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Evaluation of Spiral Computed Tomography *Versus* Ventilation/Perfusion Scanning in Patients Clinically Suspected of Pulmonary Embolism

EMMANOUELA KATSOUDA[1], KYRIAKI MYSTAKIDOU[1], AGGELIKI RAPTI[2], STELIOS ARGENTOS[3], NIKOLAOS L. KELEKIS[4], RENATA MASTORAKOU[5], OURANIA ANAGNOSTOPOULOU[2] and DIMITRIOS A. KELEKIS[4]

[1]*Pain Relief and Palliative Care Unit, Department of Radiology, Areteion Hospital, School of Medicine, University of Athens, 27 Korinthias Str., 115 26 Athens;*
[2]*Eighth Department of Thoracic Medicine, Hospital of Chest Diseases of Athens, 152 Mesogion Str., Athens;*
[3]*Attico University Hospital, Second Department of Radiology, School of Medicine, University of Athens, Athens;*
[4]*Second Department of Radiology, School of Medicine, University of Athens, 20 Papadiamantopoulou Str., 115 28 Athens;*
[5]*Department of Radiology, Onassis Cardiac Surgery Center of Athens, 356 Syngrou Avenue, 176 74 Athens, Greece*

Abstract. *Objective: To prospectively evaluate the diagnostic accuracy of spiral computed tomography (CT) versus ventilation/perfusion (V/Q) scanning in the examination of patients clinically suspected of having pulmonary embolism (PE). Patients and Methods: Sixty-three patients, presenting to the emergency department and departments of radiology and nuclear medicine of a large hospital, highly suspected of having PE, underwent sequential imaging testing with V/Q scanning and contrast-enhanced spiral CT, in addition to other clinical and laboratory tests. Results: PE was diagnosed in 42 (66.7%) of the 63 patients. Thirty-nine of these 42 patients had positive findings in their CT scans, while 18 of the remaining 21 patients without PE had negative findings in their spiral CT [sensitivity, 92.9%, specificity, 85.7% Positive Predictive Value (PPV), 92.9%, Negative Predictive Value (NPV), 85.7%]. V/Q scans showed high-probability of PE in 24 of the 42 patients with PE and were negative in 9 of the remaining 21 patients without PE (sensitivity, 57.1%, specificity, 42.9%, PPV, 66.7%, NPV, 33.3%). There were statistically significant differences in specificity and sensitivity favoring spiral CT among men and women patients or patients >50 years old. Fifty-four patients (85.7%) rated their satisfaction towards spiral CT as 'good' or 'very good', whereas the respective rate for V/Q scanning was only 14.3%. Conclusion: Spiral CT has an excellent sensitivity, specificity, PPV and NPV for the diagnosis of PE and it could be used as the first-line imaging modality in patients suspected of PE.*

Pulmonary embolism (PE) is recognized as the third most common cause of cardiovascular disease in the United States after ischemic heart disease and stroke (1). More than 400,000 out of 600,000 cases of suspected PE each year in the United States remain undiagnosed (2). A prompt and accurate diagnosis of the clinically suspected PE in these patients is essential because treatment can markedly reduce the mortality rate. The optimal diagnostic imaging modality in patients suspected of PE is a subject of considerable debate among clinicians. If imaging is deemed necessary from an initial clinical evaluation, the options include ventilation-perfusion (V/Q) scanning, pulmonary angiography and spiral (helical) computed tomography (CT).

The V/Q scan has been the preferred pivotal diagnostic test for PE due to its non-invasive character, ease of performance and low cost (3), but most V/Q scans are non-diagnostic and further testing is usually required (4). Pulmonary angiography is traditionally considered as the gold standard of reference for detecting PE, however, it is infrequently performed because it is an invasive and

Abbreviations: CT, computed tomography; V/Q, ventilation/perfusion; PE, pulmonary embolism; DVT, deep vein thrombosis; PIOPED, Prospective Investigation of Pulmonary Embolism Diagnosis; PPV, positive predictive value; NPV, negative predictive value; US, ultrasonography; FOV, field of view.

Correspondence to: Kyriaki Mystakidou, MD, Ph.D., Assistant Professor in Palliative Medicine, Pain Relief and Palliative Care Unit, Dept. of Radiology, Areteion Hospital, School of Medicine, University of Athens, 27 Korinthias Str., 115 26 Athens, Greece. Tel: +30210-7707669, Fax: +30210-7488437, e-mail: mistakidou@yahoo.com

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expensive method with high radiation burden and requires experienced physicians to perform the test and interpret the results (5). Spiral CT involves continuous movement of the patient through the CT scanner, with concurrent scanning by a constantly rotating gantry and detector system during a single breath hold. Continuous scanning after contrast injection allows direct visualization of pulmonary arterial clot in the central, lobar and segmental arteries. In addition, with spiral CT both mediastinal and parenchymal structures (lymph nodes, pleurae, lung parenchyma and pericardium) are evaluated, which may reveal abnormalities other than PE that are causing or contributing to the patients' symptoms. Spiral CT was introduced in the early 1990s as a potential diagnostic test for PE and, since then, several studies have been performed to validate the accuracy of spiral CT to detect or exclude PE, with reported sensitivity and specificity ranging from 53% to 100% and from 81% to 100%, respectively, which surpass those of V/Q scanning (6). This has resulted in a substantial clinical demand for the spiral CT test in patients suspected of having PE.

The purpose of this study was to compare the diagnostic accuracy of spiral CT *vs.* that of V/Q scanning as the first-line imaging test in outpatients with high clinical suspicion of acute PE. Additionally, we were particularly interested in finding any differences in positive and negative predictive values (PPV and NPV) of the two tests considering the patients' age and sex, and differences in patients' tolerance and satisfaction towards these tests.

Patients and Methods

This study enrolled a total of 63 patients (33 men, 30 women; age range, 17-77; median age, 62 years), who presented to the emergency department and were highly suspected of PE. The clinical suspicion of PE was decided by the referring physician, based on his or her judgment of signs and symptoms (dyspnea, pleuritic pain, tachypnea, rales, fever), laboratory findings (sinus tachycardia, $S_1Q_3T_3$, reduced pO_2 and pCO_2 values) (Table I) and the patient's medical history and predisposing factors (deep vein thrombosis, heart failure, malignancy, recent surgery, immobilization, *etc.*) (Table II). Exclusion criteria at the time of screening were clotting disorders, hypovolemia (hypotension), respiratory impairment and pregnancy. All patients were clinically highly suspected of PE and underwent V/Q scanning and spiral CT for confirmation of the disease. The time-period between the two imaging tests ranged from 3 to 12 hours. In addition, a D-dimer agglutination test was performed in each patient to rule out PE, when levels were below 500 ng/ml, together with a Doppler ultrasonography (US) of the leg veins for diagnosing deep vein thrombosis (DVT). Ethical approval was obtained from the institutional review board and all patients provided consent to participate in the study.

Spiral CT scans were obtained in all 63 patients. Contrast-enhanced CT assessment of the central, segmental and subsegmental pulmonary arteries was performed from the level of the aortic arch to 2 cm above the diaphragm. Scans were obtained in patients during suspended inspiration or during shallow breathing, depending on the patient's level of dyspnea. Scanning parameters included 3-mm collimation, a pitch factor of 1.5 and scanning time of 50-60 seconds. Images were reconstructed at 1-mm intervals by using the standard reconstruction algorithm and a field of view (FOV) appropriate to the patient's size. The presence of pulmonary algorithm was noted, as was any other abnormality in the mediastinum, the chest wall or lung parenchyma. PE was considered to be present if, in the case of a well-opacified scan, there was an intraluminal filling defect on more than one slice. A filling defect could be seen as a complete occlusion of the vessel, an eccentric partial filling defect or a partial central filling defect, surrounded by contrast agent (6). The sites of emboli (central, segmental or subsegmental arteries) in CT scans are listed in Table III.

The V/Q scans were obtained by using standard techniques and they were interpreted in conjunction with a chest radiograph by using the revised Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED) criteria (4). The final diagnosis was based upon results from both spiral CT and V/Q scans, combined with all available laboratory records, chest radiograph and clinical information.

Statistical analysis was performed using the statistical package SPSS v. 10.00 (Statistical Package for the Social Sciences). For comparing the positive predictive value of the two imaging tests, Pearson's and McNemar's Chi-square test were used, as well as descriptive statistics. A group sample size of 42 achieves 100% power to detect a difference of 0.43 between the null hypothesis that both group proportions are 0.57 and the alternative hypothesis that the proportion in group 2 is 1.0 with a significance level of 0.05. The sample size of 39 patients was selected to detect a projected minimum difference of 30% between the two methods (57% *vs.* 87%) for type I error of 0.05 and a power of 80%.

Results

All 63 patients were highly suspected of PE because of signs and symptoms, laboratory findings, imaging tests and medical history. The major signs and symptoms that attributed to the clinical diagnosis of PE included one or more of the following: dyspnea (n=60), pleuritic pain (n=56), tachypnea (n=58), cough (n=25), blood-stained sputum (n=10), fever (n=28), sinus tachycardia (n=62) and rales (n=23) (Table I).

PE was finally diagnosed in 42 of the 63 patients. The diagnosis of PE was established by means of high-probability V/Q scans (n=24) and positive spiral CT scans (n=39), positive spiral CT scans and positive Doppler US images (n=10) and positive spiral CT scans, intermediate-probability V/Q scans and clinical and laboratory findings supporting the diagnosis of PE (n=7). Spiral CT scans were positive in 39 of the 42 patients who were finally diagnosed with PE and negative in 18 of the 21 patients without PE, showing a sensitivity and specificity of 92.9% and 85.7%, respectively. PPV and NPV were 92.9% and 85.7%, respectively. Emboli were found in all levels of the pulmonary arteries (central, lobar, segmental,

Table I. *Clinical signs and symptoms and laboratory values in patients suspected of PE.*

Signs, symptoms and laboratory values	No. of patients (%)
dyspnea	60 (95.2)
pleuritic pain	56 (88.9)
tachypnea	58 (92.1)
cough	25 (39.7)
blood-stained sputum	10 (15.9)
fever	28 (44.5)
sinus tachycardia	62 (98.4)
rales	23 (36.5)
wheezing	45 (71.4)
$S_1Q_3T_3$	36 (57.1)
D-dimer	36 (57.1)
low PO_2	48 (76.2)
low PCO_2	55 (87.3)
pH	53 (84.1)

Table II. *Predisposing factors in patients suspected of PE.*

Predisposing factors	No. of patients (%)
hypertension	21 (33.3)
obesity	6 (9.5)
heart failure	8 (12.7)
fracture	4 (6.3)
DVT*	20 (31.7)
myocardial infarction	6 (9.5)
prolonged immobilization	9 (14.3)
oral contraceptives	2 (3.2)
pulmonary hypertension	4 (6.3)
COPD*	3 (4.8)

*DVT=deep vein thrombosis, COPD=chronic obstructive pulmonary disease.

subsegmental) (Table III). On the other hand, the number of patients with high-probability V/Q scans was only 24, whereas 9 patients had intermediate-probability V/Q scans, 5 patients had low-probability V/Q scans and 4 had normal findings in their V/Q scans. By classifying high-probability images as positive and all other results as negative, in the 42 patients with PE, the V/Q scan was positive in 24, showing a PPV of 66.7% (false-negative in 18 patients). In the remaining 21 patients without PE, V/Q scanning was positive in 12 (false-positive) and negative in 9, showing a NPV of 33.3%. The sensitivity and specificity were 57.1% and 42.9%, respectively. These results demonstrate a statistical significance favoring spiral CT ($p<0.0005$). Additionally, there was a statistical ($p<0.005$) difference in sensitivity, specificity, PPV and NPV of the two techniques

Table III. *Site of emboli in spiral CT scan.*

Site	No. of patients (%)
Central pulmonary artery	35 (55.6)
Pulmonary artery branches	
None	32 (50.8)
Right pulmonary artery	10 (15.9)
Left pulmonary artery	5 (7.9)
Right + left pulmonary artery	16 (25.4)
Segmental arteries	
.00	24 (38.1)
Right segmental arteries	12 (19.0)
Left segmental arteries	4 (6.3)
Right + left segmental arteries	23 (36.5)
Subsegmental arteries	
.00	26 (41.3)
Right subsegmental arteries	9 (14.3)
Left subsegmental arteries	5 (7.9)
Right +Left subsegmental arteries	23 (36.5)
Pulmonary infarct	14 (22.6)
Right ventricular thrombus	1(1.6)
Pleural effusion	15 (23.8)

Table IV. *Diagnostic indices of the two techniques among men and women patients.*

	Men		Women	
	Spiral CT	V/Q Scan	Spiral CT	V/Q Scan
Sensitivity	85.7%	52.4%	100%	61.9%
Specificity	83.3%	41.7%	88.8%	44.4%
PPV	90.0%	61.1%	95.5%	72.2%
NPV	77.0%	33.3%	100%	33.3%

Table V. *Diagnostic indices of the two techniques among patients of age <50 or ≥50 years.*

	<50 years		≥50 years	
	Spiral CT	V/Q Scan	Spiral CT	V/Q Scan
Sensitivity	93.7%	75.0%	92.3%	46.2%
Specificity	100%	60.0%	72.7%	27.3%
PPV	100%	75.0%	88.9%	60.0%
NPV	93.7%	60.0%	80%	10.6%

Table VI. *Correlation of spiral CT and V/Q scanning with clinical and laboratory manifestations of PE in patients finally diagnosed with PE.*

Signs, symptoms and laboratory values	Spiral CT No. of patients* (%)	V/Q scanning No. of patients* (%)
dyspnea	40 (95.2)+	22 (52.4)
pleuritic pain	35 (83.3)+	21 (50.0)
tachypnea	38 (90.5)+	22 (52.4)
cough	17 (40.5)	19 (45.2)
blood-stained sputum	10 (23.8)	20 (47.6)
fever	25 (60.0)	19 (45.2)
sinus tachycardia	41 (97.6)+	23 (54.8)
rales	22 (52.4)	20 (47.6)
wheezing	29 (69.0)+	23 (54.8)
$S_1Q_3T_3$	32 (76.2)+	24 (56.1)
D-dimer	31 (73.8)+	27 (64.3)
low PO_2	30 (70.4)+	22 (52.4)
low PCO_2	35 (83.3)+	25 (59.5)
pH	35 (83.3)+	23 (54.8)

*Data are the number of patients with this specific sign, symptom or laboratory value and with positive findings in their spiral CT or V/Q scans.

+Statistically significant concordance

Table VII. *Comparison of spiral CT with V/Q scanning in terms of patients' satisfaction and tolerability.*

		Patients' satisfaction			
		Bad	Average	Good	Very good
Spiral CT	No.	1	8	36	18
	%	1.6%	12.7%	57.1%	28.6%
V/Q scan	No.	31	23	7	2
	%	49.2%	36.5%	11.1%	3.2%

$p=0.0005$

considering the patient's sex (Table IV). Regarding age, there was also a statistical ($p<0.005$) difference in these diagnostic indices either in patients of age ≥50 years or in patients of age <50 years (Table V). In case of signs, symptoms and laboratory values, there was also a significant ($p<0.05$) correlation between positive spiral CT findings and the majority of clinical and laboratory manifestations of PE in patients finally diagnosed with PE (statistically significant concordance from 69.0% to 97.6%). On the other hand, this correlation in high-probability V/Q scans was not significant ($p>0.05$) and ranged from only 52% to 64.5% (Table VI).

Doppler US of the lower extremities was performed in all 63 patients, with positive findings in all 42 patients finally diagnosed with PE (66.7%). Plasma D-dimer levels were abnormal (>500 ng/ml) in 36 patients (57.1%), in 31 with PE and in 5 without PE. Among the 42 patients with positive spiral CT scans, the major cause of PE was DVT (n=18), whereas in 4 patients no cause was established. On the other hand, among the 3 patients with negative spiral CT scans, the first had DVT, the second had aspiration pneumonia in the setting of heart failure and myocardial infarction, while in the third patient, the clinical diagnosis of PE was established without confirmatory imaging or laboratory findings.

Finally, a comparison between the two techniques regarding the patients' tolerance and satisfaction was made, using a Self Satisfaction Questionnaire that assesses these parameters on a 4-point scale (bad, average, good, very good). In the case of spiral CT, 54 out of the 63 patients (85.7%) rated their satisfaction as 'good' or 'very good', whereas the respective rate for V/Q scan was only 14.3% (9 out of 63 patients), showing a significant ($p<0.0005$) difference in patients' satisfaction and tolerance favoring the spiral CT (Table VII).

Discussion

Pulmonary embolism is a serious and potentially fatal complication of thrombus formation within the venous circulation. Therefore, a definitive answer is needed in patients suspected of having acute PE. Diagnostic imaging in patients suspected of PE remains an important clinical issue. Initial validation studies suggest a high sensitivity and specificity of spiral CT in the detection of PE (7-14). In this study, we compared the diagnostic accuracy of spiral CT *vs.* that of V/Q scanning as a first-line test in patients highly suspected of, and finally diagnosed with, PE.

V/Q scanning has a better negative than positive predictive value and is, therefore, useful for excluding PE when used in selected patients who have a normal chest radiograph and no history of COPD, or those with relatively low pre-test probability (15). The Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED) study suggested that V/Q scanning added only marginally to the diagnostic yield. In our study, V/Q scanning demonstrated a PPV of 66.7%, with only 24 out of 42 patients having high-probability V/Q scans, even if all these patients were highly suspected and were finally diagnosed with PE. On the other hand, only 3 out of these 39 patients (7.7%) had a normal V/Q scan, which is consistent with the findings of the PIOPED study that V/Q scanning is more useful to rule out PE. In all other cases where V/Q scans were non-diagnostic (intermediate- or low-probability scans), the clinical assessment of pre-test probability was used to aid the interpretation of the V/Q scans, and most of these patients needed additional diagnostic testing.

The diagnostic accuracy of spiral CT in our study is comparable to that in previous publications (16-20), with 39 out of the 42 patients finally diagnosed with PE having a positive CT scan (PPV=92.9%). Additionally, 18 out of the 21 patients highly suspected of, but finally not diagnosed with, PE had a normal spiral CT scan and that also supports the diagnostic accuracy of this imaging test. In comparison with V/Q scanning, spiral CT showed statistically significant differences, regarding sensitivity, specificity, PPV and NPV of the two techniques ($p<0.0005$). This difference favoring spiral CT was still present when the diagnostic accuracy of these imaging modalities was assessed among patients of different sex. Moreover, in the setting of patients' tolerance and satisfaction, spiral CT demonstrated a significantly higher level of satisfaction and tolerance among patients who underwent both tests (85.7% *vs.* 14.3%, $p<0.0005$). In addition, our study showed that the correlation between the two techniques and clinical and laboratory manifestations of PE was higher in spiral CT than in V/Q scanning, which demonstrates the value of spiral CT as a first-choice examination for patients at risk of PE.

In many institutions, spiral CT is becoming the first-line imaging test for the assessment of patients with suspected PE in daily clinical practice. With spiral CT, a specific cause for the patient's symptoms and important additional diagnosis can be established in many cases. Additionally, not only intravascular thromboembolic filling defects, but also other manifestations of precedent PE (parenchymal infarction, pleural effusion, vascular remodeling) can be visualized with spiral CT. Furthermore, spiral CT can provide important ancillary information for the final diagnosis in patients who do not have PE. This ancillary information is not available with other PE imaging modalities, either non-invasive (V/Q scanning, Doppler US) or invasive (pulmonary angiography).

The main impediment for spiral CT has been limitations of this modality for the accurate detection of small peripheral emboli (17, 21, 22) and these limitations have prevented the establishment of spiral CT as the new gold standard of reference for imaging PE. However, the significance of peripheral emboli in the subsegmental arteries is controversial, particularly in the absence of central emboli. Likewise, there is still considerable debate among clinicians about the treatment of such emboli and whether this result improves the clinical outcome (23, 24).

In our study, the superiority of spiral CT, with regard to tolerance and patient satisfaction, is also demonstrated. The vast majority of patients were more satisfied with spiral CT than with V/Q scanning, because it is a rapid, minimally-invasive technique and more convenient to the patient than V/Q scanning.

In conclusion, spiral CT is an imaging modality with a very good sensitivity, specificity, PPV and NPV for the diagnosis of acute PE. Moreover, spiral CT is a quick, easy to perform, cost-effective test, more convenient to patients and may provide ancillary information for alternative diagnoses in the absence of PE. Despite its few limitations, we believe that spiral CT should be the preferred modality for first-line imaging in patients with suspected PE in everyday clinical practice.

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