Comprehensive Analysis of the Results of the PIOPED Study

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The goals of this review were to summarize the published data from the National Heart, Lung and Blood Institute sponsored Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED) study, present new data from the entire population and provide a comprehensive criteria for ventilation-perfusion (V/Q) lung scan interpretation. **Methods:** Data from the PIOPED frequent user tape and journal articles published between 1990 and 1994 and indexed on Medline that presented data from the PIOPED study were reviewed. **Results:** A normal V/Q lung scan excludes the diagnosis of clinically significant PE. The usefulness of the V/Q lung scan was optimized when interpreted as representing a very low, low or high probability of PE with a concordant clinical likelihood of PE. Patients with a V/Q lung scan interpreted as representing an intermediate probability of PE or patients with discordant clinical likelihood of PE and lung scan interpretation will often require further investigations to diagnose or exclude acute venous thromboembolism. **Conclusion:** The results of the PIOPED study support the use of V/Q lung scanning in the diagnostic evaluation of patients with suspected PE. Amendments to the original PIOPED interpretation criteria should reinforce the role of V/Q lung scanning in patients with suspected PE.

Key Words: pulmonary embolism; technetium-99m-aggregated albumin; venous thromboembolism; thrombosis

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Untreated pulmonary embolism (PE) is a potentially fatal condition and appropriate use of anticoagulant or thrombolytic agents improves survival (*1,2*). Effective therapy, however, requires accurate diagnosis. In the mid 1970s concerns were raised over the efficacy of diagnostic tests, particularly ventilation-perfusion (V/Q) lung scans, in diagnosing acute PE (*3*). The prospective investigation of the pulmonary embolism diagnosis (PIOPED) study was a multi-institutional study designed to evaluate the efficacy of various conventional methods for diagnosing acute PE. In particular, the study was designed to determine the sensitivity and specificity of V/Q lung scanning for diagnosing acute PE. In addition, the relative contributions of the clinical findings, chest radiograph and other routine studies were assessed. The PIOPED study also provided an opportunity to evaluate the validity of pulmonary angiography for diagnosing acute PE and determine the incidence of complications related to this procedure. Finally, the study design allowed monitoring of the clinical course and outcome in patients with PE.

In this review, we describe the specific aims and design of the PIOPED study, summarize the published data from the study, present new data from the entire PIOPED population and, finally, provide comprehensive criteria for the interpretation of V/Q lung scans.

STUDY DESIGN

Data were collected prospectively in six tertiary medical centers (Duke University, Henry Ford Hospital, Massachusetts General Hospital, University of Michigan, University of Pennsylvania and Yale University) and coordinated by the Maryland Medical Research Institute. The study population consisted of patients 18 yr or older suspected of suffering acute PE based on risk factors, symptoms, signs or laboratory findings. The clinical findings suggestive of PE were present within 24 hr of study entry. Patients were excluded from the study if, in the judgment of the responsible clinician or angiographer, pulmonary angiography could not be performed. Patients with hypersensitivity to contrast, hemodynamic instability, pregnancy or known pulmonary hypertension were also excluded.

Following entry into the study, patients were followed for 1 yr. Events such as death, suspicion of recurrent PE and complications of angiography or therapy were reviewed by the Outcome Classification Committee. This committee utilized all available clinical information, hospital records and radiographic studies when reviewing outcome events. The outcome data were used to determine the accuracy and the implications of the findings in the various diagnostic studies performed.

Of the eligible patients, 1493 patients consented to participate in the study and V/Q lung scans were completed in 1487 patients. Patients who completed V/Q lung scanning

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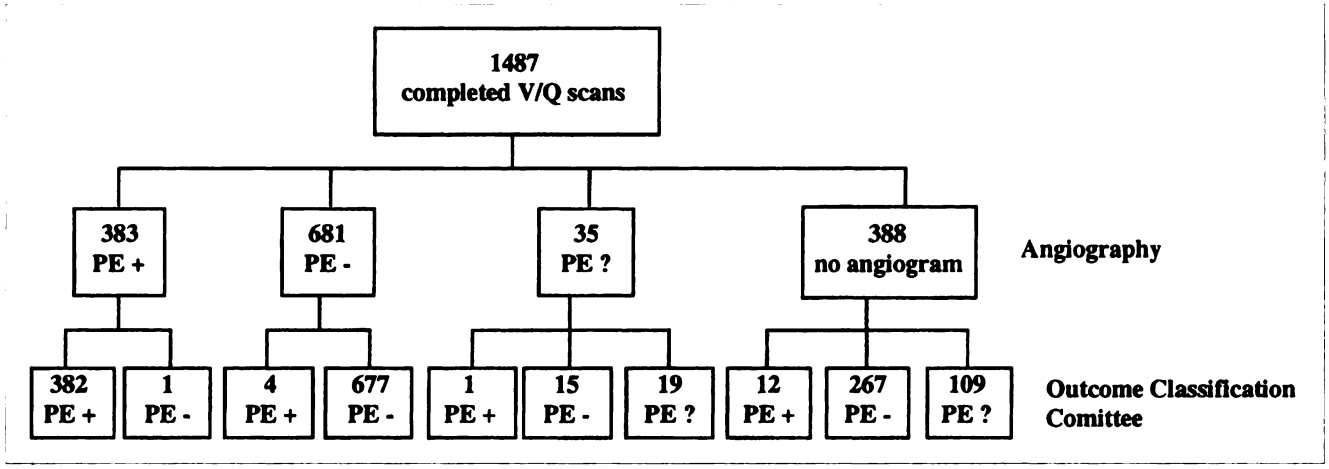

FIGURE 1. Pulmonary angiography and final PE status for 1487 patients who completed V/Q lung scan procedures in the PIOPED study.

were randomized into two groups: PIOPED angiographic pursuit (PAP) or attending physicians angiographic decision (APAD). The initial PIOPED publication included only those patients who were assigned to the PAP group (*4*). Patients enrolled in this arm of the study were required to undergo pulmonary angiography if the V/Q lung scans were interpreted as abnormal. For patients randomized to the APAD group, the decision to undergo angiography was made by the attending physician. A total of 931 patients were assigned to the PAP group. In this group, 755 (81%) patients underwent pulmonary angiography and 22 (2%) patients did not undergo angiography; all patients in this group had V/Q lung scans centrally interpreted as normal. Pulmonary angiography was not performed in 154 (17%) patients despite V/Q scans centrally interpreted as abnormal. The APAD group consisted of 556 patients. In this cohort, 334 (60%) patients underwent pulmonary angiography. Pulmonary angiography was not performed in 10 (2%) patients who had V/Q lung scans centrally interpreted as normal and in 212 (38%) patients with abnormal V/Q lung scans.

DEFINITION AND EXCLUSION OF PULMONARY EMBOLISM

The diagnosis of PE was based on the final pulmonary angiogram interpretation unless review by the Outcome Classification Committee contradicted the final angiogram interpretation. When there was disagreement between angiogram interpretation and classification by the committee, the latter was considered to represent the truth. In patients who completed pulmonary angiography, PE was excluded by a negative pulmonary angiogram and uneventful 1-yr follow-up. For patients in whom the angiographic diagnosis of PE was uncertain or no angiogram was performed, the exclusion of PE was based on uneventful 1-yr follow-up in patients who had anticoagulation withheld and low, very low or normal V/Q scan interpretations. Patients who did not meet the criteria for inclusion or exclusion of PE were classified as uncertain for the presence or absence of PE.

Using the above criteria and the entire PIOPED population (PAP and APAD groups) 27% (399 of 1487) of patients had pulmonary angiographic or autopsy evidence of PE (Fig. 1). Pulmonary embolism was excluded in 65% (960 of 1487) of patients and the diagnosis of PE was uncertain in 9% (128 of 1487) of patients.

CLINICAL DIAGNOSIS OF PULMONARY EMBOLISM

Risk factors, clinical signs and symptoms suggestive of PE were similar in men and women (*5*). The clinical findings in patients with no pre-existing cardiac or pulmonary disease were evaluated in a subset of PIOPED patients by Stein et al. (*6*). A total of 117 patients with PE and 248 patients in whom PE was excluded were included in their analysis. The prevalence of immobilization (strict bed rest for >3 continuous days) and surgery (an incision under regional or general anesthesia) within 3 mo prior to enrollment were more common in patients with PE compared to those without PE (*6*). The frequency of other risk factors that were recorded were approximately the same between the two groups. The most common symptoms of patients with PE and no pre-existing cardiac or pulmonary disease were dyspnea, pleuritic chest pain and cough (*6*). The prevalence of these symptoms, however, were not significantly different when compared with patients in whom PE was excluded. Dyspnea, tachypnea or pleuritic chest pain alone or in combination were present in 97% of patients with PE (*7*). Based on this observation, it was concluded that only a small percentage of patients do not have at least one of the important clinical manifestations of PE. While this statement is valid for the patient population examined, there was a selection bias, which was forced by the study design. Entry criteria into the PIOPED study required that only patients with risk factors, signs, symptoms or laboratory findings which were unexplained and suggestive of acute PE could be enrolled in the study. Therefore, it is not surprising that very few patients had no important manifestations of acute PE.

In the PIOPED study, the clinicians provided estimates

of the clinical likelihood of PE, which were recorded using a continuous scale from 0% to 100%. This estimate was based on clinical findings before knowledge of the V/Q lung scan results. The prevalence of PE in patients with low or very low probability V/Q lung scan interpretations and a low (<20%) clinical likelihood of PE was 7% (*8*). In patients with low or very low probability V/Q scan interpretations and no history of immobilization, recent surgery, trauma to the lower extremities or central venous instrumentation, the prevalence of PE was only 4.5% (*8,9*). Whereas in patients with low or very low probability V/Q lung scan interpretations and one or more of the previously mentioned risk factors, the prevalences of PE were 12% and 21%, respectively. In these patients, further investigations with peripheral venous studies or pulmonary angiography may be warranted.

More recently, neural networks have been developed to aid in the clinical diagnosis of PE. In simplistic terms, neural networks are computer programs capable of processing information similar to the way the human brain processes data. A more detailed description of the application of neural networks in radiological diagnoses can be found elsewhere (*10*). A neural network for the clinical diagnosis of PE has been developed utilizing 50 variables which were available from patients enrolled in the PIOPED study (*11*). These variables included information obtained from history, physical examination, chest radiograph, electrocardiograph and room air arterial blood gas measurements. The likelihood of PE based on clinical findings as predicted by the neural network was similar to that predicted by experienced clinicians. Therefore, neural networks can provide a reproducible assessment of the clinical likelihood of PE and may aid in the diagnostic evaluation of patients suspected of having acute PE. The clinical manifestations of PE, however, were quite variable and lack the specificity to reliably diagnose or exclude clinically significant PE.

CHEST RADIOGRAPHIC FINDINGS IN PULMONARY EMBOLISM

In the PIOPED study, chest radiographs were obtained within 24 hr of angiography. In the majority of cases (83%), erect posterior-anterior chest radiographs using a 72-inch source to image distance were obtained. Among patients with angiographically documented PE, only 12% (45 of 383) of patients had chest radiographs interpreted as normal (*12*). The positive and negative predictive values of a normal chest radiograph were 18% and 74%, respectively. In patients with PE and no pre-existing cardiac or pulmonary disease, only 16% had chest radiographs interpreted as normal (*6*). The most common chest radiographic findings in patients with PE were atelectasis and/or parenchymal opacities in the affected lung zone (*6,12*). Atelectasis and/or parenchymal opacities, however, were also the most common finding in patients in whom PE was excluded. Pleural effusions within the affected hemithorax occurred in approximately 35% of patients with PE. The majority of pleural effusions were small, causing only blunting of the costophrenic angles (*12*). Therefore, chest radiographic findings alone were nonspecific for PE, but they are essential in the management of patients with suspected PE to diagnose conditions that can clinically mimic PE and aid in the interpretation of V/Q lung scans.

VENTILATION-PERFUSION LUNG SCANNING IN PULMONARY EMBOLISM

In the PIOPED study, ventilation imaging was performed with 15–30 mCi of ^{133}Xe. A first breath image was obtained for 100,000 counts in the posterior projection. This was followed by two consecutive 120-sec equilibrium images. Finally, serial 45-sec dynamic washout imaging was performed in the posterior, right posterior oblique and left posterior oblique projections. The diagnostic performance of the V/Q lung scan was significantly better in patients who had ventilation studies performed in the erect position compared to the supine position (*13*). Perfusion imaging was performed following the administration of 4 mCi of ^{99m}Tc-macroaggregated albumin. While lying supine, patients were intravenously administered between 100,000 and 500,000 particles over 5–10 respiratory cycles. Anterior, posterior, anterior oblique and posterior oblique images were acquired for 750,000 counts. For the lateral views, the lung with the best perfusion was imaged from 500,000 counts. The contralateral view was obtained for the same length of time. Ventilation-perfusion lung scans were interpreted centrally by two readers who were not from the institution where the image was obtained. The probability of PE were interpreted using an ordinal scale according to original PIOPED criteria (*4*). If both readers agreed in their assessment of the probability of PE, the consensus was considered as the final interpretation. If, however, there was greater than one category step difference in probabilities assigned by the readers or if one reader reported intermediate probability and the other did not, adjudication by a third reader was required. If all three readers disagreed, adjudication by the Nuclear Medicine Working Group Panel determined the final interpretation.

Among patients who completed V/Q lung scanning, central reader agreement for high probability and very low probability or normal interpretations were 87% (179 of 205) and 89% (107 of 120), respectively. For low and intermediate probability scan interpretations, reader agreement occurred in 75% (440 of 589) and 58% (333 of 573) of cases. A greater than one step difference in the scan interpretation category was present in 4% (64 of 1487) of cases.

The sensitivity and specificity for V/Q scanning to detect acute PE for patients assigned to the PAP group have been previously published (*4*). The central V/Q scan interpretations using the entire PIOPED data and information from the Outcome Classification Committee yield similar findings for patients in both the PAP and APAD groups (Table 1). The diagnostic performance of the V/Q lung scan, as

TABLE 1
Sensitivity, Specificity and Positive Predictive Value (PPV) of V/Q Lung Scanning in Detecting Acute PE

V/Q scan interpretation	Sensitivity (%)			Specificity (%)			PPV (%)		
	PAP	APAD	Both*	PAP	APAD	Both*	PAP	APAD	Both*
High	40%	40%	40%	98%	97%	98%	88%	85%	87%
High, Intermediate	81%	83%	82%	63%	67%	64%	48%	51%	49%
High, Intermediate, Low	99%	100%	99%	12%	12%	12%	32%	32%	32%

* Includes patients from both the PAP and APAD groups in whom the diagnosis of PE was confirmed (n = 1359).
PAP = PIOPED angiographic pursuit; APAD = attending physician's angiographic decision.

determined by the area under a maximum likelihood fitted receiver operating characteristic (ROC) curve, measured 0.8437 ± 0.130. This value was significantly higher when compared with the clinical likelihood of PE which measured 0.7087 ± 0.0173 (Fig. 2). The distribution of patients in each V/Q scan category and corresponding prevalences of PE are shown in Table 2. A neural network generated from V/Q lung scan and chest radiograph interpretations obtained a maximum diagnostic performance of 0.9121 ± 0.0160 (*14*). When the clinical likelihood of PE and V/Q lung scan interpretation were concordant, the ability to diagnose or exclude PE was optimized. The value of combining the V/Q scan interpretation with associated risk factors are presented in Table 3. In patients with low or very low probability V/Q scan interpretation and no history of immobilization, trauma to the lower extremities, recent surgery or central venous instrumentation, the prevalence of PE was 4%. In patients with similar lung scan findings and two or more of the above mentioned risk factors, the prevalence of PE was 21%. Importantly, none of the patients with V/Q scans interpreted as normal had evidence of PE. Based on PIOPED data, patients in whom V/Q lung scans are interpreted as intermediate or in whom the clinical likelihood estimates of PE were discordant with the V/Q scan interpretation, further investigations, with venous studies of the lower extremities or pulmonary angiography, are usually required to diagnose or exclude venous thromboembolism.

The sensitivity and specificity, positive and negative predictive values of V/Q scanning were not significantly different in women compared with men (*5*). Similarly, the overall diagnostic performance of the V/Q scan was similar among patients with varying ages (*15,16*). The diagnostic utility of V/Q scanning to detect PE was similar among patient with pre-existing cardiac or pulmonary disease compared with patients who had no underlying cardiac or pulmonary disease (*16,17*). In a subset of patients with chronic obstructive pulmonary disease, the sensitivity of a high probability V/Q scan interpretation, was significantly lower compared to patients with no pre-existing cardiopulmonary disease (*18*). The positive predictive value of a high probability V/Q scan interpretation, however, was 100% and the negative predictive value of a low or very low probability V/Q scan interpretation was 94%.

The evaluation of mismatched vascular defects (either moderate or large segmental V/Q mismatch) has been suggested as an alternative to evaluating segmental equivalents (*19–21*). Thirty-three percent (125 of 378) of patients with PE had no mismatched vascular defects, as defined by Stein et al. (*19,20*). The reason for the relatively high prevalence of PE among patients with no mismatched vascular defects may be explained in part by the failure to include perfusion defects with substantially smaller chest radiographic or ventilation abnormalities as V/Q mismatches. Therefore, while the presence of mismatched vascular defects can be helpful in identifying patients with PE, the absence of the finding does not exclude the diagnosis.

AMENDMENTS OF ORIGINAL PIOPED CRITERIA

Several revisions of the original PIOPED criteria have been made based on the observations from the PIOPED study (Fig. 3). Multiple matched V/Q defects involving greater than 50% of one lung or greater than 75% of one lung zone were classified as intermediate probability for acute PE according to the original PIOPED criteria. Matching V/Q defects of lesser extent were classified as low probability for acute PE. The prevalence of PE in patients

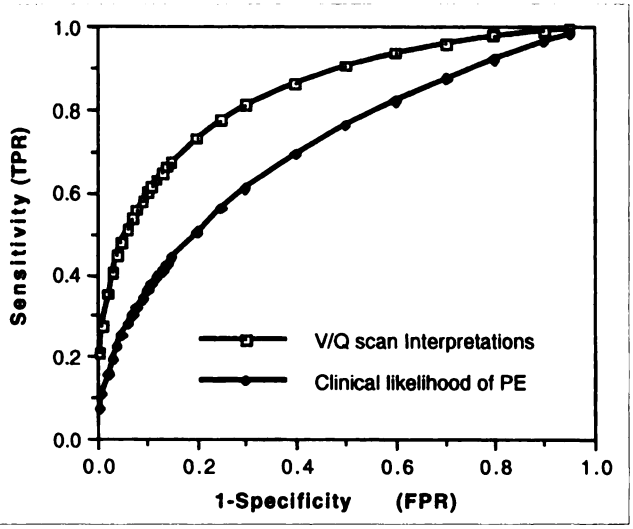

FIGURE 2. Fitted receiver operating characteristic curves demonstrate the superior diagnostic performance of V/Q scanning compared with the clinical assessment of the likelihood of PE.

TABLE 2
Distribution of Patients and Prevalence of PE for Each V/Q Lung Scan Interpretation Category

V/Q scan interpretation	PE + (No. of patients)			PE − (No. of patients)			Prevalence of PE (%)
	PAP	APAD	Total	PAP	APAD	Total	
High	105	55	160	14	10	24	87.0
Intermediate	108	61	169	216	102	318	34.7
Low	45	23	68	311	190	501	12.0
Very low	2	0	2	50	28	78	2.5
Normal	0	0	0	26	13	39	0.0
Total	260	139	399	617	343	960	29.4

PAP = PIOPED angiographic pursuit; APAD = attending physician's angiographic decision.

with extensive matched V/Q defects and no chest radiographic evidence of a pleural effusion or parenchymal abnormality was 14% (*22*). In patients with a single matched V/Q defect, the prevalence of PE was 26% (*22*). Therefore, multiple matched V/Q abnormalities (regardless of size) may be categorized as low probability of acute PE in the absence of pleural effusion or parenchymal abnormality. Patients with single, matched V/Q defects and a normal chest radiograph have a 26% prevalence of PE and therefore should be classified as intermediate probability of acute PE.

A single moderate sized V/Q mismatch was classified as representing a low probability of PE using the original PIOPED criteria. Thirty-six percent of patients with a moderate sized V/Q mismatch, however had PE. Therefore, this finding represents intermediate probability for acute PE (*22*).

The overall prevalence of PE in a zone with matching V/Q defects and chest radiographic opacities (triple matches) was 26% (*23*). Triple matches within the upper and middle lung zones have a lower prevalence of PE compared to triple matches in the lower lung zones. When triple matches were present within the upper and middle lung zones, the prevalences of PE were 11% and 12%, respectively, whereas PE was present in 33% of lower lung zones demonstrating triple matches (*23*). Therefore, patients with matching V/Q defects and chest radiographic opacities isolated to the upper or middle lung zones represent a low probability for acute PE. Similar findings within the lower lung zones are evidence for intermediate probability for acute PE.

Among patients with no previous cardiopulmonary disease, no patient with PE had radiographic evidence of pleural effusions occupying more than one-third of the hemithorax (*6*). Therefore, V/Q defects with large pleural effusions represent low probability of acute PE. In contrast, the majority of patients with PE and pleural effusions had small effusions which caused blunting of the costophrenic angles. The prevalence of PE within the lower lung zones in patients with small pleural effusions was 32% in the right hemithorax and 25% in the left hemithorax (*12*). Therefore, matching V/Q defects with a small effusion represent intermediate probability of acute PE.

The stripe sign is defined as a rim of perfused lung tissue between the perfusion defect and the adjacent pleural surface. The presence of the sign excluded the diagnosis of PE within the effected zone in 93% of patients (*24*). Therefore, perfusion defects demonstrating a stripe sign are unlikely to be due to PE, and, in the absence of perfusion defects elsewhere, should be interpreted as low probability for PE.

By utilizing a number of the above revisions to the original PIOPED criteria, it should be possible to decrease the number of intermediate V/Q scan interpretations and correctly read them as low probability of acute PE. The use of revised PIOPED criteria has already been shown to provide

TABLE 3
Value of Combining the V/Q Scan Interpretation with Selected Associated Risk Factors

V/Q scan Interpretation	0 Risk factors* PE+/No. of patients (%)	1 Risk factor* PE+/No. of patients (%)	≥2 Risk factors* PE+/No. of patients (%)
High	63/77 (82)	41/49 (84)	56/58 (97)
Intermediate	52/207 (25)	40/107 (37)	77/173 (45)
Low/Very Low	14/315 (4)	19/155 (12)	37/179 (21)
Normal	0/28 (0)	0/7 (0)	0/39 (0)

*Risk factors include immobilization for >3 days prior to presentation, surgery, trauma to the lower extremities or central venous instrumentation within 3 mo of presentation.

High Probability
- ≥ 2 large (> 75% of a segment) segmental perfusion defects without corresponding ventilation or CXR abnormalities.
- 1 large segmental perfusion defect and ≥ 2 moderate (25-75% of a segment) segmental perfusion defects without corresponding ventilation or CXR abnormalities.
- ≥ 4 moderate segmental perfusion defects without corresponding ventilation or CXR abnormalities.

Intermediate Probability
- 1 moderate to < 2 large segmental perfusion defects without corresponding ventilation or CXR abnormalities.
- Corresponding V/Q defects and CXR parenchymal opacity in lower lung zone.
- Single moderate matched V/Q defects with normal CXR findings.
- Corresponding V/Q defects and small pleural effusion.
- Difficult to categorize as normal, low or high probability.

Low Probability
- Multiple matched V/Q defects, regardless of size, with normal CXR findings.
- Corresponding V/Q defects and CXR parenchymal opacity in upper or middle lung zone.
- Corresponding V/Q defects and large pleural effusion.
- Any perfusion defects with substantially larger CXR abnormality.
- Defects surrounded by normally perfused lung (stripe sign).
- >3 small (< 25% of a segment) segmental perfusion defects with a normal CXR.
- Nonsegmental perfusion defects (cardiomegaly, aortic impression, enlarged hila).

Very Low
- ≤3 small (< 25% of a segment) segmental perfusion defects with a normal CXR.

Normal
- No perfusion defects and perfusion outlines the shape of the lung seen on CXR.

V/Q = Ventilation-perfusion
CXR = Chest radiograph

FIGURE 3. Amended PIOPED V/Q lung scan interpretation criteria.

a more accurate assessment of angiographically proven PE compared with the original criteria (*25,26*).

The nuclear medicine physician's subjective estimate of the likelihood of PE (without using specific interpretation criteria) correlated well with the fraction of patients with angiographic evidence of PE (Fig. 4). Thus, experienced readers (such as the PIOPED investigators) can provide an accurate estimate on the probability of PE based on radiographic and scintigraphic findings.

PULMONARY ANGIOGRAPHY IN PULMONARY EMBOLISM

All angiograms were obtained within 24 hr of the V/Q lung scan. Both the chest radiograph and V/Q lung scan were available at the time of angiography. The procedure was carried out utilizing femoral venous access and a Seldinger technique. Patency of the inferior vena cava was checked with hand injections of small amounts of contrast. A guide wire was used to deflect the catheter into the pulmonary artery supplying the side with the largest V/Q abnormality. Low magnification or nonmagnified anterior-posterior images were then obtained. Magnified oblique views were obtained if PE was not seen on the anterior-posterior projections. At three of the participating centers, both lungs were routinely examined, while, at the remaining three centers, the procedure was terminated when PE was identified in the first lung examined.

Angiographic diagnosis of acute PE was strictly based on the identification of an intraluminal filling defect or the trailing edge of a thrombus obstructing a vessel. All pulmonary angiograms were interpreted by two readers who were not from the institutions where the study was performed. The angiograms were interpreted as to the presence, absence or uncertainty of acute PE. If both readers agreed, the interpretation was considered final. If the first two readers disagreed, the interpretation was adjudicated by a third reader. If all three readers disagreed, the final inter-

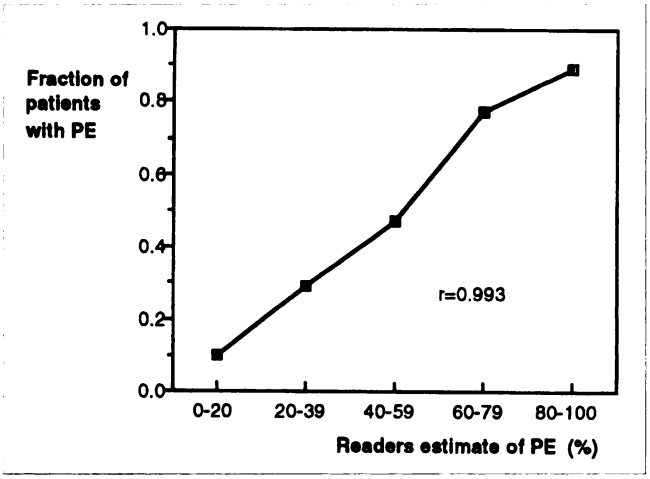

FIGURE 4. Correlation of the nuclear medicine physician's estimate of the likelihood of PE and the fraction of patients with PE on angiography.

pretation was rendered by the Angiography Working Group Panel.

In patients who had angiographic evidence of PE, reader agreement was 86% (331 of 383). In patients with angiograms interpreted as negative or uncertain for PE, reader agreement was 80% (544 of 681) and 40% (14 of 35), respectively.

Pulmonary angiography was completed in 99% (1099 of 1111) of patients who consented to undergo the procedure (*27*). The distribution of the final angiogram interpretations is presented in Figure 1. In the majority of patients in whom angiography was not completed, a complication was encountered during the procedure. Nondiagnostic pulmonary angiograms were obtained in only 3% (35 of 1111) of patients.

The validity of pulmonary angiography was assessed by the Outcome Classification Committee (Fig. 1). In 681 patients whose angiograms were interpreted as being negative for PE, only 4 patients had their diagnosis reversed by the committee. Thus, a negative pulmonary angiogram excluded the diagnosis of acute PE in 99% (667 of 681) of patients. Since angiography was considered the gold standard in the PIOPED study, the validity of a positive angiogram representing PE could not be assessed. In one patient with angiographic diagnosis of PE, however, the committee failed to document PE at autopsy.

An analysis of the regional distribution of PE on angiography demonstrated that PE occurred more frequently on the right, compared with the left, and more frequently in the lower lung zones compared with the middle or upper lung zones (*28*).

The complications related to pulmonary angiography have been well documented by Stein et al. (*27*). Death attributed to pulmonary angiography occurred in 0.5% (5 of 1111) of patients. Nonfatal major complications, including respiratory distress, severe renal failure or hematoma requiring transfusion, occurred in 1% (14 of 1111) of patients. The frequency of major complications was higher in patients from the medical intensive care unit compared with patients from other wards. Minor complications, which were not life-threatening and responded promptly to pharmaceutical therapy, occurred in 5% (60 of 1111) of patients. The most common minor complications were urticaria or pruritus and mild renal dysfunction. The frequency of complications was not related to patient age, the presence of PE or pulmonary artery pressure.

Pulmonary angiography provided a reliable method for excluding PE in 99% of patients. The low morbidity (6%) and mortality (0.5%) associated with pulmonary angiography justifies its use in selected patients with suspected PE.

OUTCOME OF PATIENTS WITH PULMONARY EMBOLISM

Of the 399 patients in whom PE was confirmed, treatment was initiated for 94% (375 of 399). Of the 24 patients who were not treated, 19 had negative angiogram interpretations at the local hospital, which were in disagreement with the final angiogram interpretation. Death attributed to pulmonary embolism occurred in only 2.5% (10 of 399) of patients with PE (*29*). Of the patients who died of PE, only one was untreated. Nine of the deaths were due to clinically suspected recurrent PE. Therefore, when properly diagnosed and treated, death attributed to PE was relatively uncommon.

CONCLUSION

The V/Q lung scan is an effective, noninvasive method to diagnose or exclude the presence of acute PE. Based in part on the data from the PIOPED study, diagnostic strategies have been developed and V/Q scanning remains a pivotal tool in the diagnostic evaluation of patients with suspected PE (*30–32*). The utility of the V/Q lung scan is optimized when interpreted as representing a low or high probability of PE with a concordant clinical likelihood of PE. A normal V/Q lung scan interpretation excludes clinically significant PE. Revisions to the original PIOPED interpretation criteria should strengthen the role of V/Q lung scanning in patients with suspected PE. Many patients, however, will require further investigation with peripheral venous studies or pulmonary angiography to confirm the presence or absence of clinically significant thromboembolism.

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