Assessing Clinical Probability of Pulmonary Embolism in the Emergency Ward

A Simple Score

Jacques Wicki, MD; Thomas V. Perneger, MD, PhD; Alain F. Junod, MD; Henri Bounameaux, MD; Arnaud Perrier, MD

Objective: To develop a simple standardized clinical score to stratify emergency ward patients with clinically suspected pulmonary embolism (PE) into groups with a high, intermediate, or low probability of PE to improve and simplify the diagnostic approach.

Methods: Analysis of a database of 1090 consecutive patients admitted to the emergency ward for suspected PE in whom diagnosis of PE was ruled in or out by a standard diagnostic algorithm. Logistic regression was used to predict clinical parameters associated with PE.

Results: A total of 296 (27%) of 1090 patients were found to have PE. The optimal estimate of clinical probability was based on 8 variables: recent surgery, previous thromboembolic event, older age, hypocapnia, hypoxemia, tachycardia, band atelectasis, or elevation of a hemidiaphragm on chest x-ray film. A probability score was calculated by adding points assigned to these variables. A cutoff score of 4 best identified patients with low probability of PE. A total of 486 patients (49%) had a low clinical probability of PE (score ≤4), of which 50 (10.3%) had a proven PE. The prevalence of PE was 38% in the 437 patients with an intermediate probability (score of 5-8; n=437) and 81% in the 63 patients with a high probability (score ≥9).

Conclusions: This clinical score, based on easily available and objective variables, provides a standardized assessment of the clinical probability of PE. Applying this score to emergency ward patients suspected of having PE could allow a more effective diagnostic process.

Arch Intern Med. 2001;161:92-97

From the Medical Clinic 1 (Drs Wicki, Junod, and Perrier), Quality of Care Unit and Institute of Social and Preventive Medicine (Dr Perneger), and Division of Angiology and Hemostasis (Dr Bounameaux), Geneva University Hospital, Geneva, Switzerland.

ALTHOUGH NEWLY available, noninvasive diagnostic tools (leg vein ultrasonography[1-4] and plasma D-dimer measurement[2,5-7]) are being increasingly used in the workup of suspected pulmonary embolism (PE), clinical assessment of PE remains a cornerstone of the recently validated diagnostic strategies for PE.[2,4,8,9] Indeed, the so-called clinical or pretest probability (which rests on risk factors for venous thromboembolism, history, physical examination, blood gases, chest x-ray examination, and electrocardiogram) may aid in both the selection and interpretation of further diagnostic tests. Moreover, patients with a low clinical probability of PE seldom require a pulmonary angiogram.

Although individual symptoms, signs, and findings on frequently performed tests (chest x-ray examination, electrocardiogram, and blood gases) are neither sensitive nor specific for PE,[10,11] their combination, either empirical[2,9,12] or by a scoring system,[4,8] allows a fairly accurate classification of patients suspected of having PE into 3 clinical probability categories, ie, low, intermediate, and high. For example, in a database combining 2 prospective management studies of PE diagnosis,[9] 41% of the patients had a low clinical probability of PE, and the prevalence of PE was only 8%, a figure similar to that obtained in the PIOPED study.[12] None of these patients required a pulmonary angiogram. However, the predictive value of a high clinical probability of PE was poor (67% of patients with PE), and clinical probability was assessed empirically in these trials. In a recent Canadian trial,[4] probability of PE was assessed by a clinical model based on the presence of risk factors for venous thromboembolism and clinical signs and symptoms. Although safe and effective for reducing the need for invasive testing, this score was highly dependent on the clinician's decision of whether an alternative diagnosis was as or more likely than PE and was, therefore, explicit but not standardized. Finally, a score has also been developed by an Italian group,[8] but it rested on assessment by a limited number of highly spe-

PATIENTS AND METHODS

PATIENTS

The data analyzed herein were pooled from 2 previous studies,[2,6] totaling 1093 consecutive patients more than 16 years old who presented with clinically suspected PE to the emergency center of the University Hospital of Geneva, Geneva, Switzerland, between October 1, 1992, and October 31, 1997. Exclusion criteria in these trials were as follows: suspected PE during hospital stay, symptoms of deep vein thrombosis (DVT), DVT or PE in the previous 3 months, refusal or inability to consent, contraindication or impossibility to perform pulmonary angiography, ongoing anticoagulant treatment at study entry, expected survival less than 3 months, impossible follow-up, or lung scan read in comparison to a previous examination. Three patients were excluded from the present analysis because they had a large number of missing items (PaO_2, $PaCO_2$, oxygen alveolar-arterial difference [$PAO_2 - PaO_2$], platelike atelectasis, pleural effusion, and/or elevation of a hemidiaphragm).

DIAGNOSTIC STUDIES

Diagnosis of PE rested on a sequence of noninvasive instruments, including clinical assessment, lung scan, enzyme-linked immunosorbent assay (ELISA) plasma D-dimer measurement, and lower limb venous compression ultrasonography. Throughout the 2 studies on which we performed the present analysis, no change occurred in the methods and availability of all diagnostic tests, except for D-dimer. Plasma D-dimer was assayed by the Asserachrom D-Di enzyme immunoassay kit (Diagnostica Stago, Asnières-sur-Seine, France) in the first study and by a rapid ELISA assay (Vidas DD; bioMérieux, Lyon, France) in the second study.[2] However, both assays were ELISAs, and they had a very similar performance. An angiogram was performed in patients with an inconclusive noninvasive workup. In the second study,[2] the diagnostic sequence was modified, plasma D-dimer and ultrasonography being performed before instead of after lung scan. Pulmonary embolism was ruled out by a normal lung scan, an ELISA plasma D-dimer level of less than 500 µg/L, the combination of low clinical probability and a nondiagnostic lung scan, or a normal angiogram. Pulmonary embolism was established by a high-probability lung scan, a DVT shown by ultrasonography, or an abnormal angiogram. The diagnosis of PE was established in 296 patients by a high-probability lung scan, a DVT shown by ultrasonography and an abnormal lung scan, a pulmonary angiogram showing an embolus, a high clinical probability and an abnormal albeit nondiagnostic lung scan, or a high clinical suspicion with echocardiographic signs of acute right ventricular pressure overload. These last 2 criteria were used in only 17 patients (1.6% of the entire population). Criteria for absence of PE were a normal or near-normal lung scan or a normal pulmonary angiogram. Moreover, a plasma D-dimer level below 500 µg/L or the combination of a low empirical clinical probability of PE and a low-probability lung scan were considered to rule out PE in the absence of venous thromboembolic events during 3-month follow-up. The prevalence of PE in this population (27%), as well as the proportion of normal and high-probability lung scans, is consistent with that in other series reported in the literature.[12,13]

FOLLOW-UP

Venous thromboembolic events (DVT or PE) and episodes of bleeding were recorded during the 3-month follow-up. Patients were followed up by their family physicians and were interviewed by telephone by one of the study coordinators at the end of the follow-up period. The family physician was contacted whenever a possible event was disclosed by the interim history, and charts were reviewed if a patient was readmitted to a hospital for any cause. The death registries of Geneva and the Province of Quebec were consulted for patients who could not be traced after checking with the family physician. For patients who died, the cause of death was ascertained either by autopsy or the death certificate. Follow-up was completed in 99.3% of patients.

STUDY DESIGN

On study entry, patients were examined by a physician in the emergency ward who rated the probability of PE as low

Continued on next page

cialized pulmonary physicians and included sophisticated and potentially unreliable readings of chest x-ray films.

Therefore, we performed the present study to develop a simple standardized estimate of clinical probability of PE from a database of consecutive unselected patients admitted to the emergency ward for clinically suspected PE in whom the diagnosis of PE was established or excluded by a standardized algorithm.

RESULTS

CHARACTERISTICS OF STUDY POPULATIONS

A total of 1090 consecutive patients were evaluated. Their characteristics are displayed in **Table 2**. The median age of the patients was 62 years (range, 17-97 years).

PREDICTOR VARIABLES OF PE

Except for sex, recent cough, stroke, cancer, chronic obstructive pulmonary disease, heart disease, estrogen treatment, and recent trauma, all variables were significantly associated with PE in univariate analysis (Table 2). Patients with confirmed PE slightly differed in age and sex from those without PE (mean±SD age, 67.6±16.7 years and 57.2±18.8 years, respectively; 49% and 43.6% male, respectively). Among patients with PE, the mean±SD PaO_2 was 8.8±2.0 kPa compared with 10.3±2.4 kPa in patients without PE ($P<.001$). The mean±SD $PaCO_2$ was 4.5±0.7 kPa in

(0% to 20%), high (80% to 100%), or intermediate (21% to 79%) before any other test to avoid bias. Data were collected by means of a standardized case report form, including the variables listed in **Table 1**. The list was established on the basis of the literature.[10,11,14] The variables fell into 4 groups: signs and symptoms of PE, risk factors for PE, interpretation of the chest radiograph, and measurement of arterial blood gas.

Patients were considered to have chronic heart disease (coronary heart disease, heart failure, or arrhythmia), chronic venous disease (varicose veins, chronic insufficiency), cancer, history of previous DVT or PE, stroke, or chronic obstructive pulmonary disease if these conditions were known before admission. Recent cough was defined as cough during the last 3 days. Recent major surgery was defined as orthopedic, hip, knee, or extensive pelvic or abdominal surgery during the last month. Only trauma of the inferior limbs, pelvis, or spine during the last month was considered. Bed rest of 48 hours or more and air or road travel of 6 hours or more during the last week were considered as recent immobilization. Postpartum period was defined as up to 4 weeks after delivery. Arterial blood samples were obtained while the patients were breathing room air. Oxygen alveolar-arterial difference ($P_{A}O_2 - P_{a}O_2$) was calculated from the following simplified equation: $P_{A}O_2 = P_{I}O_2 - (P_{C}O_2/0.8) - P_{a}O_2$. Chest radiographs were obtained at the time of study entry using a stationary x-ray unit. In most patients, anteroposterior chest radiographs were obtained in the semirecumbent position. Chest radiographs were examined by the physician of the emergency ward. Care was taken to identify band atelectasis, pleural effusion, and position of the diaphragm. Questionnaires were completed before the patients underwent specific diagnostic tests, and they were systematically reviewed for completeness.

ANALYSIS

Descriptive statistics were applied for all variables collected. The univariate relation between baseline characteristics and presence of PE was examined by the Fisher exact test for categorical variables. All candidate predictor variables associated with diagnosis of PE in univariate analysis were incorporated into a multivariate logistic regression model. For all analyses, a 2-tailed *P* value of less than .05 indicated statistical significance. Negative predictive value was the proportion of patients with a low probability score among those classified as not having PE.

CLINICAL SCORE FOR ASSESSING CLINICAL PROBABILITY OF PE

A simple integer diagnostic score was computed from the multivariate logistic regression model, assigning points in proportion to the regression coefficients. The ideal score was defined as a score based on objective and reproducible variables, clinically relevant for the diagnosis of PE. The individual diagnostic scores were calculated, and the patients were assigned to a low-, intermediate-, or high-probability category. The optimal cutoff for discriminating between the low- and intermediate- or high-probability categories was chosen to identify a low-probability group as large as possible with a prevalence of PE below 12%, a figure found in previous studies using empirical probability.[2,9,12] To examine the degree of overfitting of the prediction model to the development sample, we performed a cross-validation procedure.[15] First, the sample was split at random into 10 equal groups. Second, a logistic regression model predicting diagnosis of PE was developed on nine tenths of the sample, and the resulting prediction equation was applied to the remaining tenth; this procedure was repeated 10 times, each time rotating the cross-validation subset. Finally, the ability of the cross-validated scores to predict PE was examined by comparing the area under the receiver operating characteristic curve (AUC)[16] with that obtained from the naive prediction scores, without cross validation. This cross-validation procedure was performed for the full multivariable prediction model, where each covariate was assigned a separate regression coefficient, and for the simple model, where the clinical probability score was the sole predictor. Confidence intervals on AUCs were obtained by the bootstrap method[17]: 250 subsamples with sample sizes of 986 were taken with replacement from the original sample, the AUC was computed in each, and the 95% confidence interval was derived from percentiles 2.5 and 97.5 of the distribution of AUCs.

patients with PE and 4.8±0.9 kPa in patients without PE ($P<.001$).

In multivariate analysis, 8 predictors showed a significant association with PE: recent surgery, previous thromboembolic event, older age, hypocapnia, hypoxemia, tachycardia, platelike atelectasis, or elevation of a hemidiaphragm on chest x-ray film (**Table 3**).

CLINICAL SCORE

Based on multivariate regression coefficients, a clinical risk score ranging from 0 to 16 points was established in 986 patients (104 patients had missing data, mainly arterial blood gas analysis not performed or performed while breathing oxygen) (Table 3). The best cutoff score for identifying a low-probability group as large as possible while not exceeding a prevalence of PE of 12% was 4 points or less (**Figure**). After the individual risk scores were calculated, patients with a total score of 4 or less were assigned to the low-probability category (486 patients [49%]; prevalence of PE, 10%), those with a total score of 5 to 8 points to the intermediate-probability category (437 patients [44%]; prevalence of PE, 38%), and those with a total score of 9 points or higher to the high-probability category (63 patients [6%]; prevalence of PE, 81%). The difference in prevalence of PE in the 3 categories was statistically significant. The prevalence of PE for each score is given in the Figure.

CROSS VALIDATION

When the 8 variables in the prediction model were allowed to vary independently, the AUC was 0.79 (range,

Table 1. Standardized Questionnaire Used to Evaluate Patients With Suspected Pulmonary Embolism (PE)

- Patient characteristics
  - Age
  - Sex
- Risk factors for venous thromboembolism
  - Previous deep vein thrombosis or PE
  - Varicose veins
  - Chronic venous disease
  - Chronic heart disease
  - Stroke
  - Chronic obstructive pulmonary disease
  - Cancer
  - Recent surgery (<1 mo)
  - Recent trauma (<1 mo)
  - Immobilization (bed rest ≥48 h or travel ≥6 h in the previous week)
  - Pregnancy
  - Post partum
  - Oral contraception
  - Estrogen replacement therapy
- Symptoms
  - Recent cough (<3 d)
  - Chest pain
  - Dyspnea
  - Hemoptysis
- Signs
  - Heart rate
  - Respiratory rate
  - Temperature
  - Blood pressure
- Chest x-ray examination
  - Pleural effusion
  - Platelike atelectasis
  - Elevation of a hemidiaphragm
- Blood gases
  - Pa_{O_2}
  - Pa_{CO_2}
  - Oxygen alveolar-arterial difference

0.76-0.81) for the naive equation and 0.77 (range, 0.74-0.80) after cross validation. When the 8 variables were added to form the diagnostic score, the AUC was 0.79 (range, 0.76-0.81) for naive prediction and 0.78 (range, 0.75-0.80) after cross validation. Hence, this analysis allows us to rule out substantial overfitting of the clinical score.

COMPARISON WITH EMPIRICAL PROBABILITY ASSESSMENT

In all patients, the clinical probability of PE was evaluated empirically by an emergency ward physician, usually a second- or third-year internal medicine resident. The accuracy of the empirical assessment is similar to that of the prediction by the score (**Table 4**). The score tended to identify the patients with a high clinical probability more accurately than empirical evaluation (prevalence of PE: 81% vs 66%, respectively), but the difference did not reach statistical significance.

COMMENT

In this study, we identified the main characteristics associated with PE in a cohort of consecutive outpatients admitted to the emergency ward with clinically suspected acute

Table 2. Characteristics of 1090 Patients With Clinically Suspected Pulmonary Embolism (Univariate Analysis)*

Patient Characteristics†	No. (%) of Patients	No. (%) of PEs	Odds Ratio (95% CI)	P‡
Age, y				
<60	487 (45)	71 (15)	1	. . .
60-79	421 (39)	147 (35)	3.1 (2.3-4.3)	<.001
≥80	182 (17)	78 (43)	4.4 (3.0-6.5)	<.001
Sex				
Male	491 (45)	145 (30)	0.8	.1
Female	599 (55)	151 (25)	(0.6-1.1)	
Previous PE				
Yes	110 (10)	51 (46)	2.6	<.001
No	980 (90)	245 (25)	(1.7-3.9)	
Previous DVT				
Yes	154 (14)	79 (51)	3.5	<.001
No	936 (86)	217 (23)	(2.5-5.0)	
Previous PE or DVT				
Yes	202 (19)	99 (49)	3.4	<.001
No	888 (81)	197 (22)	(2.5-4.6)	
Chronic heart disease				
Yes	327 (30)	99 (30)	1.2	.1
No	763 (70)	197 (26)	(0.9-1.7)	
Chronic venous disease				
Yes	408 (37)	145 (36)	1.9	<.001
No	682 (63)	151 (22)	(1.5-2.5)	
Stroke				
Yes	44 (4)	14 (32)	1.3	.5
No	1046 (96)	282 (27)	(0.7-2.4)	
COPD				
Yes	132 (12)	39 (30)	1.1	.5
No	958 (88)	257 (27)	(0.8-1.7)	
Cancer				
Yes	138 (13)	47 (34)	1.5	.06
No	952 (87)	249 (26)	(1.0-2.1)	
Recent surgery				
Yes	76 (7)	36 (47)	2.6	<.001
No	1014 (93)	260 (26)	(1.6-4.2)	
Recent trauma				
Yes	63 (6)	20 (32)	1.3	.4
No	1027 (94)	276 (27)	(0.7-2.2)	
Recent immobilization				
Yes	272 (25)	92 (34)	1.5	.006
No	818 (75)	204 (25)	(1.1-2.1)	
Pregnancy or post partum				
Yes	30 (3)	2 (7)	0.2	.01
No	1060 (97)	294 (28)	(0.0-0.8)	
Estrogen treatment				
Yes	114 (10)	25 (22)	0.7	.2
No	976 (90)	271 (28)	(0.5-1.2)	
Recent cough				
Yes	314 (29)	88 (28)	1.1	.7
No	776 (71)	208 (27)	(0.8-1.4)	
Chest pain				
Yes	836 (77)	197 (24)	0.5	<.001
No	254 (23)	99 (39)	(0.4-0.7)	
Dyspnea				
Yes	805 (74)	246 (31)	2.1	<.001
No	285 (26)	50 (18)	(1.5-2.9)	
Hemoptysis				
Yes	63 (6)	30 (48)	2.6	<.001
No	1027 (94)	266 (26)	(1.6-4.3)	
Heart rate ≥100/min (2)				
Yes	370 (34)	127 (34)	1.7	<.001
No	718 (66)	168 (23)	(1.3-2.3)	

Table 2. Characteristics of 1090 Patients With Clinically Suspected Pulmonary Embolism (Univariate Analysis)* (cont)

Patient Characteristics†	No. (%) of Patients	No. (%) of PEs	Odds Ratio (95% CI)	P‡
Respiratory rate, /min (85)				
8-20	592 (59)	133 (22)	1	. . .
21-30	280 (28)	86 (31)	1.5 (1.1-2.1)	.009
>30	133 (13)	58 (44)	2.7 (1.8-4.0)	<.001
Temperature >38.5°C (49)				
Yes	45 (4)	10 (22)	0.8	.5
No	996 (96)	274 (28)	(0.4-1.5)	
Systolic blood pressure ≤100 mm Hg (3)				
Yes	61 (6)	25 (41)	2.0	.02
No	1026 (94)	269 (26)	(1.2-3.3)	
Pleural effusion (1)				
Yes	224 (21)	77 (34)	1.6	.007
No	865 (79)	218 (25)	(1.1-2.1)	
Platelike atelectasis (1)				
Yes	189 (17)	84 (44)	2.6	<.001
No	900 (83)	211 (23)	(1.9-3.6)	
Elevation of diaphragm (1)				
Yes	180 (17)	76 (42)	2.3	<.001
No	909 (83)	219 (24)	(1.7-3.2)	
Pao_2, kPa (88)§				
<6.5	47 (5)	29 (62)	11.6 (5.8-23)	<.001
6.5-7.99	134 (13)	57 (43)	5.3 (3.2-8.7)	<.001
8.0-9.49	281 (28)	93 (33)	3.6 (2.3-5.5)	<.001
9.5-10.99	262 (26)	63 (24)	2.3 (1.4-3.6)	<.001
≥11	278 (28)	34 (12)	1	
$Paco_2$, kPa (103)				
<4.8	537 (54)	181 (34)	2.7 (1.8-3.9)	<.001
4.8-5.19	199 (20)	47 (24)	1.6 (1.0-2.6)	.04
≥5.2	251 (26)	40 (16)	1	. . .
Oxygen alveolar-arterial difference (106)				
<2.5	344 (35)	45 (13)	1	. . .
2.5-2.99	90 (9)	17 (19)	1.5 (0.8-2.9)	.2
3-3.49	96 (10)	25 (26)	2.3 (1.3-4.1)	.003
3.5-3.99	95 (10)	25 (26)	2.4 (1.4-4.1)	.002
≥4.0	359 (36)	156 (43)	5.1 (3.5-7.4)	<.001

*PE indicates pulmonary embolism; CI, confidence interval; DVT, deep vein thrombosis; and COPD, chronic obstructive pulmonary disease.

†Numbers in parentheses indicate number of patients for whom data were missing.

‡P values refer to the difference in diagnosis of PE between subgroups. The Fisher exact test was used.

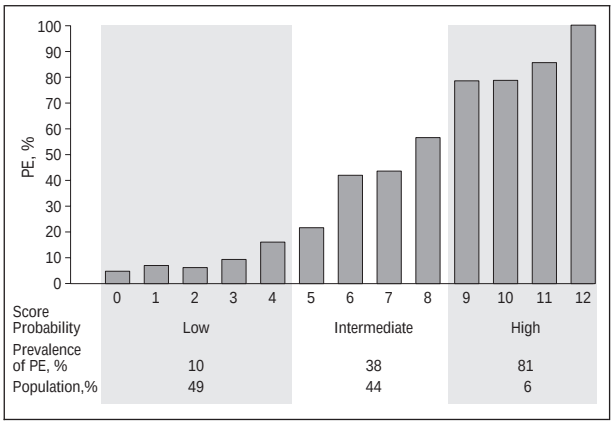
§Data were missing for the 88 patients or test performed while breathing oxygen.

Table 3. Multivariate Predictors of Pulmonary Embolism (PE) and Development of the Clinical Score*

Variable	Logistic Regression Coefficients	Adjusted Odds Ratio (95% CI)	P	Point Score†
Age, y				
60-79	0.6	1.9 (1.3-2.7)	.002	+1
≥80	1.0	2.8 (1.8-4.4)	<.001	+2
Previous PE or deep vein thrombosis	1.1	3.0 (2.1-4.4)	<.001	+2
Recent surgery	1.5	4.6 (2.6-8.3)	<.001	+3
Pulse rate >100/min	0.5	1.6 (1.1-2.2)	.008	+1
$Paco_2$, kPa				
<4.8	1.1	2.9 (1.9-4.4)	<.001	+2
4.8-5.19	0.6	1.9 (1.1-3.2)	.02	+1
Pao_2, kPa				
<6.5	2.0	7.2 (3.2-15.8)	<.001	+4
6.5-7.99	1.4	3.9 (2.2-6.8)	<.001	+3
8-9.49	1.0	2.6 (1.6-4.2)	<.001	+2
9.5-10.99	0.6	1.8 (1.1-2.9)	.03	+1
Chest x-ray				
Platelike atelectasis	0.7	1.9 (1.3-2.9)	.001	+1
Elevation of hemidiaphragm	0.5	1.6 (1.1-2.4)	.02	+1

*Data are from 986 patients: 104 patients had missing data, mainly arterial blood gases analysis. CI indicates confidence interval.

†The total score ranged from 0 to 16.



Application of the score to the study population. Also indicated under the graph are the mean prevalence of pulmonary embolism (PE) and the proportion of patients in each clinical probability category (low clinical probability defined as a score of 0 through 4, intermediate as a score of 5 through 8, and high as a score of 9 or above).

PE and combined them into an easily calculated score (Table 3) to predict the probability of PE before specific tests for the disease, such as plasma D-dimer measurement, lower limb venous ultrasonography, lung scan, and pulmonary angiography. This score is based on clinical, arterial blood gas analysis, and chest x-ray findings, which are widely available in the emergency ward. It allows classifying patients into 3 categories of clinical probability of PE with a fair degree of accuracy. The prevalence of PE is only 10% in the low-probability category (which included 49% of the entire cohort), 38% in the intermediate-probability category (44% of all patients), and 81% in the high-probability category (6% of all patients). Hence, the accuracy of the prediction rule is comparable to that of empirical clinical probability assessment in our institution (Table 4). The advantage of the score over empirical or implicit evaluation by the clinician lies in its explicitness and, therefore, its standardization. Moreover, the score was developed in a cohort of unselected consecutive outpatients, because our hospital is both a primary and a tertiary hospital, and most of these patients were not referred. Therefore, we believe this score could also be applied to other institutions.

The importance of clinical evaluation in suspected PE is highlighted by several recent studies.[2,4,8,9,12] The influence of clinical probability, also named prior or pretest probability, on the predictive value of any diagnostic test is well known and can be inferred from Bayes rule.[18] In the realm of PE diagnosis, the PIOPED study[12] applied this concept to lung scan and was able to prove its relevance by showing that the prevalence of angiographically proven PE was only 4% in patients with both a low-probability lung scan and a low clinical probability of PE.

More recently, the association of a low clinical probability (assessed empirically), a nondiagnostic scan, and a normal lower limb venous ultrasonography was used to rule out PE in 2 consecutive outcome studies.[2,6] This combination allowed forgoing pulmonary angiography in 21% of the entire cohort, and the 3-month thromboembolic risk in such patients left untreated was only 1.7%.[9] Finally, clinical probability assessment was also used to select the appropriate diagnostic workup in a Canadian outcome study.[4] In that series, 702 of the 736 patients with a nondiagnostic lung scan had a low or intermediate clinical probability of PE (as assessed by a prediction rule) and could be managed by a serial ultrasonography strategy. Hence, clinical assessment associated with serial ultrasonography avoided a pulmonary angiogram in 57% of the study patients.

Since clinical evaluation is the linchpin of all the recent diagnostic strategies for PE validated in outcome studies,[2,4] its standardization is of utmost importance for its use to become more widespread. The prediction rule by Wells et al[4] relies heavily on the clinician's judgment regarding whether an alternative diagnosis is as or more likely than PE. Moreover, its complexity renders it difficult to apply in daily clinical practice. In contrast, the score proposed in this study is simple and completely standardized.

Our conclusions might yet be challenged on the basis of 4 potential limitations. First, this score is derived from a database of emergency ward patients, and it can, therefore, not be applied to patients who experience a suspected PE during a hospital stay due to another medical or surgical illness. For such patients, the Wells score may be preferred.[4] Second, the score could be calculated only in 90% of the patients. This is mainly due to arterial blood gas values that were missing, because the patient was already receiving supplemental oxygen at admission. However, characteristics of the patients with missing data are very similar to those of analyzed patients, and the prevalence of PE was identical (27%) in that group. Third, misclassification bias could be a concern for those patients in which the diagnosis was established by either a high clinical probability and an abnormal, albeit nondiagnostic scan, or indirect signs of PE on echocardiography. However, these patients represented only 1.5% of the entire cohort. Fourth, the score is not accurate enough to allow diagnosing or ruling out PE in even a subset of patients. Nevertheless, this is merely a consequence of the modest sensitivity and/or specificity of the symptoms and signs of PE. Moreover, it is undoubtedly as accurate as the clinician's empirical estimate and accurate enough to guide the diagnostic workup. Finally, although the internal validity of our score is well established by the cross-validation procedures, it still awaits external validation in patients from other centers.

In summary, we developed a simple score based on variables commonly available in the emergency ward, which is capable of classifying patients suspected of having PE into 3 clinical probability categories (low, intermediate, and high) with fair accuracy. This score could allow a standardized and accurate identification of an important subset of patients with low (10%) likelihood of PE. Such patients may be eligible for a completely noninvasive diagnostic evaluation, provided this is confirmed by adequate management studies. This score should now be externally validated in other centers.

Table 4. Comparison Between Empirical Probability and Score Probability According to Diagnosis of Pulmonary Embolism (PE) Among 986 Patients*

	Empirical		Score	
Clinical Probability	Patients, No. (%)	PE,% (95% CI)	Patients, No. (%)	PE, % (95% CI)
Low	368 (37)	9 (6-12)	486 (49)	10 (8-13)
Intermediate	523 (53)	33 (29-37)	437 (44)	38 (34-43)
High	94 (10)	66 (57-76)	63 (6)	81 (69-90)

*CI indicates confidence interval.

Accepted for publication July 20, 2000.

Corresponding author and reprints: Arnaud Perrier, MD, Medical Clinic 1, Department of Internal Medicine, Geneva University Hospital, 24 Rue Micheli-du-Crest, CH-1211 Geneva 14, Switzerland (e-mail: Arnaud.Perrier @medecine.unige.ch).

REFERENCES

1. Becker DM, Philbrick JT, Abbitt PL. Real-time ultrasonography for the diagnosis of lower extremity deep venous thrombosis: the wave of the future? *Arch Intern Med.* 1989;149:1731-1734.
2. Perrier A, Desmarais S, Miron MJ, et al. Noninvasive diagnosis of venous thromboembolism. *Lancet.* 1999;353:190-195.
3. Turkstra F, Kuijer PMM, van Beek EJR, Brandjes DPM, ten Cate JW, Büller HR. Diagnostic utility of ultrasonography of leg veins in patients suspected of having pulmonary embolism. *Ann Intern Med.* 1997;126:775-781.
4. Wells PS, Ginsberg JS, Anderson DR, et al. Use of a clinical model for safe management of patients with suspected pulmonary embolism. *Ann Intern Med.* 1998; 129:997-1005.
5. Bounameaux H, de Moerloose P, Perrier A, Miron MJ. D-dimer testing in suspected venous thromboembolism: an update. *Q J Med.* 1997;90:437-442.
6. Perrier A, Desmarais S, Goehring C, et al. D-dimer testing for suspected pulmonary embolism in outpatients. *Am J Respir Crit Care Med.* 1997;156:492-496.
7. Ginsberg JS, Wells PS, Kearon C, et al. Sensitivity and specificity of a rapid whole-blood assay for D-dimer in the diagnosis of pulmonary embolism. *Ann Intern Med.* 1998;129:1006-1011.
8. Miniati M, Prediletto R, Formichi B, et al. Accuracy of clinical assessment in the diagnosis of pulmonary embolism. *Am J Respir Crit Care Med.* 1999;159:864-871.
9. Perrier A, Miron M-J, Desmarais S, et al. Combining clinical evaluation and lung scan to rule out suspected pulmonary embolism. *Arch Intern Med.* 2000;160: 512-516.
10. Hildner FJ, Ormond RS. Accuracy of the clinical diagnosis of pulmonary embolism. *JAMA.* 1967;202:115-118.
11. Stein PD, Terrin ML, Hales CA, et al. Clinical, laboratory, roentgenographic, and electrocardiographic findings in patients with acute pulmonary embolism and no pre-existing cardiac or pulmonary disease. *Chest.* 1991;100:598-603.
12. The PIOPED Investigators. Value of the ventilation-perfusion scan in acute pulmonary embolism. *JAMA.* 1990;263:2753-2759.
13. Hull RD, Raskob GE, Ginsberg JS, et al. A noninvasive strategy for the treatment of patients with suspected pulmonary embolism. *Arch Intern Med.* 1994;154: 289-297.
14. Stein PD, Willis PWD, De Mets DL. History and physical examination in acute pulmonary embolism in patients without preexisting cardiac or pulmonary disease. *Am J Cardiol.* 1981;47:218-223.
15. Efron B, Tibshirani R. Statistical data analysis in the computer age. *Science.* 1991; 253:390-395.
16. Hanley JA, McNeil BJ. The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology.* 1982;143:29-36.
17. Efron B, Tibshirani R. *An Introduction to the Bootstrap.* New York, NY: Chapman & Hall; 1993.
18. Sackett DL, Haynes RB, Guyatt GH, Tugwell P. *Clinical Epidemiology: A Basic Science for Clinical Medicine.* 2nd ed. London, England: Little Brown & Co; 1991.