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Application of an evidence-based decision rule to patients with suspected pulmonary embolism

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Abstract

Background:

Pulmonary embolism is a frequently missed diagnosis, which can lead to severe consequences. To support physicians in diagnosing patients who have a suspicion of pulmonary embolism, the Christopher evidence-based decision rule is implemented in hospitals in the Netherlands. This study examined whether the Christopher evidence-based decision rule is correctly applied in clinical practice. In addition, physicians' reasons for not applying this decision rule were explored.

Methods:

Dyspnea patients were included in the study prospectively. The diagnostic process of the patients with a suspicion on pulmonary embolism, as judged by the treating physician, was compared to the Christopher evidence-based decision rule using patient record reviews. In addition, 14 interviews were conducted with physicians who did not follow the Christopher evidence-based decision rule to obtain insights in their considerations.

Results:

In 80 of 247 dyspnea cases, the treating physicians suspected pulmonary embolism. The Christopher evidence-based decision rule was correctly applied in 17 out of 80 cases. In 22 cases unnecessary tests were performed (i.e. CTa or D-dimer), while in 41 cases pulmonary embolism was insufficiently examined, meaning that pulmonary embolism might have been missed. Considerations for not following the decision rule included; judging another diagnosis to be more likely and not wanting to expose the patient to the CTa radiation.

Conclusions:

The Christopher evidence-based decision rule for diagnosing pulmonary embolism was not always followed correctly in everyday clinical practice. It is recommended to train physicians about the use of evidence-based decision rules and keep paying attention to the decision rule.

Background

Pulmonary embolism (PE) is one of the most frequently missed diagnoses.^{1,2} Missing PE might have severe consequences for the patient; i.e. withholding treatment with anticoagulants could lead to a higher mortality rate.^{3,4} However, an easily applicable test that can confirm or rule-out PE does not exist. The sensitivity of the D-dimer test is too low in patients with a high pretest probability to rule out PE, and the pulmonary computer assisted tomographic angiography (CTa) has a risk of harm to the patient, such as contrast induced nephropathy in the short run and breast cancer in the long run.⁵⁻⁷ Studies showed that in 1% of the cases having had a CTa contributed to major permanent harm to the patient, and in 0.5% of the cases to the patients death.⁵ Therefore, various studies have been conducted to optimize the diagnostic strategy for PE and as a result, several evidence-based decision rules have been proposed.^{8,9} One of the most recently validated decision rules, is the evidence-based decision rule of the Christopher group.¹⁰ The Christopher decision rule differentiates between diagnostic strategies based on the prior probability of having PE. First, using the Wells score, the patients risk on PE can be stratified in a low or a high risk of having PE by examining the patients medical history and various symptoms.¹¹ Subsequently, the Christopher decision rule states that for patients with a low risk, a D-dimer test needs to be performed and when positive, followed by a CTa. For patients with a high risk on PE, the CTa should be done immediately (see Figure 1). In the Netherlands, the Christopher evidence-based decision rule is implemented by several national symposia and the publication of a guideline, and it is general policy in hospitals in the Netherlands.¹²

It is not known if the Christopher evidence-based decision rule is applied accurately in everyday clinical practice. In this study, we used a database of patients presenting with dyspnea¹³, a common (but not essential) complaint in patients with PE, to examine the application of this evidence-based decision rule in everyday clinical practice. The decision rule does not apply to patients without a suspicion on PE and therefore these patients were not included in the study. The main objective of this study is (1) to determine whether physicians diagnose patients with suspected PE according to the Christopher evidence-based decision rule and (2) what the reasons are for not following the evidence-based decision rule.

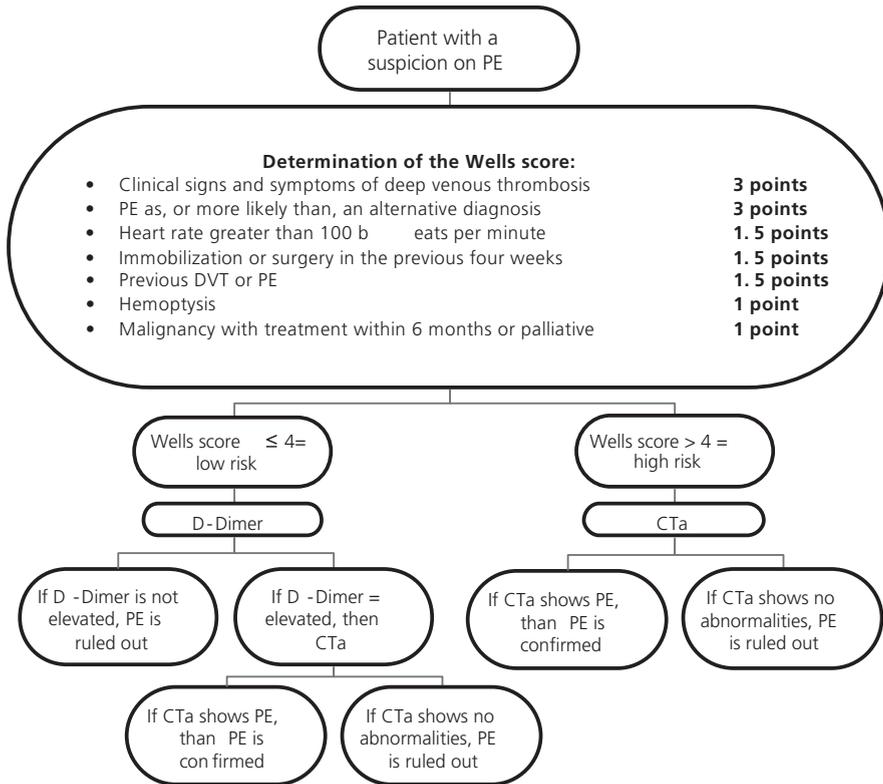


Figure 1. The Christopher evidence-based decision rules for diagnosing pulmonary embolism

Methods

This study is part of a larger study in which we studied suboptimal decisions in the diagnostic reasoning process using record reviews and interviews with the treating physicians. For this sub-study the dyspnea patients in which the treating physician raised the suspicion on PE were selected. To answer the research questions we made use of three data sources. Record reviews were used to determine the Wells score and to examine whether the Christopher evidence-based decision rule was applied. Physicians were asked to write down the differential diagnoses and the likelihood of those diagnoses of being correct. This served two goals, (1) it provided information to determine the Wells score (together with record review) and (2) to reveal reasons for not applying the Christopher evidence-based decision rule. To obtain insight in reasons for not

applying the Christopher evidence-based decision rule, we analyzed several interviews with the treating physicians who did not follow the Christopher evidence-based decision rule.

Patient selection

Five acute care hospitals in the Netherlands (one university hospital, two tertiary teaching hospitals and two general hospitals) participated in the study. The study took place in seven departments of internal medicine, cardiology and pulmonology. The start of the study was phased for practical reasons. The hospitals started about a month after each other and every hospital participated 6-8 months between May 2007 and February 2008. The treating physicians of the participating departments included all patients who (1) had dyspnea (based on the judgment of the treating physician) and (2) were admitted to the ward of a participating hospital department during the research period and (3) who gave their informed consent to review their patient record. Most patients arrived through the emergency department, but patients who were transferred from another department or whose admission was planned were also eligible.

Participating physicians

The physicians who included the patients were residents who were employed at one of the participating hospitals. The residents were supervised by attending physicians. The physicians were aware that the diagnostic reasoning process was studied, but they did not know that PE was studied specifically.

Record reviews

Expert internist reviewers, who had recently retired and had at least 10 years of post-graduate work experience in internal medicine, reviewed the patient records.¹³ The internist reviewers attended several training sessions and had experience with patient record reviews. According to the Christopher evidence-based decision rule the risk of PE (high or low) is determined based on the Wells score.^{8,10,14} The Wells score exists of seven items on the patients' history and clinical findings, each item is assigned a number of points (range 1-3). The expert reviewers inquired from the patient record whether all aspects to determine the Wells score were assessed by the treating physicians and whether they were abnormal (see Table 1). This was done retrospectively in order not to interfere in the physicians clinical decisions. Based on this record review in combination with the differential diagnoses as indicated by the treating physicians, the Wells score

for each patient was calculated by one of the researchers (LZ). The elements of the Wells score were generally complete with the exception of hemoptysis which was not always described in the patient record. However, as this is a very important factor we assume that in cases it was deviating, this was mentioned in the patient record.

Table 1. The questions of the record review used to determine the Wells score¹¹

Wells score	Questions in record review
Clinical signs and symptoms of deep venous thrombosis (DVT)	<ul style="list-style-type: none"> • Color of lower leg • Symmetry of lower leg • Pain in lower leg
PE as, or more likely, than an alternative diagnosis	<ul style="list-style-type: none"> • The likelihood of the differential diagnoses was indicated after the first examination of the patient. When the value of PE was highest or the same as the highest alternative this item of the Wells score was considered to be true.
Heart rate greater than 100 beats per minute	<ul style="list-style-type: none"> • Was the pulse rate checked/ abnormal?
Immobilization or surgery in the previous four weeks	<ul style="list-style-type: none"> • When a recent surgery or immobilization was mentioned in the description of co-morbidity or recent history • When the patient was relocated to the participating department after surgery • When immobilization was mentioned as a reason for hospital admission
Previous DVT or PE	<ul style="list-style-type: none"> • When a DVT or PE was mentioned in the description of co-morbidity or recent history
Hemoptysis	<ul style="list-style-type: none"> • Was hemoptysis checked and present?
Malignancy (with treatment within 6 months or palliative)	<ul style="list-style-type: none"> • When a malignancy was mentioned in the description of co-morbidity or recent history

Based on the total Wells score, a patient's risk on PE can be determined. The Christopher evidence-based decision rule divides the Wells score into two categories; a low and a high risk on PE with a cut-off value of 4 (≤ 4 represents a low risk, >4 represents a high risk).^{10,14} When the Wells score is ≤ 4 , a D-dimer test needs to be performed. If the D-dimer is elevated (500ng/mL is the currently used cut-off value) a CTa will confirm or rule out PE. For the patients with a Wells score >4 , a CTa needs to be performed immediately to confirm or rule out PE (See Figure 1). These diagnostic steps of the Christopher evidence-based decision rule were also obtained from the record review, i.e. the application of the d-dimer and the CTa.

Differential diagnoses

We asked the treating physicians to note down their differential diagnoses after the first diagnostic steps (history taking, physical exam and results of laboratory tests). The differential diagnoses were written down in order of likelihood (1 to maximum of 5 diagnoses) and the numerical likelihood of each of the diagnoses was indicated on a visual scale of 1-10 (1 being very unlikely, 10 being very likely).

Interviews

Treating physicians were interviewed about their suboptimal decisions in the diagnostic process. We selected the cases in which the physicians were interviewed about their decision to deviate from the Christopher evidence-based decision rule (14 interviews). We analyzed the interviews of 14 physicians who performed insufficient tests to diagnose PE. The interviews consisted of simple questions such as: "The elevated d-dimer was not followed by a CTa, could you explain why not?" or "PE was a possible diagnosis, why did you decide not to conduct any further tests to establish or rule out PE?". The answers of the treating physicians were noted down and clustered by a researcher (LZ).

Statistical analysis

Descriptive statistics were used for the quantitative analyses. The interviews were analyzed by clustering the answers into categories making sure all answers were represented in the themes.

Confidentiality and ethical approval

The review board of the VU medical center approved of the research protocol, and all participating hospitals granted approval to participate. The internist reviewers and researchers involved in the data collection signed a confidentiality agreement to maintain the secrecy of the data. Patients included in the study gave informed consent to review their patient record.

Results

Application of Christopher evidence-based decision rule

A total of 261 patients were included in the study of which 14 were excluded because their patient records were lost. For 80 out of 247 dyspnea patients, the physicians indicated PE in the differential diagnoses (see Table 2 for patient characteristics). 56 patients had a low risk on PE (Wells ≤ 4) and 24 patients

had a high risk on PE (Wells >4). The physicians diagnosed PE according to the Christopher evidence-based decision rule in 21% (17 patients, 95%CI: 13.7 to 31.4%). In 51% (41 patients, 95% CI: 40.5-61.9%) no diagnostic tests or insufficient diagnostic tests were used and PE could have been missed. In 28% (22 patients, 95% CI: 18.9-38.4%) the diagnostic tests were not applied according to the Christopher decision rule.

Table 2. Patient characteristics of patients with a suspicion on PE (N=80)

Average age (SD)	67.8 (14.3)
Male sex	33 (41.3%)
Final diagnosis	
○ Pulmonary embolism	14(18%)
○ Chronic obstructive pulmonary disease/Bronchitis/Asthma	16 (20%)
○ Pneumonia	12 (15%)
○ Heart failure	11(14%)
○ Malignancy	6 (8%)
○ Other (e.g.: ischemic heart disease, cholecystitis, pneumothorax, viral infection, hyperventilation, bronchiolitis)	21 (25%)
Relevant co-morbidity (can be more than one diagnosis per patient)	30 (38%)
○ Malignancy	4 (9%)
○ Chronic obstructive pulmonary disease/Bronchitis/Asthma	4 (9%)
○ Pneumonia	3 (7%)
○ Heart failure	3 (7%)
○ Hypoglycemia	3 (7%)
○ Renal insufficiency	2 (5%)
○ Ischemic heart disease without heart failure	2 (5%)
○ Pulmonary embolism	1 (2%)
○ Other (e.g: aorta valve stenosis, viral infection, lung fibrosis, liver failure, HIV)	22 (49%)
Median length of stay (inter quartile range)	8 (11)

Of the patients with a low risk (Wells ≤ 4) on PE, in 63% (35 out of 56, 95% CI: 49.5-74.0%) of the cases no diagnostic tests or insufficient diagnostic tests were performed and PE could have been missed (see Figure 2). Furthermore, out of the 8 cases in which the D-dimer was not elevated, the physicians applied CTa in four cases. In 10 cases a CTa was performed immediately without a preceding D-dimer.

Of the patients with a high risk on PE (Wells score >4), for 21%, 5 of 24 patients (95% CI: 9.2-40.5%), no further diagnostic tests were performed (See Figure 3). In one patient, an elevated D-dimer was not followed by a CTa, and PE was initially missed. In 13 cases the physician performed a D-dimer even though the Christopher evidence-based decision rule recommends an immediate CTa. Those cases showed an elevated D-dimer in 92%, 12 out of 13 patients.

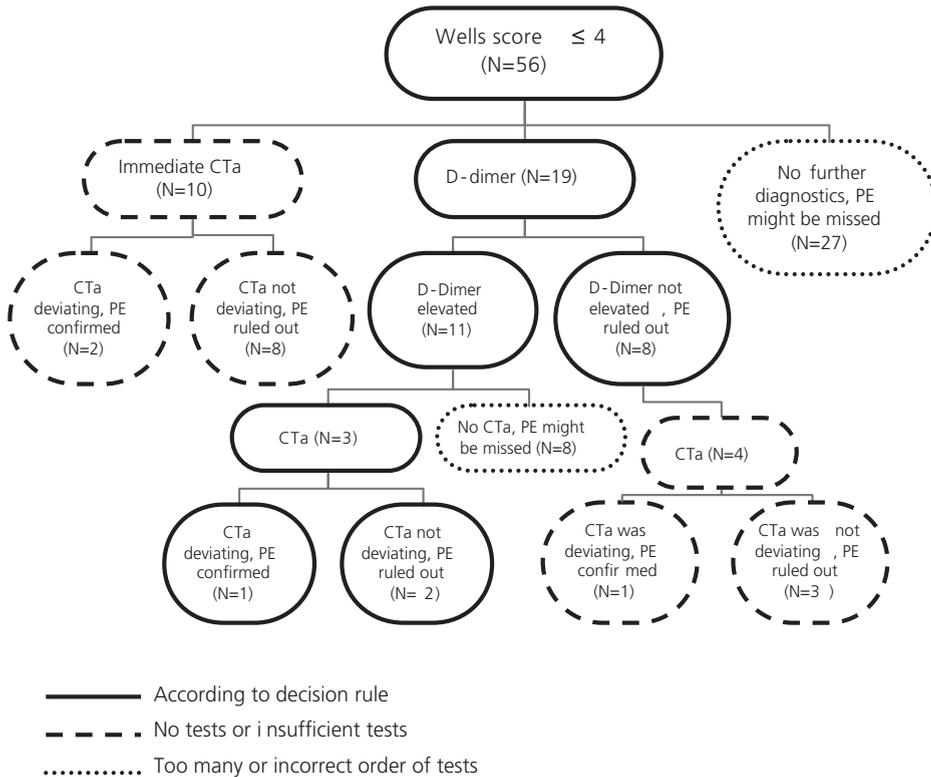


Figure 2. Diagnostic steps as performed by the physicians for patients with a Wells score ≤ 4

Likelihood of PE in differential diagnoses

Physicians were significantly more likely to refrain from further diagnostic tests to diagnose or rule out PE, when PE was considered to be less likely than other diagnoses (i.e. the rank of PE was lower in the differential diagnoses ($\chi^2 = 13.3$, $p < 0.0001$). The likelihood ratings of PE of the cases with a Wells score ≤ 4 were low. When the Wells score was > 4 the likelihood ratings were high, except for the cases in which no further diagnostics were performed, in which they were significantly lower compared to the cases in which diagnostic tests were performed ($t = 3.75$, $p = 0.001$). See table 3.

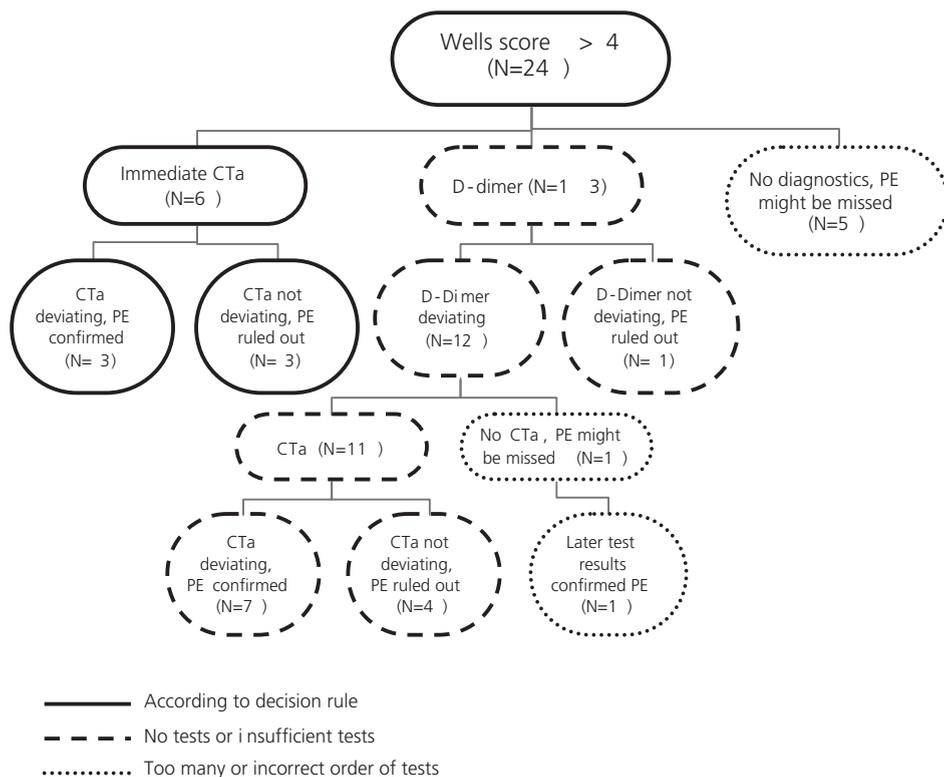


Figure 3. Diagnostic steps as performed by the physicians for patients with a Wells score >4

Table 3. Average Wells score and physicians considerations for the different diagnostic strategies

		N	Rank of PE in DD, mean (range)	Likelihood of PE in DD, mean (range)
Wells ≤ 4	No diagnostic tests	28	3.0 (1-5)	3.7 (1-9)
	D-dimer first	18	2.8 (1-5)	3.8 (1-8)
	Immediate CTa	10	2.8 (1-4)	4.1 (2-10)
Wells > 4	No diagnostics tests	5	2.8 (2-4)	4.0 (1-7)
	D-dimer first	13	1.2 (1-3)	8.3 (2-10)
	Immediate CTa	6	1.3 (1-2)	8.3 (7-10)

Reasons for not applying the Christopher evidence-based decision rule

We conducted interviews in cases in which PE might have been missed. This involved cases where no diagnostic tests were done and cases without an adequate follow up on a deviating D-dimer.

No further diagnostic tests

When the physician did not perform further diagnostic tests, the three clusters of reasons were mentioned:

- An alternative diagnosis was more likely than PE, therefore PE was not further examined.
 - “I thought pneumonia was more likely considering the patients’ symptoms and therefore I did not perform diagnostic tests, i.e. D-dimer”.
- Insufficient time on the ER and the assumption that further examination and adequate testing would be performed on the ward.
 - “I did not check for all of the symptoms needed to determine the Wells score. It was busy during my night shift and therefore I did not examine symptoms for DVT and hemoptysis. I assumed the physicians on the ward would perform a more thorough examination”.
- Not wanting to expose patients to unnecessary tests while anticoagulants were already prescribed for another disease.
 - “There was a low suspicion on DVT or PE and the patients’ main symptom was pain in the thorax with an unclear cause. It was a deliberate choice not to perform diagnostic tests for DVT and PE, mainly because the patient would get anticoagulants for a different reason anyway”.

No adequate follow up after elevated D-dimer value

When the physician did not follow up on an elevated D-dimer value (which would require a CTa), two clusters of reasons were mentioned:

- Assuming the high D-dimer value was due to other reasons.
 - “The Wells score was low and I expected the D-dimer was elevated because of a high C-reactive protein, therefore I did not perform a CTa”.
- Not wanting to expose patients to unnecessary tests while anticoagulants were already prescribed for another disease.
 - “The patient already got anticoagulants for other reasons and therefore I did not perform a CTa which can also be harmful for the patient”.

Discussion

Our results show that physicians do not always use the Christopher evidence-based decision rule when diagnosing PE, although it is the general guideline in Dutch hospitals. In only 21% of the patients with a suspicion on PE the Christopher evidence-based decision rule was followed correctly, while in 79% of the patient's insufficient diagnostic tests or unnecessary tests were performed. Reasons for not applying the Christopher decision rule were e.g. considering the likelihood of PE to be too low to perform more tests.

Our study has several limitations. First, due to the clinical setting and the record review, the Wells score might be an underestimation for some cases. Sometimes the treating physician did not examine all elements of the Wells score (i.e. hemoptysis) or did not write them down in the patient record. This means, that some of the patients with a Wells score of ≤ 4 , actually could have had a Wells score of >4 . Therefore, the decision to perform an immediate CTa might have been correct for some of the cases. Particularly, in our study two out of ten patients with the low risk (Wells ≤ 4) patients who got an immediate CTa, had a PE. This was less in the original study of the Christopher group.¹⁰ This may have been caused by symptoms that originated later during the hospital stay. These symptoms that originated during the hospital stay may have influenced the Wells score, but may not be noted down in the patient record. Secondly, we examined only the cases in which the physician thought of PE as a possible diagnosis after the first examination of the patient. Cases of patients with a missed PE because the physician did not think of PE in the first place were not examined. This is not a part of the decision rule and therefore was outside the scope of this article. Lastly, since the PE diagnosis was determined by record review, we do not have a complete overview of the patients who actually had PE. Some of the patients died, either in the hospital or at home after being discharged and did not have an autopsy. Therefore, results on the prevalence of PE and the number of PE diagnosis that were missed might be an underestimation.

Although the physicians knew that the Christopher evidence-based decision rule and the Wells score are validated and should be used, they still did not follow the decision rule correctly in the majority of the cases. This demonstrates that development and implementation of a decision rule does not mean that it is always used in everyday practice. Not following the Christopher decision rule could lead to patient harm in several ways. Insufficient tests could lead to missing PE, which has been shown to occur frequently and has severe consequences for

the patient, including death.^{1,2,15} The use of unnecessary tests could lead to harm such as contrast-induced nephropathy and also to overdiagnosis (false positives).^{5,6,16}

It seems that physicians were mostly driven by their own assessment of the likelihood on PE. If they considered PE to be likely (high rank in differential diagnoses and high likelihood score), subsequent diagnostic tests were performed. When the physicians did not consider PE as likely (lower rank in differential diagnosis and a lower likelihood score), no further diagnostic tests were conducted. This is of particular importance when according to the physicians own assessment (intuition) PE was not very likely, but the objective measures of the Wells score did result in a high risk on PE (Wells >4). In those cases, the physicians followed their own assessment and did not conduct further diagnostic tests. The interviews also showed that physicians did not use the Christopher evidence-based decision rule when they considered PE not very likely. It thus seems that physicians' own assessment, their intuition, of the likelihood of PE is used as basis for the decisions for testing instead of the Wells score.

The Christopher evidence-based decision rule is based on data from a large number of patients and therefore not applicable to all individual cases. Therefore, adherence to the rule in all circumstances would be incorrect. When circumstances indicate to deviate from the rule, this should be possible. Nevertheless, the Christopher decision rule is applicable in the majority of the cases and should therefore be followed in absence of an apparent justification not to follow the rule. This accounts particularly in cases with a high Wells score and insufficient diagnostic tests, since in patients with a low risk on PE the consequences of a missed PE are less severe.¹⁷ Furthermore, when a patient has PE, a specific dose and duration of anticoagulants is needed and the dose and/or duration provided for another disease might be insufficient. Also, when a D-dimer is suspected to be elevated due to co-morbidity, this does not mean that the patient does not have PE.¹⁸ In fact, PE often co-occurs with other diseases such as asthma and COPD and has a higher mortality rate and gets missed more often in those cases.^{18,19} Missed PE is still one of the most frequently missed diagnoses and consequences of a missed PE can be severe.^{2,15} The Christopher evidence-based decision rule should therefore get continuous attention so physicians are encouraged to correctly follow it.

Conclusions

The Christopher evidence-based decision rule based on the Wells score to diagnose PE is often not correctly followed in everyday clinical practice even though the use of the prediction rule is propagated nationally in the national guideline for diagnosing PE. Physicians seem to base their diagnostic strategy on their own estimate of the likelihood of PE rather than the whole Wells score. Since the Christopher evidence-based decision rule has been shown to be valid in several studies, interventions to improve the diagnostic process of PE lies in overcoming barriers to use evidence-based decision rules for diagnosing PE. The first step is to increase the attention to the more objective elements of the Wells score and educate physicians to refrain from following their intuition only.

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