clinical probability of pulmonary embolism as a continuous function, and allow estimating precisely likelihood ratios [9].

In this study, we used the Pisa model 2 because it is easier to apply, does not require the detailed interpretation of the chest radiograph.

The Pisa model is entirely based on the evaluation of relevant clinical symptoms and signs, and the interpretation of the electrocardiogram. Therefore, it is applicable in any clinical context. Among the symptoms, sudden-onset dyspnea is a strong predictor of pulmonary embolism. The importance of characterizing dyspnea in terms of onset has long been recognized [20], but it was largely overlooked in most studies reported thus far [4,5,7,21]. Although the interpretation of the electrocardiogram requires medical expertise, the abnormalities associated with acute cor pulmonale are based on clearly defined criteria, which have been known and applied for many years [22]. The original Geneva score is based on eight variables: recent surgery, previous thromboembolic event, older age, hypoca-nia, hypoxemia, tachycardia, band atelectasis, or elevation of a hemidiaphragm on chest X-ray film [4]. It is the only score among the ones we studied that included the arterial blood gases, but it has a great drawback which is neglecting the patients’ relevant symptoms apart from tachycardia.

In the Wells score, the physician assigns points for the following: clinical signs and symptoms of deep venous thrombosis (objectively measured leg swelling and pain with palpation in the deep vein region), heart rate higher than 100 beats/min, immobilization (for more than 3 consecutive days) or surgery in the previous 4 weeks, previous objectively diagnosed deep venous thrombosis or pulmonary embolism, hemoptysis, malignancy (patients with cancer who were receiving treatment, those in whom treatment had been stopped within the past 6 months, or those who were receiving palliative care), and pulmonary embolism as likely as or more likely than an alternative diagnosis [7]. For the final variable, which was not strictly defined, physicians were told to use the clinical information (obtained by history and physical examination), along with results on chest radiography, electrocardiography, and whatever blood tests were considered necessary to diagnose pulmonary embolism [23]. From our point of view, this is the main disadvantage of Wells score, because despite being an important informative variable, it is largely ill defined and totally dependent on the physician’s skills and personal predictions not on well defined criteria that could be assessed by any physician. One of the strengths of the Wells Criteria rule is that it relies only on the history and physical signs, requiring no ancillary testing for risk stratification. One problem with the Wells Criteria is the “alternate diagnosis less likely than PE” component. This component adds some degree of subjectivity to an otherwise objective rule [24].

In our study, the frequencies of pulmonary embolism in the high, intermediate, and low probability categories were, respectively: 75%, 81.2%, and 29.4% for the original Geneva score; 80%, 42.1%, and 0% for the Wells model; 90% in high probability, 80% in substantial probability, 36.8% in moderate probability, and 0% in the slight probability groups, respectively, for the Pisa model.

In the Pisa model derivation cohort, the prevalence of PE was 4% when predicted clinical probability was slight, 26% when moderate risk was predicted, 65% when substantial risk was predicted, and 91% when high risk was predicted. In the validation cohort, the prevalence of PE was 2% when predicted clinical probability was slight, 28% when moderate risk was predicted, 67% when substantial risk was predicted, and 94% when high risk was predicted [9].

<table>
<thead>
<tr>
<th>Table 7</th>
<th>Sensitivity, specificity, positive predictive value, negative predictive value and accuracy of different clinical probability scores.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical probability score</td>
<td>Sensitivity</td>
</tr>
<tr>
<td>Original Geneva score</td>
<td>0.25</td>
</tr>
<tr>
<td>Revised Geneva score</td>
<td>0.54</td>
</tr>
<tr>
<td>Simplified Geneva score</td>
<td>0.79</td>
</tr>
<tr>
<td>Wells score</td>
<td>0.67</td>
</tr>
<tr>
<td>Simplified Wells score</td>
<td>0.92</td>
</tr>
<tr>
<td>Simplified Charlotte score</td>
<td>0.79</td>
</tr>
<tr>
<td>Pisa model</td>
<td>0.71</td>
</tr>
</tbody>
</table>
Miniati et al. [25] compared the performance of three models (Wells model, Geneva model and Pisa model) in 215 consecutive patients with suspected pulmonary embolism. The clinical probability predicted by the models was categorized as low, intermediate, or high. In all patients, pulmonary angiography was used as the reference diagnostic standard. In patients with pulmonary embolism, the extent of pulmonary embolization was assessed on the lung scan as an index of disease severity. The prevalence of pulmonary embolism was 43.3%. The frequencies of pulmonary embolism in the low, intermediate, and high probability categories were, respectively: 50%, 39%, and 49% for the Geneva model; 12%, 54%, and 64% for the Wells model; 5%, 42%, and 98% for the Pisa model. Among patients with pulmonary embolism, there was a strong, positive relation between clinical probability predicted by the Pisa model and the extent of pulmonary embolization. The Pisa model proved more accurate than the two other models.

When the predictive accuracy and concordance of the Wells and Geneva criteria were compared, the two prediction rules were found to have similar predictive accuracy for PE. It could be argued that the Wells criteria are quicker, easier, and more cost effective as well as providing results similar to those of the Geneva criteria. The Wells criteria have the lowest pretest probability in the low risk group and are the only criteria recommended for use with whole blood cell qualitative D-dimer [24].

In the present work, revised Geneva score and simplified Geneva score had weaker correlation with CTPA results (P ≤ 0.05) while simplified Well's score and simplified Charlotte score had negative correlation with CTPA results (P > 0.05).

The revised Geneva score does not include figures which require an arterial blood gas sample to be performed [5]. This simplifies the scoring process, and has also been shown to be as effective as the Wells score [26].

A newer revision referred to as the simplified revised Geneva score has been prospectively studied and reported in the Archives of Internal Medicine on October 27 of 2008. The simplified scoring system replaced the weighted scores for each parameter with a 1 point score for each parameter present, to reduce the likelihood of error when the score is used in a clinical setting [27].

Douma et al. [6] compared four clinical probability scores (Wells rule, revised Geneva score, simplified Wells rule, and simplified revised Geneva score) in combination with D-dimer testing to exclude PE in 807 consecutive patients with suspected acute PE. They concluded that all four scores show similar performance for exclusion of acute PE in combination with a normal D-dimer result. This prospective validation indicates that the simplified scores may be used in clinical practice.

The Charlotte Criteria rule was specifically developed to determine if a patient is at low enough risk of PE to allow for diagnostically definitive bedside testing. It stratifies patients into low-risk or high-risk groups. Among low-risk patients, PE can presumptively be excluded by the use of a D-dimer assay. The Charlotte Criteria results have been prospectively validated in conjunction with a diagnostic algorithm; patients deemed negative for PE through the combined use of this decision rule and the algorithm had a less than 1% false negative rate [24].

In the present work, the sensitivity of high probability scores, the specificity of low probability scores were estimated.

For determining the sensitivity and specificity of ventilation-perfusion scintigraphy in PIOPED II Study 1, Sostman et al. [28] determined the sensitivity of a high probability (PE present) scan finding with the exclusion of patients with intermediate or low probability, while the specificity of very low probability or normal (PE absent) scan finding was determined with the exclusion of patients with high or intermediate probability.

In the present study, Simplified Wells score had the highest sensitivity (0.92), while the original Geneva had the lowest sensitivity (0.25). Pisa model had the highest specificity (0.82) while Wells score had the lowest specificity (0.12). The highest and lowest positive predictive values were in the Pisa model (0.85) and Charlotte (0.59) scores, respectively, while the highest and lowest negative predictive values were in the Wells (1) and Charlotte (0.44) scores, respectively. The Pisa model had the highest overall accuracy (0.76).

The Pisa models include variables that are negatively associated with pulmonary embolism. This gives the models greater flexibility, which may explain why they perform equally well in detecting and in ruling out pulmonary embolism [9].

In their comparison of the four clinical scores for PE (Wells rule, revised Geneva score, simplified Wells rule, and simplified revised Geneva score), Douma et al. [6] found that the sensitivity and negative predictive value of the four scores were 99.5% while their specificity ranged from 29% to 31%.

Lucassen et al. [29] in their meta analysis found that the Wells rule with a cutoff value less than 2 had sensitivity of 0.84 and specificity 0.58 and Wells rule with a cutoff value 4 or less had sensitivity of 0.60 and specificity of 0.80, the Geneva rule had sensitivity of 0.84 and specificity of 0.50, and the revised Geneva rule had sensitivity of 0.91 and specificity of 0.37.

Conclusion

Clinical probability should be determined for every patient suspected of having pulmonary embolism. For most patients, it is an easy and effective way to decide which patient should undergo further investigations. Among the studied seven scores, the Pisa model has the best correlation with the CTPA results and it has a good sensitivity, specificity, positive and negative predictive values and the highest overall accuracy.

References


[10] Available at: <http://medcalc3000.com/PulmonaryEmbRiskPisaCXR.html>.


