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Advances in the Diagnosis of Venous Thromboembolism

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Abstract. **This review summarizes recent information about the diagnosis of deep venous thrombosis (DVT) and pulmonary embolism (PE) using noninvasive imaging tests, clinical assessment, and D-dimer assays, and describes how these tests can be employed in diagnostic testing algorithms for the investigation of patients with suspected DVT and PE. The clinical diagnosis of deep venous thrombosis is unreliable, but clinical prediction rules based on signs and symptoms do facilitate the categorization of patients into high, low, or medium risk categories. High sensitivity D-dimer assays further help in excluding cases but do not help in ruling in venous thromboembolism. D-dimer assays and clinical prediction rules also help in the diagnosis of pulmonary embolism. These assessments, along with objective imaging studies such as compression ultrasonography for DVT or computerized tomographic pulmonary angiograms for PE can be used in a systematic way to reliably rule in or exclude venous thromboembolism.**

Key Words. **diagnosis, clinical probability, deep vein thrombosis, pulmonary embolism, D-dimer, computerized tomography**

Introduction

The last two decades have seen the introduction of new strategies in the diagnostic process for suspected deep vein thrombosis (DVT) and pulmonary embolism (PE) including ultrasound imaging, clinical pretest probability assessment, D-dimer testing, and computerized tomographic pulmonary angiography (CTPA). It is unknown if these strategies have improved patient outcomes but a reported decrease in mortality from pulmonary embolism is encouraging and may in part reflect more accurate diagnoses [1]. The signs and symptoms of both DVT and PE are largely non-specific and as a consequence many patients presenting with leg pain or swelling, or chest pain or dyspnea, are investigated but do not have DVT or PE. Mismanagement has been a problem [2].

In this review I will discuss noninvasive imaging tests, clinical assessment, and D-dimer, and describe how they can be employed in diagnostic testing algorithms for the investigation of patients with suspected DVT and PE.

Investigation for Suspected DVT

Imaging tests for DVT

Accurate identification of DVT will minimize the risk of thromboembolic complications and avoid exposing patients without thrombosis to the unnecessary risks of anticoagulant therapy. As such the dogma has been that patients with clinically suspected DVT should undergo an imaging test and the test of choice is venous ultrasound imaging. Due to the very high specificity of this test, a positive compression ultrasound result is sufficiently predictive in most patients that treatment can be initiated [3–6]. The exception is patients with a previous history of DVT as will be discussed.

In many centres ultrasound testing is limited to the proximal veins (from the common femoral caudally to the region of the calf veins where they join the popliteal vein) since the sensitivity for proximal DVT has been reported as 97% but for calf DVT it is only 73% [7]. Since imaging for calf DVT is not performed it has been suggested that a negative ultrasound should be repeated one week later (serial testing) to detect extending calf DVT and this approach has been validated [4] (Fig. 1). However, in symptomatic patients only 10% to 20% of thrombi detected are isolated to the calf, and only 20% to 30% of these calf vein thrombi will eventually extend to the proximal venous system so routine serial testing is inefficient and inconvenient. Indeed studies employing the serial ultrasound testing approach suggest very few patients (1% to 2% in two recent studies) with suspected DVT who have a negative initial ultrasound test will be confirmed to have proximal DVT upon serial testing [7,8]. As a result serial testing is not cost-effective [9,10] Three recent studies have suggested that imaging of the entire deep vein system, proximal and calf veins, with exclusion of DVT with a single negative result, is a safe and effective strategy [11–13]. These studies are welcome additions to the

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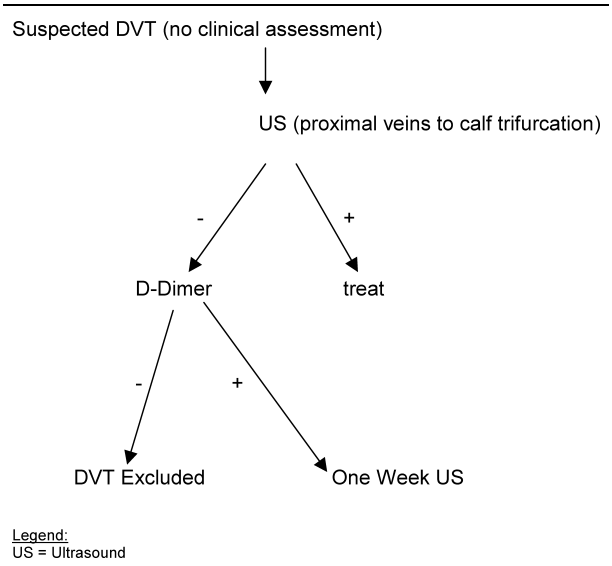

Fig. 1. *Diagnostic algorithm using D-dimer and ultrasound in patients with suspected DVT without consideration of clinical probability.*

DVT diagnostic literature but there are no prospective randomized trials that have compared the safety of withholding anticoagulants solely on the basis of a single negative ultrasound assessment of both the proximal and calf venous systems to strategies that only evaluate the proximal venous system. It is unknown if the single whole-leg vein assessment can be widely applied with the accuracy described in these studies, and the technique is more labor intensive and hence more costly. It would also result in many needless diagnostic tests. As I will discuss, a strategy that employs a combination of D-dimer, clinical probability and ultrasound imaging is ideal.

The clinical diagnosis of deep vein thrombosis

Although the clinical diagnosis of DVT is non-specific since none of the symptoms or signs in isolation are diagnostic, it has now been well established that a clinical prediction rule incorporating signs, symptoms and risk factors, can be accurately applied to categorize patients as low, moderate or high probability for DVT (Table 1). Alternatively the same rule can be used to categorize patients as "DVT likely" or "DVT unlikely" [14]. Over 14 studies have demonstrated the reproducibility of this model [15]. Determination of pretest probability allows for several potential diagnostic strategies in patients with suspected DVT all of which utilize the principals so elegantly described over 300 years ago by Thomas Bayes and elucidated by others [16,17]. Used in combination with ultrasound imaging, it has been demonstrated that patients at low clinical pre-test probability as determined by the clinical criteria can have DVT safely excluded on the basis of a single negative ultrasound test of the proximal veins [18]. However, it is my opinion that pretest probability determination is best used in algorithms that also incorporate D-dimer testing.

Table 1. *Clinical model for predicting pretest probability of DVT**

Clinical Characteristic	Score
Active cancer (treatment ongoing, within previous 6 months or palliative)	1
Paralysis, paresis, or recent plaster immobilization of the lower extremities	1
Recently bedridden > 3d or major surgery within previous 12 weeks requiring general or regional anaesthesia	1
Localized tenderness along the distribution of the deep venous system	1
Entire leg swollen Calf swelling > 3 cm larger than asymptomatic side (measured 10 cm below tibial tuberosity)	1
Pitting edema confined to the symptomatic leg	1
Collateral superficial veins (nonvaricose)	1
Previously documented DVT	1
Alternative diagnosis at least as likely as DVT	−2

* A score of 2 or higher indicates the probability of DVT is "likely"; <2 indicates the probability for DVT is "unlikely". In patients with symptoms in both legs, the more symptomatic leg is used. Alternatively a score of <1 is low probability, 1 or 2 moderate and > 2 high probability

D-dimer

D-Dimer is a degradation product of a cross-linked fibrin blood clot. Levels of D-dimer are typically elevated in patients with acute venous thromboembolism. D-dimer levels may also be increased by a variety of nonthrombotic disorders including recent major surgery, hemorrhage, trauma, malignancy or sepsis. D-dimer levels have also been demonstrated to increase with age and some advocate that D-dimer should not be performed in patients over 80 years of age [19–21]. Therefore, D-dimer assays are, in general, sensitive but non-specific markers for venous thromboembolism. A positive D-dimer result is not useful to "rule in" the diagnosis of venous thromboembolism; rather, the potential value is for a negative test result to "rule out" the diagnosis. Although the negative predictive value of the D-dimer increases proportionately as the sensitivity increases specificity is also important since a very nonspecific assay would have limited utility since most tests would be positive (mostly false positives).

There are qualitative and quantitative D-dimer assays. Qualitative D-dimer assays are interpreted by visual inspection to be positive or negative. The first tests developed were latex agglutination assays including the D-dimer test (Diagnostica Stago), the Dimertest and Dimertest II (Agen Biomedical),

Minutex (Biopool), Nephelotex (Biopool) and Accuclot (Sigma Diagnostics). The second was a whole blood agglutination assay (SimpliRED™- Agen Biomedical). The SimpliRED™ is the qualitative test with the most clinical data. In general the sensitivities and specificities for these assays have been in that range of 90% and 70%, respectively [22,23]. Qualitative D-dimer assays have the advantages that they are simple to perform, have a rapid turn around time, and are inexpensive. Inter-observer reliability has been questioned in at least three studies [24–26], although a fourth study found excellent inter-observer reliability [27]. Regardless, it is advisable that only trained observers perform and interpret these assays. Recent studies have proven that the sensitivity is highest for quantitative assays but the specificity is less with these methods. Data suggest that most D-dimer assays lie on the same Receiver Operating Characteristic curve although one meta-analysis suggests that the Dimertest, Nycocard and Turbiquant were significantly worse then the other assays [23, 28–30]. Overall the data suggests the accuracy of specific D-dimer tests are similar regardless of whether suspected DVT or PE is evaluated [29].

Approach to the diagnosis of the first episode of deep vein thrombosis

Patients with leg symptoms compatible with DVT should initially have a determination of pretest probability of DVT using an established prediction model/rule (Table 1). It is important that a history and physical be done first, and only if DVT remains a diagnostic possibility should the model be applied. After the clinical pretest probability is determined a D-dimer test should be performed. If qualitative D-dimers are used then the pretest clinical probability should be less then 10% to reliably exclude the diagnosis without the need for ultrasound imaging. In our centre a score of $\leq$ one by our model is sufficient to use with a qualitative D-dimer but most studies have employed our earlier scoring system, and use a score of zero or less to enable exclusion of DVT with a negative qualitative D-dimer [14,15]. Due to its higher sensitivity, a negative ELISA D-dimer assay may be used to exclude the diagnosis of venous thromboembolism when the pretest probability is less than 22% which is a score $\leq$2, using our model. In both cases this ensures the post-test probability of DVT is <2% [31]. No D-dimer assayshould be used to exclude DVT in patients who are high pretest probability. Clinical assessment and D-dimer testing have the further advantage of enabling the management of patients presenting with suspected DVT at times when radiographic imaging is not routinely available. Patients in whom there is a moderate or high clinical suspicion of DVT may receive an injection of low molecular weight heparin in doses designed to treat an acute DVT. Diagnostic imaging can then be arranged on a more elective basis the following day. Since low molecular weight heparins are safe and effective therapy for patients with proven DVT it would provide adequate protection for patients with suspected DVT [32,33]. Patients at low risk by either clinical diagnostic models or with use of a sensitive D-Dimer test may have diagnostic imaging delayed for a 12 to 24 hour period without the need for anticoagulant coverage. Finally, it is important to note that the D-dimer should not be used as a screening test. It should only be employed if the physician is convinced that DVT is a diagnostic possibility. Indiscriminant use of the D-dimer as a screening test will result in many unnecessary ultrasound tests. The accepted algorithms are outlined in Figures 2 and 3.

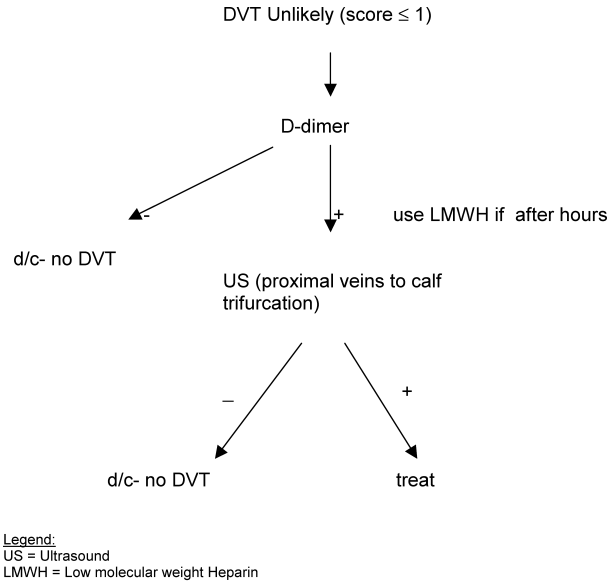

Fig. 2. *Diagnostic algorithm using clinical probability, D-dimer and ultrasound in patients with suspected DVT.*

Recurrent DVT

The ideal strategy in for diagnosing DVT in patients with a prior DVT in the symptomatic leg is still a subject of debate but the same randomized trial described above demonstrated the safety of combining clinical probability, D-dimer and ultrasound imaging in these patients [14]. The biggest concern is false positive ultrasound results in this patient population. It is helpful to recognize that acute DVT is usually not echogenic or non-occlusive, and it tends to be continuous. Therefore if the ultrasound reveals thrombosis that is echogenic, non-occlusive, or discontinuous then chronic DVT should be considered. Serial testing or venography can help clarify the issue. If previous ultrasound results are available for comparison this is also helpful. Increase in clot diameter by 4mm is suggestive of

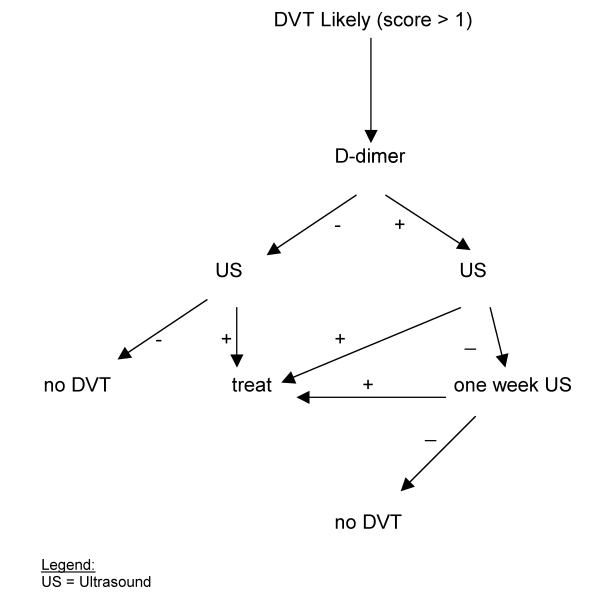

Fig. 3. *Diagnostic algorithm using clinical probability of DVT likely, D-dimer and ultrasound in patients with suspected DVT.*

recurrence, as of course, is more proximal extension [34]. A recent study has suggested a negative result with a sensitive D-dimer test can be used to exclude recurrent DVT with imaging tests but this is not recommended as outlined above [35]. Application of Bayes theorem demonstrates the danger of this strategy since high pretest probability patients may have a 21% or higher probability of DVT even after a negative highly sensitive D-dimer test. The British Society for Haematology guidelines support this [31].

Investigation for Suspected Pulmonary Embolism

Imaging procedures for pulmonary embolism

Pulmonary angiography has long been regarded as the gold standard test for the diagnosis of PE, but pulmonary angiography is an invasive procedure requiring a skilled radiologist and a cooperative patient. Although the procedure is usually well tolerated, arrhythmias, hypotension, as well as other adverse reactions to contrast dye may be observed [36]. For many centres pulmonary angiography is unavailable and in others it is simply not practical to use this procedure routinely to exclude PE. In addition, a negative pulmonary angiogram does not exclude the development of thromboembolic complications. In the PIOPED study, 1.6% of patients with normal pulmonary angiograms developed PE in a one year follow-up period. Most of these events occurred within a month of the procedure [37,38].

Ventilation perfusion (V/Q) lung scanning became the imaging procedure of choice in patients with suspected PE. A normal perfusion lung scan essentially excludes the diagnosis of PE and a high probability lung scan has an 85% to 90% predictive value for PE [38,39]. Unfortunately, most lung scans fit into a non-diagnostic category (neither normal nor high probability) in which the incidence of PE varies from 10% to 30% and further investigation is necessary. Limitations with VQ scans have led to CTPA as the first imaging test in many centres for the investigation of patients with suspected PE. However, this test has limitations many of which are not appreciated by clinicians. CTPA is an evolving technology with early single-slice detectors unable to sufficiently visualize subsegmental arteries [40]. In 2000, a pooled analysis of comparative studies using single slice detector CT scans compared to pulmonary angiography as the gold standard determined CTPA had a sensitivity between 53% and 100% and specificity between 81% and 100% for the diagnosis of PE [41]. Forgie et al. in an earlier meta-analysis reported the pooled sensitivity to be 72% (95% CI 59% to 83%) and specificity to 95% (95% CI 89% to 98%), but for central PE, those involving the main, lobar or segmental pulmonary arteries the sensitivity increased to 94% (95% CI 86% to 98%) and the specificity remained high (94%; 95% CI 88% to 98%) [42]. Since pulmonary angiography studies indicate that from 6% to 36% of pulmonary emboli may be limited to the subsegmental arteries and small emboli may be harbingers for subsequent thromboembolic complications management studies were needed. As discussed below management studies have now been done and the initial fears that CT would miss PE seem to be unfounded provided CT is used in conjunction with ultrasound, clinical assessment or D-dimer. Indeed with current multi-detector scanners sensitivity is likely much better but falsely detecting PE may be more of an issue. CT may also be used in conjunction with VQ scanning since Mayo et al demonstrated that patients with nondiagnostic VQ scans investigated by CT, will have a definitive diagnosis in 80% of cases [43]. Furthermore, CT may identify alternative causes for symptoms in patients with suspected PE but most parenchymal and pleural changes, including wedge-shaped pleural opacities, are found in patients with and without PE [44].

Clinical diagnosis of pulmonary embolism

Similar to the situation with DVT the clinical diagnosis of PE was also felt to be inaccurate and of little value. However, the PIOPED investigators demonstrated that experienced clinicians were able to separate cohorts of patients with suspected PE into high, moderate and low probability groups using clinical assessment alone [37]. Since then, studies have demonstrated that the use of clinical prediction rules allows reasonably accurate stratification of patients into different risk categories.

Table 2. *Variables used to determine patient pretest probability for pulmonary embolism*

• Clinical signs and symptoms of DVT (minimum of leg swelling and pain with palpation of the deep veins)	[3.0 points]
• PE as or more likely than an alternative diagnosis	[3.0 points]
• Heart rate greater than 100	[1.5 points]
• Immobilization or surgery in the previous four weeks	[1.5 points]
• Previous DVT/PE	[1.5 points]
• Hemoptysis	[1.0 points]
• Malignancy (on treatment, treated in the last six months or palliative)	[1.0 points]

Low probability <2.0.
Moderate probability 2.0–6.0.
High probability >6.0.
PE unlikely ≤4.0.
PE likely >4.0.

The clinical assessment consists of consideration of symptoms, signs and risk factors and consideration of an alternative diagnosis. In a study evaluating over 1200 inpatients and outpatients with suspected PE, clinicians using a clinical model were able to distinguish low, moderate, and high probability cohorts in whom the incidence rates of PE were 3%, 28% and 78%, respectively [45]. This model was simplified, tested in several studies and it classifies patients with reasonable accuracy. (Table 2) One investigator concluded the model was of no use but this study did not use the model prospectively, did not use the model for clinical decisions, had a very high overall PE rate, many patients suspected of PE did not complete the study, and physician gestalt assessments were poor, in contrast to other studies [46]. Miniati et al also reported the benefits of clinical assessment [47]. Their combination of symptoms had a negative predictive value of 94% and PE could be excluded in 42% of patients in their validation set. Wicki also described a clinical prediction rule [48]. (Table 3) Comparisons with the model developed by our group have demonstrated both rules to be effective [49]. Selection of patients with a relatively low pretest probability comprises the single most important factor in the derivation of a protocol to safely rule out PE. In summary there are a few prediction rules to choose from and not much evidence exists to advise one over the other [45,48,50–52]. However, only the model published by our group has data assessing interobserver reliability. Wolfe et al demonstrated moderate to substantial interrater agreement and reproducibility of the Wells et al model [53]. Reproducibility was also demonstrated in low risk factor patients [19].

Approach to patients with suspected pulmonary embolism

The approach in patients with suspected PE is similar to that described for patients with suspected DVT. The safety of a protocol for the diagnosis of PE is primarily defined by the rate of PE in patients in whom the protocol excludes PE after performing the indicated investigations i.e. the false negative rate. Protocols are unlikely to result in a 0% post-test probability. Instead, we must settle on a low threshold of about 1% to 2%, i.e. comparable to the reference standard pulmonary angiography. This threshold is chosen for several reasons: Accepted methods to rule out PE are the VQ scan with a normal perfusion pattern or a pulmonary angiography with no evidence of PE yet on follow-up, approximately 1%–2% of patients with either a normal VQ or a negative pulmonary angiography are diagnosed with PE in the subsequent year [38,54–56]. To get a much lower rate seems unlikelysince the rate of PE discovered in a composite population of hospitalized patients and outpatients without recognized signs or symptoms of PE but who underwent contrast-enhanced CT scanning of the chest ranges from 1.5% to 3.4% [57,58]. Finally, if a post-test probability less than 1% is sought, this quest would lead to an unacceptable trade-off in increased pulmonary vascular imaging, and increased false-positive diagnosis of PE.

Several studies have evaluated VQ scanning and CTPA without concomitant use of the D-dimer. An approach combining VQ scanning with clinical probability has been validated [45]. The largest prospective CTPA study to date combined clinical probability and ultrasound imaging with CTPA [59]. Patients with a negative CTPA, negative ultrasound and low or moderate pretest probability had PE excluded

Table 3. *Clinical model described by Wicki et al for assessment of pretest probability for PE*

Criteria	Points
Age 60–79	1
Age >79	2
Prior DVT/PE	2
Recent Surgery	3
Heart rate >100	1
PaCO2, mmHg	
<36	2
36–39	1
PaO2, mmHg	
<49	4
49–60	3
>60–71	2
>71–82	1
Chest X-ray	
Platelet atelectasis	1
Elevation of hemidiaphragm	1

Score range	Mean probability of PE	% with this score	Interpretation of risk
0–4	10%	49%	Low
5–8	38%	44%	Moderate
9–12	81%	6%	High

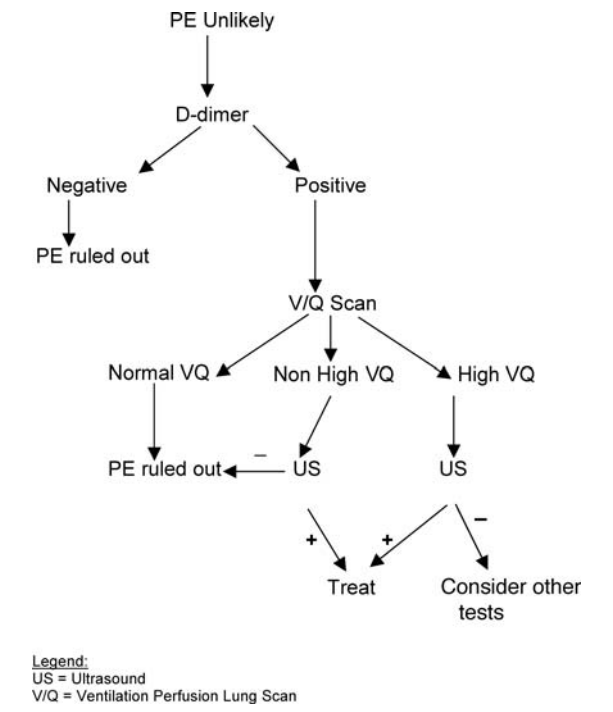

Fig. 4. *Strategy for diagnosis of PE using V/Q and patients who are PE unlikely.*

and the follow-up event rates were 1.8% [59]. Importantly, 15% of patients had a negative CTPA and positive ultrasound study. A recent meta-analysis suggested that a negative CT rules out PE but as the authors indicate only one study employed CT alone [60].

As with DVT the D-dimer assay can be the first objective test used in addition to clinical assessment with the goal of determining which patients require diagnostic imaging. As outlined in the section on DVT clinicians must appreciate that the choice of which D-dimer test to use depends on both sensitivity and specificity. Although sensitivity is important, a safe protocol must also have reasonably high specificity for two reasons: 1) isolated use of a very sensitive test can reduce the post-test probability to 1% but only in a relatively small subset of patients with suspected PE if the specificity is very poor; 2) a test with low specificity will lead to increased use of imaging tests in relatively low-risk patients and this can lead to false positive imaging tests. If CTPA and VQ scans were performed without the consideration of clinical probability or the D-dimer there would be evidence of a diagnostic "positive" result in approximately 5% and 10% of patients without PE, respectively [41,61–63]. This results in at least six months of unnecessary oral anticoagulation therapy with risk of major hemorrhage, and effects on an individual's personal expenditure on health and life insurance.

I recommend that physicians use our clinical model to categorize patients' pretest probabilities as low, moderate or high; alternatively our model can also be used to score patients as "PE likely" or "PE unlikely" [51]. When patients are low probability the SimpliRED, IL-test, or other qualitative D-dimer assays can be performed next and a negative result rules out PE. Since the negative likelihood ratio with the IL test and SimpliRED is about 0.20, the patients pretest probability of PE must be <10% to rule out PE with a negative D-dimer. If the pretest probability is 5% or less the post test probability is about 1%, and if the pretest probability is 10% the post test probability is just over 2% [16]. All other patients should undergo VQ scans or CTPA as outlined in Figure 5. Bilateral deep vein ultrasound is performed if the VQ scan is non-diagnostic or the CTPA is normal. High probability VQ results or positive results on CT should be considered diagnostic of PE except in low pretest clinical probability patients. In these cases the results should be reviewed with the radiologist with consideration of a false positive result. Confirmatory ultrasound or conventional pulmonary angiography should be considered. When the CTPA is negative or the VQ scan non-normal and non-high probability further testing by serial ultrasound, or angiography depends on the pretest probability. Figures 4 and 5 outline acceptable V/Q and

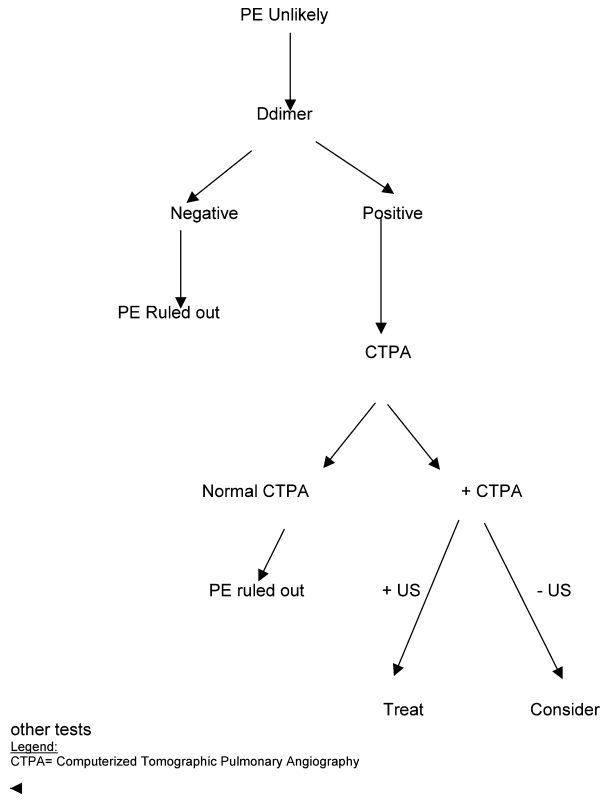

Fig. 5. *Strategy for diagnosis of PE using CTPA and patients who are PE unlikely.*

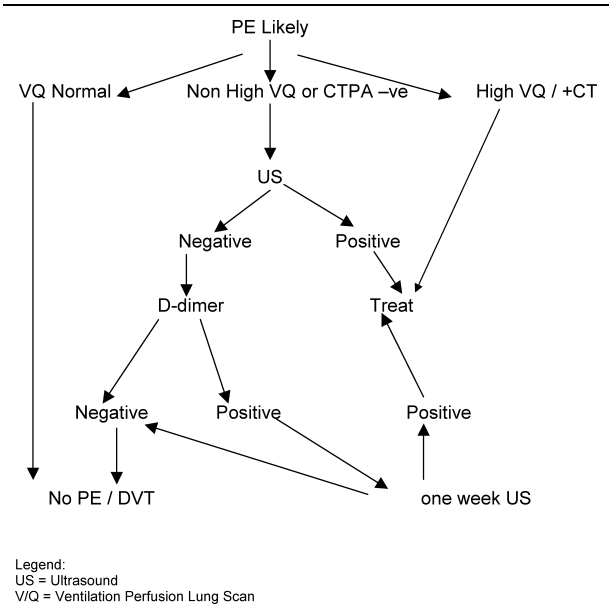

Fig. 6. *Strategy for diagnosis of PE using CTPA or V/Q in patients who are PE Likely.*

CT strategies, respectively. In general, a negative D-dimer in a moderate or perhaps high probability patient negates the need for either serial ultrasound testing or angiography. This strategy should result in <1% of patients considered to have PE ruled out experiencing venous thromboembolic events during three-month follow-up. Incorporation of the D-dimer into the diagnostic algorithm with pretest probability, significantly and safely decreases the need for diagnostic tests [64].

If the VIDAS D-dimer is used in patients who are PE "unlikely" by our revised model [51] or low or moderate probability by the Wicki clinical model the physician can avoid the need for diagnostic imaging when the D-dimer is negative. The likelihood ratio of 0.06 with the VIDAS test implies patients can have a pretest probability of 22% and a negative D-dimer will negate the need for diagnostic imaging. As mentioned the VIDAS is limited by very low specificity in the elderly and hospitalized patients so imaging tests would often be required in these groups. Although Perrier et al have demonstrated that a negative VIDAS D-dimer can negate the need for diagnostic imaging irrespective of pretest probability, I personally am reluctant to adopt this strategy [65]. Perrier and others have chosen to perform ultrasound imaging prior to CT. This may be advantageous since CTPA can be avoided in patients with a positive result (up to 20% of cases) but if this strategy results in significant delay in CTPA then anticoagulation may be advisable prior to sending patients for imaging tests.

It must be recognized that the use of these diagnostic algorithms will probably increase the number of patients in whom a diagnosis of PE is considered since, with implementation of the algorithm, physicians will probably "screen" patients for PE. Our recent study suggests this possibility, since PE was detected in only 8% of patients in whom the diagnosis was considered [64]. The increase in the number of patients considered for a possible diagnosis of PE can increase the overall number of imaging tests performed. Goldstein et al implemented a D-dimer-based screening system for hospitalized patients and found a 40% increase in the rate of VQ scanning [66]. This may create the sense that algorithms will not improve efficiency but algorithms do have a positive effect. It can be calculated that the implementation of the screening system does afford the diagnosis of PE to be made in more patients. In fact, in the study by Goldstein et al, although the D-dimer protocol led to an increase in the rate of VQ scanning of inpatients, the percentage of VQ scans that were ultimately read as positive for PE actually increased. Furthermore, the number of patients in whom PE was diagnosed almost doubled in the centres using a D-dimer algorithm. Additionally, at a hospital where pulmonary vascular imaging is not available at night, algorithms may offer a rational method to decide which patients should receive temporary anticoagulation until pulmonary vascular imaging is available. Emergency physicians faced with a requirement to understand so many diseases welcome protocols that safely simplify care.

Magnetic resonance imaging

MRI of the chest is a relatively recent addition for the diagnosis of PE. This delay in the use of MR for investigation of pulmonary embolism is due to several difficulties, such as motion of both heart and lungs, a risk of artifacts due to interfaces between air and soft tissue and the difficulty of accessing this technology in many places in the world. However, magnetic resonance angiography (MRA) has been increasingly studied for the diagnosis of pulmonary embolism. New technologies have allowed the development of single breath-hold, three-dimensional contrast-enhanced MRA. The potential advantages of MR include the fact that the contrast material is gadolinium which does not have the toxicity of CT contrast material. Contrast-enhanced MRA has demonstrated a sensitivity of 77% and specificity of 98% [67]. Magnetic resonance direct thrombus imaging is also receiving increasing attention. This technique exploits the fact that methemoglobin develops as clotted blood undergoes oxidative denaturation. This technique has been demonstrated to accurately diagnose DVT and has demonstrated an ability to provide a definitive diagnosis in 95% of patients compared to 66% with a VQ scan [67]. However, at this point in time, the technique is not sufficiently standardized and has not been widely enough evaluated to provide definitive conclusions on its ability

to safely diagnose pulmonary embolism. No doubt in the future we will see many publications evaluating MR in patients with suspected pulmonary embolism. As with CT, it will be several years before management studies are available that will allow us to make definitive conclusions on the safety of using MR in patients with suspected PE. It is also possible that due to the cost of the technology and the lack of availability, this technique may never be fully embraced in the diagnostic process. Nonetheless, if we can obtain information on accuracy it will be of value, as there will always be patients who cannot undergo CTPA because of allergy to contrast or renal impairment, and these patients would be ideal for imaging by MR.

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