Original Article

Correlation between the clinical pretest probability score and the lung ventilation and perfusion scan probability

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ABSTRACT

Purpose: Aim of the study was to determine the accuracy of the clinical pretest probability (PTP) score and its association with lung ventilation and perfusion (VQ) scan. **Materials and Methods:** A retrospective analysis of 510 patients who had a lung VQ scan between 2008 and 2010 were included in the study. Out of 510 studies, the number of normal, low, and high probability VQ scans were 155 (30%), 289 (57%), and 55 (11%), respectively. **Results:** A total of 103 patients underwent computed tomography pulmonary angiography (CTPA) scan in which 21 (20%) had a positive scan, 81 (79%) had a negative scan and one (1%) had an equivocal result. The rate of PE in the normal, low-probability, and high-probability scan categories were: 2 (9.5%), 10 (47.5%), and 9 (43%) respectively. A very low correlation (Pearson correlation coefficient r = 0.20) between the clinical PTP score and lung VQ scan. The area under the curve (AUC) of the clinical PTP score was 52% when compared with the CTPA results. However, the accuracy of lung VQ scan was better (AUC = 74%) when compared with CTPA scan. **Conclusion:** The clinical PTP score is unreliable on its own; however, it may still aid in the interpretation of lung VQ scan. The accuracy of the lung VQ scan was better in the assessment of underlying pulmonary embolism (PE).

Keywords: Pretest probability score, pulmonary embolism, ventilation and perfusion

INTRODUCTION

The diagnostic yield of pulmonary embolism (PE) using symptoms, signs, and common laboratory tests individually is limited; however, the combination of these variables using one of a standardized prediction rules (SPRs) such as Wells score and Geneva score, is used to express a clinical pretest probability (PTP) of PE. Several studies have tested the performance of different SPRs in different population and clinical settings, with an intention of improving the accuracy of the diagnosis.[1,2] The planar lung ventilation and perfusion (VQ) scan is the standard initial imaging investigation of choice for patients suspected with PE.[3,4] The purpose of this study was to determine whether there was any correlation between the clinical PTP score and planar lung VQ scan.

Access this article online

Quick Response Code:

Website: www.ijnm.in

DOI: 10.4103/0972-3919.121967

MATERIALS AND METHODS

Patients and materials

A retrospective review of the hospital records of 528 patients who underwent lung VQ scanning at a Teaching Hospital, London from 01.01.2008 to 31.12.2010 was performed. Eighteen VQ scans were excluded due to having no PTP score or poor quality data. In this study, 87 (out of 510) VQ scans were reported as indeterminate probability scans. These scans were reread by an independent clinician using simple criteria[5] [Table 1] and the second interpretations of these indeterminate scans were randomized with the rest of the study sample [Figure 1]. Figure 1 demonstrates that overall, out of 510 patients, 155 had normal VQ scan results, 289 had low probability scan results and 66 had high probability scan results.

The Computerized Radiological Information Solution (CRIS) system was reviewed for patient demographics, symptoms on presentation, risk factors for PE, D-dimer assay, plain radiography

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of chest, lung VQ scan, and computed tomography pulmonary angiography (CTPA). Ethical approval was sought and obtained from the Trust Local Research Ethics Committee and the Clinical Governance Department authorized the study to be carried out in the Nuclear Medicine Department.

The standardized data form for the evaluation of PTP of PE was completed for each patient by the physician incharge before any specific tests for suspected PE were performed. The clinical assessment of PE using Wells score was categorized as low, moderate, and high probability.[6] Each patient had both the lung VQ scans on the same day, except pregnant women whose ventilation scan was performed the next day only if perfusion scan showed any abnormalities. The nuclear medicine physician on duty interpreted the lung VQ scans on completion using modified Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED) criteria.[7]

The VQ scan was performed using the local protocol and 600 MBq of 99mTc-diethylenetriaminepentaacetic acid (DTPA) aerosol was administered through a breathing mask. The ventilation scan performed with the subject in the supine position using a 20% symmetric window set over the 140 keV energy peak. The static images for anterior, posterior, right posterior oblique (RPO), and left posterior oblique (LPO) projections were acquired for 180 s each. The perfusion lung scan was performed using intravenous administration of 100 MBq of 99mTechnetium-labeled macroaggregated albumin (MAA). The patient was administered between 100,000 and 500,000 particles of 99mTc-MAA over five to 10 respiratory cycles to enhance the homogeneous distribution of radiotracer. The static images, using the same projected views, were acquired for 150 s each. Scintillation cameras with a wide field of view (38 cm in diameter) were used; with low-energy all purpose (LEAP) collimators using 256 × 256 matrixes. CTPAs were performed using either a Siemens Somatom Sensation 16 multislice or a GE LightSpeed VCT 64 slices CT scanner. Most of the CTPA scans performed within 7 days of referral.

Statistical methods

The Pearson correlation coefficient (r) quantifies the strength of the relationship between the variables, ranging from −1.0 to 1.0.[8] The receiver operating characteristic (ROC) analysis was performed using the Rockit 0.9 beta version.[9] The accuracy of the clinical PTP and the VQ scan probability were compared with the CTPA scan by means of the area under the curve (AUC). In order to have continuous scores for the ROC analysis, the clinical probability from the Wells score was coded 0-2, 2-6, and above 6 for low, moderate, and high probability, respectively; while the VQ scan categories were coded as 0, 1, and 2 for normal, low probability, and high probability, respectively. Similarly, the CTPA scan results were coded as 0 for negative and 1 for positive results for the purpose of this study.

Table 1: Simple criteria

High probability scan	A perfusion defect larger than ventilation defect or A perfusion defect with normal ventilation
Low probability scan	A perfusion defect smaller than the ventilation defect Matched ventilation and perfusion defect The defect does not follow the anatomical distribution of segments
Normal scan	No perfusion defect

Table 2: Correlation between the clinical pretest probability with ventilation and perfusion probability

PTP	VQ probability			
Category	Normal	Low	High	Total
Low	69 (44%)	103 (36%)	13 (20%)	185
Moderate	74 (48%)	166 (57%)	39 (59%)	279
High	12 (8%)	20 (7%)	14 (21%)	46
Total	155	289	66	510

The Clinical PTP score compared with CTPA. PTP: Pretest probability, VQ: Ventilation and perfusion

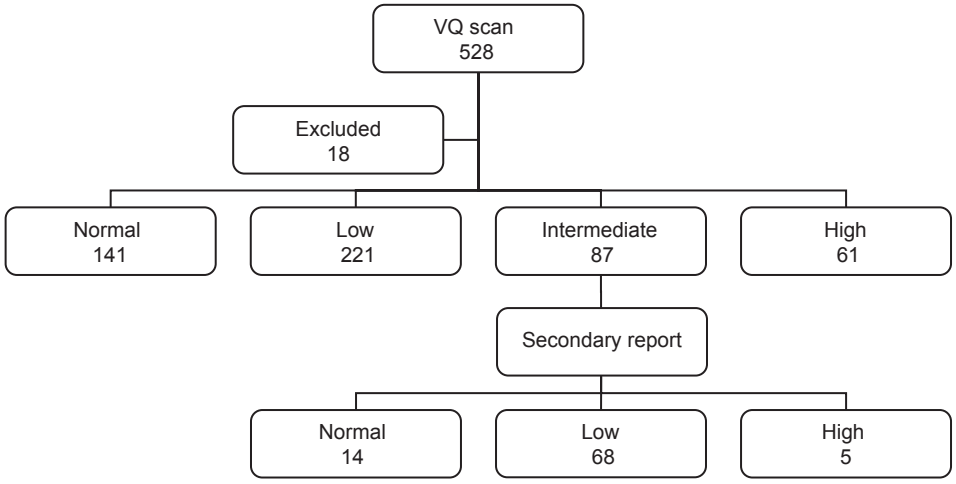

Figure 1: Flow chart diagram representing distribution of ventilation and perfusion scans

RESULTS

A total of 510 patients who had both the clinical PTP and lung VQ scan [Table 2]. Of these, 171 (34%) were male and 339 (66%) were female, with a median age at the time of scan of 52 years (range 18-91 years). Approximately 80% of patients presented with risk factors for PE and the remaining 20% of patient records indicated that the patient had pleuritic chest pain. In this study, only 20% (103 of 510) patients required a CTPA scan to establish the final diagnosis in whom 62 scans were originally reported as indeterminate scans and remaining 41 scans had high/moderate clinical PTP with low probability/normal scans. D-dimer results available for 480 patients in whom 470 patients had positive results and 10 patients had negative results.

The number of high probability scans was 14 (21%), 39 (59%), and 13 (20%) if the clinical PTP was high, moderate, and low, respectively. A total of 36% (103 of 289) of patients with low probability VQ scans also had a low clinical PTP; however, only one of these patients had a negative D-dimer result. Forty-four percent (69 of 155) of patients with normal VQ scans also had a low clinical PTP, and again, only one patient had a negative D-dimer result.

Interestingly, 80% (407 of 510) of patients were managed clinically according to a decision based on their lung VQ scan alone. Our previous study, using teaching hospital algorithm, reported that 81% of patients with suspected PE had decisions regarding their further management based on their VQ scan result.[10] The correlation coefficient (r) among the clinical PTP score and lung VQ scan probability in this study was 0.20 (confidence interval (CI) 0.09-0.26) [Figure 2]. A similar study reported the agreement between the clinical PTP and lung VQ scan was 0.23.[11]

A clinical PTP score for PE was performed prior to the scan for each of the patients; however, CTPA scan results were available for only 20% (103 of 510) of the patients in this study [Table 3]. A clinical assessment of high probability of PE was made in 12 patients and was correct for three of these 12 patients. A clinical assessment of low probability for PE was made in 31 patients, 24 of whom had a negative CTPA result. A clinical assessment of moderate probability for PE was made in 60 patients; however, 11 of 60 patients were confirmed with PE. The AUC for the clinical PTP was 0.52 when compared with CTPA results [Figure 3].

VQ scans compared with CTPA results

The positive CTPA results with corresponding normal, low-probability, and high probability VQ scan categories were: 2 (9.5%), 10 (47.5%), and 9 (43%), respectively [Table 3]. The frequency of CTPA demonstrable emboli among patients with low probability VQ scans was 14% (10 out of 71 patients) and among patients with normal VQ scans was 11% (two out of 18 patients). It must be noted; however, that these results may have been influenced by the relatively large number of patients for whom CT angiography was not completed, interpretations were uncertain or the images were of poor quality. Nevertheless, 86% (61 out of 71 patients) with a low clinical probability VQ scan and 89% (16 out of 18 patients) with a normal VQ scan excluding PE were confirmed as negative by CTPA. In this study, nine out of the 21 patients

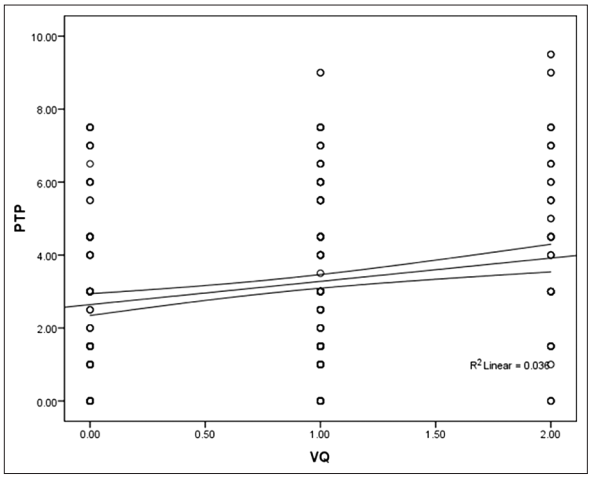

Figure 2: Correlation graph between clinical pretest probability and lung VQ scan

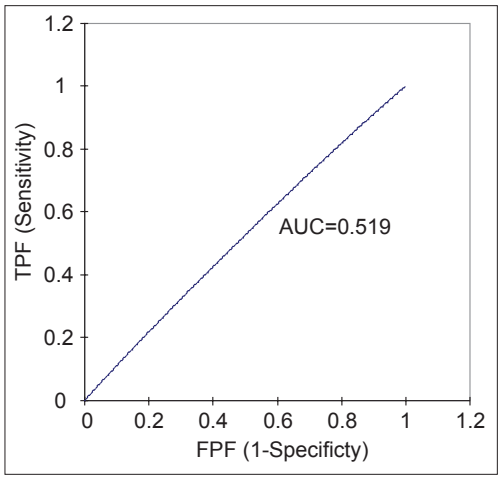

Figure 3: Receiver operating characteristic curve between clinical PTP and computed tomography pulmonary angiography (CTPA)

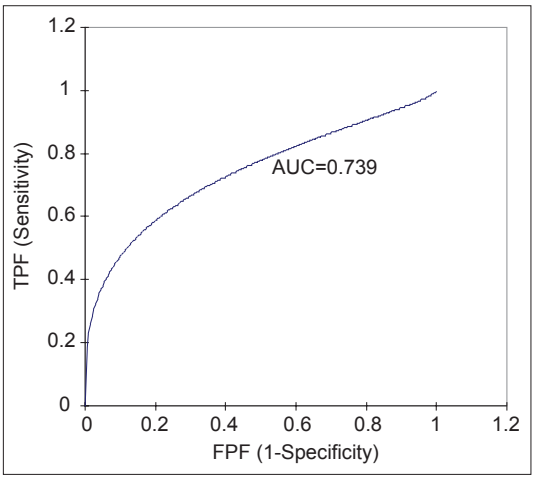

Figure 4: Receiver operating characteristic curve between VQ scan and CTPA

Table 3: Clinical pretest probability score and ventilation and perfusion scan compared with pulmonary embolism status as determined by computed tomography pulmonary angiography

Categories	Number of patients who underwent CTPA	Patients with PE (CTPA)
PTP		
High probability	12	3
Moderate probability	60	11
Low probability	31	7
Total group	103	21
VQ scan		
High probability	14	9
Low probability	71	10
Normal	18	2
Total group	103	21

PTP: Pretest probability, VQ: Ventilation and perfusion, PE: Pulmonary embolism, CTPA: Computed tomography pulmonary angiography

with a positive CTPA result also had high probability VQ scans. The AUC for lung VQ scan was 0.74 when compared with CTPA results [Figure 4].

DISCUSSION

According to the Teaching Hospital algorithm for PE, if the clinical PTP score indicates that PE is likely, the plain chest radiograph is normal and the D-dimer is positive, then diagnostic imaging should commence with either a VQ or CTPA scan. The clinical PTP assessment using the Wells score provides greater accuracy in estimating the clinical PTP score, independent of clinician's experience, and allows the option for alternative diagnosis.[6,12] Although the sensitivity of the D-dimer test is high, the specificity is not sufficiently high enough for the test to be diagnostic;[13] however, D-dimer is a valuable tool in the exclusion of PE, as the negative predictive value of D-dimer is high.[14] The advantage of the VQ scan are a lower radiation dose than CTPA and the lack of need for iodinated contrast; therefore, VQ scanning is often considered as the preferred alternative chest imaging to CTPA.[14,15]

The statistical analysis showed that the Pearson correlation coefficient between the clinical PTP scores and the lung VQ scan was weak (r = 0.20). The percentage of high probability scan (13%) and low probability scan (57%) in our study, were being close to Barghouth *et al.*, study (14 and 57%, respectively). However, our study showed a higher proportion of normal scan (30%) than Barghouth *et al.*, study (11%). There are some difference between our study and Barghouth *et al.*, study. Firstly, the Wells score was used for clinical PTP assessment in our study; whereas, Barghouth *et al.*, study used clinicians' experience. Secondly, modified PIOPED criteria were used for interpretation of VQ scan in our study; whereas, Barghouth *et al.*, study used revised PIOPED criteria. Thirdly, CTPA scan was used as a reference standard test in our study; whereas, Barghouth *et al.*, used pulmonary angiogram. Finally, intermediate probability category was not discussed in our study. Only 20% of the patients required CTPA, which reproduces our previous annual distribution and is comparable with Barghouth *et al.*, study that reported 20% of their study population required pulmonary angiogram.

Although lung VQ scans are the most frequently performed procedure for the diagnosis of PE, there are growing controversies about its relevance, particularly due to the complexity of its reporting criteria, the high interobserver variability and the high number of non-diagnostic scans.[15] This issue is addressed in VQ single photon emission computed tomography (SPECT) guidelines as interpretation allows only either positive or negative scan.[16] A study comparing lung VQ SPECT, lung VQ planar scanning, and CTPA showed the sensitivity and specificity of lung VQ SPECT are superior to planar imaging and comparable to CTPA.[17] Pulmonary angiogram is considered to be the gold standard imaging test; however, it is not practiced in many centers. CTPA is a popular choice in many hospitals due to its high efficiency and accuracy, and the relatively low rate of non-diagnostic examinations. Many clinicians have embraced this procedure; however, concerns such as radiation exposure and the side effects of contrast administration keep the role of the VQ scan relevant.[18,19] The effective radiation dose from a VQ scan is 1.4 mSv[20] compared to 10-12 mSv[21] from routine CTPA. CT dose may be reduced using adaptive statistical iterative reconstruction technique.[22]

There was some crossover in the study populations: If patient had a CTPA first, crossover to VQ scanning occurred if there was a non-diagnostic CTPA, radiation dose, unable to cannulate a vein, poor renal function, or contrast allergy. Vice versa, crossover from a VQ scan to CTPA occurred for non-diagnostic VQ scans and inability to perform VQ scan.

CONCLUSIONS

The PTP is a clinical entity to assess PE, but does not have insufficient accuracy to determine even in patients with positive D-dimer result. However, use of diagnostic algorithm including D-dimer, clinical PTP, VQ scan, and CTPA; the efficiency to determine presence of PE in majority of the patients with normal radiography of chest and no cardiorespiratory disease present in the emergency department.

Although the clinical PTP is a key step in the diagnostic algorithm for suspected PE, it appears to be less useful in the diagnosis of PE when correlated with VQ scan results. The majority of the cases in this study were managed according to their VQ scan results without the need for further imaging. Moreover, VQ scans are accurate when CTPA is contraindicated. The study results were consistent with our previous results and our algorithm for the diagnosis of PE was confirmed to be both reliable and safe.

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How to cite this article: Bhoobalan S, Chakravartty R, Dolbear G, Al-Janabi M. Correlation between the clinical pretest probability score and the lung ventilation and perfusion scan probability. Indian J Nucl Med 2013;28:221-5.

Source of Support: Nil. **Conflict of Interest:** None declared.