Pulmonary embolism: lung scan and computed tomography

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Key words:
Nuclear medicine; Pulmonary embolism; Radiography.

The diagnosis of pulmonary embolism may be confounded by a clinical presentation that is often subtle or atypical. Therefore pulmonary angiography, although invasive, has been widely used to prove pulmonary embolism. The aim of this review is to discuss the value of non-invasive techniques, such as lung scan and chest computed tomography scan, in the diagnosis of pulmonary embolism. Ventilation-perfusion scan has demonstrated a very high specificity (97%) but a quite low sensitivity (41%) in the diagnosis of pulmonary embolism, while perfusion lung scan not associated with ventilation scan has shown a specificity of 92% and a considerably high sensitivity (87%). The chest computed tomography scan has not yet shown a definite degree of specificity and sensitivity in the diagnosis of pulmonary embolism, although we suppose that this technique will become widely used. However, we emphasize that the diagnosis of pulmonary embolism is not a mere technical problem.

(Ital Heart J 2005; 6 (10): 811-817)

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Lung scan: past and present

Prior to 1960, physicians diagnosed pulmonary embolism (PE) by the identification of a suspicious combination of symptoms, signs, and non-specific laboratory tests. Dyspnea, pleuritic chest pain, hemoptysis occurring after surgery represented a particularly convincing set of diagnostic findings of PE.

After 1960, the diagnostic capabilities were enriched by the development of angiographic and radionuclide pulmonary imaging techniques[1,2]. By the end of the '60s, selective pulmonary angiography was widely accepted as the most accurate technique for the diagnosis of PE. In a large study[3] it was reported that, although invasive, this technique was safe and highly accurate in the diagnosis of PE, thus becoming a "gold standard" for a validation of any other technique in the diagnosis of PE. Moreover, that study tested the sensitivity and specificity of perfusion lung scan in the diagnosis of PE. About 227 of those patients were included and submitted to perfusion lung scan and pulmonary angiography for suspected PE. The authors concluded that a normal perfusion lung scan essentially excludes the presence of PE, while an abnormal perfusion scan is not specific for PE[3].

In the mid '70s, due to some limitations of pulmonary angiography such as the need of expertise in performing and interpreting the test and, not less, the potential risk for the patient, ventilation scan was added to perfusion lung scan in the attempt to increase diagnostic capability for PE by non-invasive techniques[4,5]. The basic assumption of this operation mostly theoretical because not supported by experimental or clinical study was that ventilation in PE would be normal in those lung areas in which perfusion is poor or absent (V/Q mismatch)[5].

However, despite the availability of this new diagnostic tool, a retrospective clinical pathologic correlative study published in the early '80s indicated a frequency of only 10% of *in vita* successful PE diagnoses[6].

In the meantime, a study performed at our Institute, based on the detailed description of site and shape of lung perfusion defects, showed an excellent correlation with findings of the selective pulmonary angiography in the diagnosis of PE[7]. In that study, the scintigraphic criteria used to diagnose PE were: a) presence of segmental or subsegmental perfusion defects; b) shift of perfusion away from the dependent lung zones where it normally prevails, consequent to the elevation of pulmonary arterial pressure. According to recommendations[8], the radioactive tracer injection was made having the patient positioned as closely as possible to the sitting position in order to preserve the effect of gravity on the regional distribution of pulmonary blood flow. The attending physician who had followed the patient diagnostic work-up step by step could non-invasively confirm or exclude

PE. However, as already mentioned it was reported that perfusion lung scan, although extremely sensitive in detecting regional perfusion abnormalities, could not be used *per se* to establish the diagnosis of PE[9]. For this reason perfusion lung scan has now become a routine test in our Institute, for patients suspected for PE who have already undergone physical examination, chest X-ray, ECG, and arterial blood gas analysis.

Thus, the association of ventilation with perfusion scan in the diagnosis of PE based on the V/Q mismatch finding became the nuclear medicine technique most likely to distinguish occlusion of the pulmonary vasculature due to embolic material from perfusion abnormalities secondary to ventilation disturbances[5]. However, the findings of V/Q match turned out to be unable *per se* to rule out PE[10]. Attempts to improve the diagnostic value of the V/Q scan by considering the size and number of mismatched perfusion defects led to the development of exceedingly complex classification criteria which, in turn, engendered considerable confusion in the interpretation of scan images with no significant improvement of diagnostic accuracy[11].

As a consequence, in the mid '80s, despite the addition of ventilation to perfusion scanning in patients with PE, there was still a high rate of non-diagnostic results[12].

In summary, at that time the non-invasive diagnosis of PE was still a problem due to a couple of reasons: a) clinical history, symptoms, signs, and all the instrumental techniques routinely available such as ECG, chest roentgenogram, and arterial blood gas analysis were deemed inaccurate[13,14]; b) the use of V/Q lung scan did not increase the diagnostic capability[11,12].

In 1990, a large prospective study on PE diagnosis, which involved 931 patients, was published: its aim was to determine the sensitivity and specificity of V/Q lung scans, taking also in account the role of the clinician's assessment for evaluating the likelihood of PE before the V/Q scan was performed[15].

Few years later, a large-scale study involving 890 patients with suspected PE was published[16] and it was aimed to assess the value of perfusion lung scan, without ventilation scan, performed after the assignment of clinical probability of PE by the clinician. In both studies, pulmonary angiography was used to prove the presence or absence of PE.

The aim of this review is to describe the results of these two large studies indicating the role of the clinical assessment, the nuclear medicine techniques, and the combination of both in the diagnosis of PE. In addition, it will also evidence the role of new diagnostic techniques such as computed tomography.

The PIOPED study[15]

Clinical assessment of patients suspected for pulmonary embolism. Prior to acknowledging the results of V/Q scans and angiography, clinical investigators recorded their clinical impressions as to the likelihood of PE on the basis of history, physical examination, arterial blood gas analysis, ECG, chest roentgenogram findings without any standardized diagnostic algorithm.

In 887 (95%) of the 931 patients the clinical assessment of the likelihood of PE recorded before the scan achievement ("prior probability") was compared to PE diagnosis determined by angiography. A clinical assessment of PE probability ranging between 80 and 100% was found for 90 patients (10%) and was confirmed to be correct in 61 (68%) of 90. On the other hand a clinical assessment of 0 to 19% likelihood of PE was made in 228 patients (26%) and was correct in 207 (91%) of 228. Hence, it turns out that the clinical assessment was more often correct in excluding rather than in identifying PE. Finally, a clinical assessment of 20 to 79% likelihood of PE was non-committal in the majority of patients, i.e. 569 (64%) of 887 patients.

Value of ventilation and perfusion scan. Of the 931 patients enrolled in the study, 755 (81%) were submitted to pulmonary angiography to validate the results of V/Q lung scans which had been classified by the readers as high-probability scan, intermediate-probability scan, low-probability scan, very-low-probability scan, and near-normal/normal scan.

The scan interpretation was made taking also in account the findings of chest roentgenogram according to pre-established criteria. Table I reporting such criteria shows how complex the scan interpretation was because of its particularly detailed structure, including the number, size, and site of perfusion defects matching or not matching ventilation and roentgenographic abnormalities.

One hundred and two of the 251 patients with angiographically proven PE had high-probability V/Q scans: the sensitivity, therefore, was 41%. Thus, the high-probability scan category lacked sensitivity in diagnosing PE because it failed to detect 59% of patients with this disorder. On the other hand, this scan category was present in only 14 (3%) of 480 patients with angiographic exclusion of PE: the specificity, therefore, was 97%. As for the intermediate-probability V/Q scan category, it was present in 105 patients, i.e. in 42% of those 251 patients with angiographically proven PE, and in 217 (45%) of 480 patients without PE. Thus, this category of V/Q scans, which included nearly the half (44%) of the patient population (322 of 731 patients), appeared ineffective in detecting the presence or absence of PE.

Combination of clinical assessment with the ventilation and perfusion scan interpretations. Among the 29 patients in whom the clinical impression and the scan interpretation were both of high probability for PE, 28 (96%) had PE. When the 80 patients with high-probability scan interpretation were paired with an intermediate-likelihood or low-likelihood clinical assess-

Table I. PIOPED scan interpretation categories and criteria[15].

High probability
≥ 2 large (> 75% of a segment) segmental perfusion defects without corresponding ventilation or roentgenographic abnormalities or substantially larger than either matching ventilation or chest roentgenographic abnormalities
≥ 2 moderate segmental (≥ 25% and ≤ 75% of a segment) perfusion defects without matching ventilation or chest roentgenogram abnormalities and 1 large mismatched segmental defect
≥ 4 moderate segmental perfusion defects without ventilation or chest roentgenogram abnormalities

Intermediate probability
Not falling into normal, very-low, low, or high-probability categories
Borderline high or borderline low
Difficult to categorized as low or high

Low probability
Non-segmental perfusion defects (e.g. very small effusion causing blunting of costophrenic angle, cardiomegaly, enlarged aorta, hila, and mediastinum, and elevated diaphragm)
- Single moderate mismatched segmental perfusion defect with normal chest radiogram. Any perfusion defect with a substantially larger chest roentgenogram abnormality
- Large or moderate segmental perfusion defects involving no more than 4 segments in one lung and no more than 3 segments in one lung region with matching ventilation defects either equal to or larger in size and chest roentgenogram either normal or with abnormalities substantially smaller than perfusion defects
- > 3 small segmental perfusion defects (< 25% of a segment) with a normal chest roentgenogram

Very low probability
≤ 3 small segmental perfusion defects with a normal chest roentgenogram

Normal
No perfusion defects present
Perfusion outlines exactly the shape of the lungs as seen on the chest roentgenogram (hilar and aortic impressions may be seen), chest roentgenogram and/or ventilation study may be abnormal

ment, then the probability of the patient having PE fell to 70 (88%) of 80 and 5 (56%) of 9, respectively. The combination of low likelihood of clinical assessment with low-probability V/Q scan, correctly excluded the diagnosis of PE in 86 (96%) of 90 patients, while the combination of near-normal/normal V/Q scan with low likelihood of clinical assessment, correctly excluded PE in 60 (98%) of 61 patients. It appears that also the combination of clinical assessment and V/Q scan helps better in excluding than in confirming PE.

Conclusions from the PIOPED study. From the results of the study, it appears that the diagnostic value of V/Q scan in PE is questionable. Indeed the authors concluded that a high-probability scan category, which usually indicates PE, was found in the minority of patients. Instead, a low-probability scan with a strong clinical impression that PE is unlikely makes the diagnosis of PE remote. Near-normal/normal lung scans make the diagnosis of acute PE very unlikely. An intermediate-probability V/Q scan category, which was found in the majority of patients, is of no help in establishing a diagnosis. Thus, for a substantial number of patients in the PIOPED study, angiography was required for a definitive diagnosis of PE.

The PISA-PED study[16]

On the basis of the results of the PIOPED study, it was reasonable to reconsider the value of perfusion lung scan without ventilation scan in the diagnostic work-up of patients with suspected PE and to ascertain whether the combination of clinical assessment with perfusion lung scan interpretation could help restrict the need for pulmonary angiography.

Clinical assessment of patients suspected for pulmonary embolism. Data of clinical history, physical examination, chest roentgenogram, ECG, and arterial blood gas were obtained for each patient by pulmonary specialists, experienced in the diagnostic procedures for PE nuclear medicine techniques included to assess the clinical probability.

Pulmonologists recorded all clinical and instrumental data on a standard form, and then assigned a clinical probability for PE considering three alternatives: very likely (90%), possible (50%), and unlikely (10%). The clinical probability was assigned, without any standardized diagnostic algorithm, before any further objective testing was done (pre-test probability). Clinical evaluation was completed in all the 890 patients enrolled in the study.

Pulmonary angiography was performed only in patients with abnormal scan, given that by then it was already widely recognized that a normal lung perfusion scan practically excludes the presence of PE[3,17,18]. However, an angiographic study was precluded in 253 patients with abnormal lung scan for several reasons: refused consent (44.6%), critical illness (36%), technical problems (13.8%), death before angiography (2%), allergy to contrast material (1.6%), pregnancy (1.2%), and

atrioventricular block during right heart catheterization (0.8%). Indeed, these figures suggest that angiography is difficult to perform on a routine basis for the diagnosis of PE particularly in an unselected patient population.

Thus, pulmonary angiography was performed in 413 (62%) of the 670 patients with abnormal scan, while the final diagnosis for 4 patients was established at autopsy. The overall agreement between the two angiogram readers was 91% (374 of 413 cases). The interpretation of 39 angiograms was discordant. After consensus adjudication, PE was considered present in 11 angiograms and absent in 7. The remaining 21 angiograms were considered non-diagnostic. Therefore, a definitive diagnosis was established in 386 of 413 cases (93%) with angiography and in 4 at autopsy for a total number of cases with definitive diagnosis of 390.

The remaining 220 patients had a perfusion lung scan classified as normal/near-normal and, therefore, did not undergo pulmonary angiography but were evaluated further by follow-up.

The clinical likelihood of PE was compared with the definitive diagnosis (confirmation or exclusion of PE) in 783 (88%) of 890 patients (220 with normal or near-normal scans, and 563 with abnormal scan for whom the diagnosis was based on angiography, autopsy, and follow-up data).

PE was considered very likely in 255 (33%) of 783 patients, and this judgment was correct in 231 of 255 (91%). An unlikely clinical probability was assigned to 349 patients (44%), and was correct in 317 of 349 (91%). In 179 patients (23%), PE was considered possible on clinical grounds, and was confirmed by angiography and follow-up data in 84 cases (47%). Hence, the overall rate of correct clinical classification was 81%.

Conversely, in the PIOPED study the overall rate of correct clinical classification could not be obtained, because one of the clinical assessment categories, i.e. the 20 to 79% likelihood of PE, was non-committal in 569 (64%) of 887 patients.

Value of perfusion lung scan. Perfusion images were interpreted according to the pre-established categories as shown in table II. It helps to remind that the intravenous injection of radioactive bolus was routinely done with the patient positioned as closely as possible in the sitting position[8]. The results of the comparison between perfusion scan and angiographic findings are summarized in table III. As already mentioned, in 4 patients the diagnosis was made at autopsy: therefore, the total number of patients with definitive diagnosis was 390.

Of the 236 patients with a confirmed diagnosis of PE, 217 had wedge-shaped perfusion defects (PE-positive scan). The sensitivity of this scan category was therefore 92%. Conversely, 134 of 154 patients in whom PE was excluded had perfusion defects other than wedge-shaped (PE-negative scan): therefore, the specificity was 87% (Table III).

In the PIOPED study the rate of angiographic studies was 81% due to the inclusion of patients with normal and near-normal scans, while in the PISA-PED study the rate of angiographies was 62% due to the exclusion of patients with normal/near-normal scan and those in whom angiography was precluded. The observed sensitivity and specificity of the PE-positive scan in the PISA-PED study were corrected for selection bias in referring patient by applying the Bayes' theorem[19] to compare the results between the two studies. The addition, in stepwise fashion, of those patients with abnormal, near normal, and normal scans who did not undergo pulmonary angiography changed the sensitivity and specificity of PE-positive scan respectively from 92% to a debiased value of 86%, and from 87% to a debiased value of 93%.

Table III. Comparison of scan category with angiogram findings in the PISA-PED study[16]*.

	PE		Total
	Present	Absent	
PE+	217	20	237
PE-	19	134	153
Total	236	154	390

Sensitivity: 217/236 = 92% (95% confidence interval 88 to 95%); specificity: 134/154 = 87% (95% confidence interval 80 to 92%). PE = pulmonary embolism. * in 4 patients, confirmation or exclusion of pulmonary embolism was made at autopsy.

Table II. PISA-PED perfusion scan categories and interpretation criteria[16].

Normal	No perfusion defects of any kind
Near-normal	Perfusion defects smaller or equal in size and shape to the following roentgenographic abnormalities: cardiomegaly; enlarged aorta, hila and mediastinum; elevated diaphragm; blunting of the costophrenic angle; pleural thickening; intrafissural collection of liquid
Abnormal (PE+)	Single or multiple wedge-shaped perfusion defects with or without matching chest-roentgenographic abnormalities. Wedge-shaped areas of overperfusion usually coexist
Abnormal (PE-)	Single or multiple perfusion defects other than wedge-shaped, with or without matching chest-roentgenographic abnormalities. Wedge-shaped areas of overperfusion are usually not seen

PE = pulmonary embolism.

These results are by far different from those of the PIOPED study: in fact the latter showed a specificity of 97% and a sensitivity of 41% of the high-probability scan category, while the PE-positive scan of the PISA-PED study showed a moderate lower specificity (87%) and a much higher sensitivity (92%).

Combination of clinical assessment with the perfusion scan interpretations. The results of combining clinical assessment with perfusion scan interpretation in 390 patients with abnormal lung scans and definitive diagnosis by angiography or autopsy are shown in table IV.

When a very likely, possible, or unlikely clinical presentation was associated with a PE-positive scan, the prevalence of PE was 99, 92, and 55%, respectively. When a very likely, possible, or unlikely clinical presentation was paired with a PE-negative scan, the prevalence of PE was 39, 20, and 3%, respectively.

Thus, by relying only on clinical and perfusion scan data, pulmonologists would have non-invasively confirmed or excluded PE in 296 (76%) of 390 patients with abnormal scans, with an accuracy of 97% (287/296 cases) (Table IV).

Angiography would then be required in approximately one fourth of patients with abnormal scans: those in whom a PE-negative scan is associated with a very likely or possible clinical presentation and those with a PE-positive scan paired with an unlikely clinical presentation (Table IV).

Conclusions from the PISA-PED study. Data reported in this study, indicate that: a) the accurate diagnosis or exclusion of PE is possible by perfusion lung scanning alone, without ventilation imaging; b) combining perfusion scanning with clinical assessment helps to restrict the need for angiography to a minority of patients with suspected PE.

Comments on the comparison between the PIOPED and PISA-PED studies. It has been already mentioned that in the PIOPED study the sensitivity of the high-probability V/Q scan was exceedingly low (41%): it means that in 59% of patients, PE was associated with V/Q abnormalities other than those of the high-probability V/Q scan. It is conceivable that the failure in the correct scan interpretation may lie on the assumption that ventilation is normal in patients with PE. In fact, in a review of chest radiographs of 1063 patients recruited in the PIOPED study[20], it was observed that the majority of patients with established PE (88%) had abnormal chest radiographs. Nearly 50% of the patients who had emboli in the right and left lower lung zones had roentgenographic evidence of atelectasis and/or parenchymal areas of increased density in the corresponding lung zones. Such parenchymal abnormalities of the lung are likely to affect not only perfusion scan but also ventilation scan images. Given that the PIOPED study based V/Q scan interpretation on matching or mismatching of V/Q defect evaluated on scans, taking into account the size of the scan and site of radiographic abnormalities (Table I), it is expected that scan interpretation may be considerably difficult. In fact in that study as many as 322 (44%) of 731 patients with a definitive angiographic diagnosis of PE had an intermediate (indeterminate)-probability scan. Yet, of 251 patients with angiographically proven PE, 105 (42%) fell into the intermediate-probability scan category[15].

The PISA-PED diagnostic approach for PE differs substantially from that of the PIOPED study in that: a) ventilation scan was omitted; b) scan images were classified according to the shape of perfusion defects regardless of their number or size; and c) the presence of matching roentgenographic abnormalities was not considered in the evaluation of perfusion defects. By adopting these criteria, the reader was constrained to choose only between two categories of abnormal scan (Table II). This may explain the remarkable difference between the results of the PISA-PED study and those of the PIOPED study, in which a much larger combination of scan categories was considered.

Despite the results of the PIOPED and PISA-PED studies, ventilation scan still remains the nuclear medicine technique of choice according to the European PE guidelines[21], although from the practical point of view perfusion lung scan remains the technique most frequently used without ventilation scan in the diagnosis of PE. In fact, the International Cooperative Pulmonary Embolism Registry (ICOPER)[22] reported that perfusion lung scan was associated with ventilation scan in less than half instances when diagnosing PE.

Therefore, the suggestion of the Committee of Italian Cardiologists[23] to attribute perfusion lung scan a central role in the diagnostic work-up of patients with suspected PE appears to be justified.

Table IV. Combined clinical and perfusion scan evaluation in the PISA-PED study[16].

Clinical likelihood	Patients (n=390)
Very likely	
PE+	151/153 (99%)
PE-	7/18 (39%)*
Possible	
PE+	49/53 (92%)
PE-	9/45 (20%)*
Unlikely	
PE+	17/31 (55%)*
PE-	3/90 (3%)

PE = pulmonary embolism. * in these patients (94/390, 24%), angiography is needed (see text).

The emerging role of computed tomography

In spite of the practical availability of several diagnostic strategies[24], there is still much request for that

single test that can accurately and non-invasively allow to diagnose PE. To this end, the use of computed tomography (CT) has been considered a major advance indeed, unlike pulmonary angiography, it is largely available and easy to perform, and unlike pulmonary scintigraphy it allows to directly visualize pulmonary emboli. In addition, it may allow to detect pulmonary diseases different from PE and thus provide perhaps an alternative diagnosis. However, traditional CT is not suitable for evaluating suspected embolism as it requires a 3-min infusion of radiographic contrast medium to opacify the pulmonary arteries, with the ensuing risks for the patient and the poor image quality caused by motion artifacts. New instruments, namely the helical (or spiral) CT, have now overcome such problems since image acquisition can be completed within a single breath hold (e.g. 20 s)[25]. Therefore, these advances have raised great enthusiasm and brought to the belief that the issue of PE diagnosis was closed or at least near to be closed. However, several questions still need to be addressed.

The overall accuracy of computed tomography scan in the diagnosis. In spite of the large number of studies, the sensitivity and the specificity of spiral CT in the diagnosis of acute PE has not been definitively assessed. Indeed, the sensitivity ranges from 57 to 100% and the specificity from 78 to 100%[26,27], greater accuracy being demonstrated for emboli located in the main or lobar pulmonary arteries and lower accuracy for emboli confined to segmental or subsegmental ones. In 2001, Perrier et al.[28] found a positive predictive value varying from 100% in the main pulmonary arteries to 85% in the lobar and to only 62% in the segmental pulmonary arteries. Worse results were obtained by the Dutch group: a sensitivity of 86% for segmental or larger PE and 21% for subsegmental brought to an overall sensitivity of 69% and an overall specificity of 86%[25]. Since then, a wealth of papers have been published, the combined results of which may be summarized as follows: in centrally located emboli, a positive spiral CT would confirm the diagnosis; conversely, in isolated subsegmental PE the sensitivity of spiral CT is too low (30%) to exclude the diagnosis. Because this latter group entails about 20% of symptomatic PE, possible alternative techniques for diagnosis should be available[29]. This brings to the issue of whether therapy may be withheld in case of negative CT. Outcome studies have demonstrated that this could be safe (mostly if the decision is taken in association with a negative ultrasonographic study) except in patients with a high clinical probability of PE[30].

Based on the aforementioned considerations, Kearon[31] concludes that spiral CT plays a role similar to V/Q scintigraphy: when positive in the main or lobar arteries, it equals a high probability V/Q scan, when showing defects in segmental or subsegmental arteries it is non-diagnostic ("indeterminate probability" V/Q at the scan); when normal, it reduces probability but does not exclude the diagnosis ("low probability" V/Q at the scan). It is likely that the advent of 16-detector row scanners and, mostly 64-detector row scanners, might eliminate part of biases such as poor contrast enhancement of pulmonary vessels, patient motion, and increased image noise in obese patients, which are now responsible for poor detection of peripheral emboli. Most recent papers on the use of multidetector row CT have led to improved visualization of peripheral emboli but failed to demonstrate definitive clinical improvement in the management of data.

The feasibility of spiral computed tomography as a primary tool. The spreading use of spiral CT as a primary test in the diagnosis of PE puts great pressure on radiology departments. Indeed, spiral CT is often utilized for several diagnoses different from PE, frequently interesting organs other than the lungs, which may cause the impossibility of satisfying all requests in real time. In the recent British Thoracic Society guidelines, the authors state that "although most clinicians and radiologists recognize that CT pulmonary angiography should be the preferred initial imaging modality in suspected PE, current resources make this impracticable"[32]. Even less practicable is to repeat spiral CT with the purpose of controlling the efficacy of therapy after an adequate time interval, usually in the vicinity of hospital discharge (usually after 7 days of heparin). As a consequence, it occurs more and more frequently that patients firstly diagnosed with spiral CT be later referred for pulmonary scintigraphy with the query on whether or not they have improved.

The radiation dose. The use of single-detector row CT scan with 5-mm collimation spiral CT of the chest carries a quite high patient's radiation burden, much higher than the one the patient gets with V/Q scintigraphy or with perfusion scintigraphy alone. It is calculated that the use of a single-row detector spiral CT of the chest gives the patient a radiation dose of 7-8 mSv[33], a dose that doubles whenever the examination is repeated after the intravenous infusion of a contrast medium. The use of a 4-detector row CT with 1-mm collimation increases the radiation dose from 30 to 100%, although similar increases in radiation dose are not to be expected using the 16-detector row CT with submillimiter resolution thanks to a better tube output utilization[34]. Altogether, in consideration of this further issue, it does not seem cost-effective to utilize spiral CT as the primary test to detect and rule out PE.

Overall conclusions

Since most patients affected by PE still go undetected and thus untreated during life[35], the real issue is not which technique is the best or when it must be used

as a primary or secondary tool but, rather, how to improve the recruitment of patients for the diagnosis. This improvement cannot be made by newer tools, even by the most sophisticated; it may be accomplished uniquely by an accurate clinical suspicion, prerequisite for a correct diagnosis. To this purpose clinicians should become accustomed with the multiform clinical manifestations of PE and, above all, appropriately consider PE in the differential diagnosis of patients with acute cardiopulmonary manifestations.

To conclude with Eisner "helical CT may provide the illusion of certainty through means of yes/no answer, instead of a probabilistic one ..."[36]. This is a potential risk for patients, clinicians, and public health systems.

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