Original Article

Comparison of CT pulmonary angiogram with V/P scintigraphy in the diagnosis of pulmonary embolism

Pulmoner emboli tanısında BT pulmoner anjiyografi ile V/P sintigrafinin karşılaştırılması

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Abstract
Background: We compared the effectiveness of multi-detector row computed tomography (MDCT) angiogram and Ventilation-Perfusion scintigraphy (V-P scintigraphy) in the diagnosis of acute pulmonary embolism (PE).
Methods: Thirty-nine patients (17 men, 22 women, mean age of 54,2), in whom acute PE was suspected, underwent MDCT (collimation, 4 x 1,3 mm; pitch, 1.25; scanning time, 0.5 second, 120 kV, 150 mAs) and Ventilation-Perfusion scintigraphy within 48 hours after the hospital admission. Patients in whom pulmonary embolism was not found at both MDCT and V-P scintigraphy were clinically followed up at least 3 months. The final diagnosis was reached according to clinical, radiological and scintigraphy findings. MDCT and V-P scintigraphy findings were compared with each other in terms of presence and location of pulmonary embolism.
Results: Final diagnosis for the 39 patients were pulmonary embolism in 20 (51,3%) and no pulmonary embolism in 19 (48,7%). The sensitivity of MDCT and V-P scintigraphy in the detection of PE was 95% (19 of 20); and 65% (13 of 20). The specificity of MDCT and V-P scintigraphy was 100% (19 of 19) and 58% (11 of 19).
Conclusions: MDCT is more accurate than V-P scintigraphy in the diagnosis of acute PE. Additionally, MDCT provides the differential diagnoses for patients without PE. MDCT should be considered the first imaging modality in the assessment of PE.

Özet
Amaç: Biz akut pulmoner emboli (PE) tanısında ventilasyon-perfüzyon sintigrafisi (V-P sintigrafisi) ve çok kesitli bilgisayarlı tomografi (ÇKBT) pulmoner anjiografinin etkinliğini karşılaştırmayı amaçladık.
Materyal ve metod: Hastaneye PE kuşkusuyla başvuran, başvurudan itibaren 48 saat içerisinde ÇKBT (kolimasyon:4X1.3, pitch:1.25, tarama süresi:0.5 saniye, 120 kV, 150 mAs) ve V-P sintigrafi tetkiği yapılan 39 hasta (17 erkek, 22 kadın; ortalama yaş 54,2) çalışmaya dahil edildi. ÇKBT ve V-P sintigrafide PE saptanmayan olgular klinik olarak en az üç ay takip edildi. Son tanı klinik, radyolojik ve sintigrafik bulgulara göre konuldu. ÇKBT ve V-P sintigrafi bulguları PE varlığı ve yerleşim yeri açısından birbirleri ile karşılaştırıldı.
Bulgular: 39 hastadan 20(%51.3)'sinde PE saptanırken; 19(%48.7)'unda PE saptanmadı. ÇKBT ve V-P sintigrafinin sensitiviteleri %95 (20 de 19) ve %65 (20 de 13); spesifiteleri %100 (19 da 19) ve %58 (19 da 11) olarak tespit edildi.
Sonuç: Akut PE tanısında ÇKBT V-P sintigrafiye göre daha kesin sonuçlar vermektedir. ÇKBT ek olarak PE bulunmayan hastalarda farklı tanılar konulmasını sağlamaktadır. ÇKBT PE değerlendirilmesinde ilk görüntüleme yöntemi olmalıdır.

Introduction

Diagnosis of pulmonary embolism (PE) is elusive due to nonspecific signs and symptoms associated with the disease, which renders its actual prevalence unknown. The entity is the third most common cause of death in USA, following cardiac diseases and cancer, with an annual incidence of up to 600.000 and a mortality of up to 100.000 (1,2) Appropriate management with anticoagulant agents can reduce mortality from 30 to 2-8 percent (1).

Signs and symptoms such as chest pain, dyspnea, tachycardia, cough and hemoptysis are not specific to this entity. Various imaging modalities including chest radiographs, V/P scintigraphy (scan), spiral computed tomography pulmonary angiography (SCTPA), MR angiography, echocardiography, and conventional pulmonary angiography are utilized to diagnose thromboembolism (2). Nowadays V/P scanning is the most commonly used noninvasive imaging technique to identify PE. In cases with low clinical probability of PE, a normal or low-probability scan yield a high negative predictive value (NPV). On the other hand, high-

probability scan has a high positive predictive value (PPV) in a highly suspected patient, although only 34% of the patients fall into these categories (3).
SCTPA has become a favorable option in diagnosing PE in the recent years. The technique has been reported to maintain a sensitivity of 60% to 100% and a specificity of 78% to 100% (4,5). Multidetector row CT pulmonary angiography (MDCTPA) allows thin-slice imaging and shortens imaging times, while providing improved visualization of subsegmental pulmonary vasculature (5).
The objective of this study is to compare the results of V/P scanning and MDCTPA in patients suspected to have PE.

Methods

All consecutive adult patients evaluated in the department of pulmonary diseases and suspected to have PE with regard to physical examination, CXR and blood chemistry were enrolled in the study between September 2002 and May, 2004 after the approval of the institutional review board had been obtained. The patients' charts were reviewed retrospectively. A total of 262 patients underwent V/P scanning while MDCTPA was obtained in 210 within this period in order to rule out PE. Data analysis was restricted to patients who had undergone both diagnostic modalities within 48 hours after admission (17 males, 22 females, mean age 54.2). All patients were also scored empirically regarding clinical findings. Patients with high-probability V/P scan along with MDCTPA visualizing PE were undoubtedly diagnosed with PE without any additional diagnostic tests. PE was ruled out in patients with normal or low-probability scan results, and without emboli in MDCTPA. The rest of the patients were diagnosed with PE after adjunctive tests such as clinical scoring, Doppler USG and three-month clinical follow-up of hospital charts.

All CT imaging studies were performed using a MD spiral CT device (MX8000; Philips Medical Systems, Cleveland, Ohio), automatic injector (MEDRAD MCT injection system) with intravenous contrast enhancement. The patients were trained on holding their breath. The examination area (between diaphragm and aortic arch) was determined on the scanogram obtained in the supine patient. Investigations were carried out while the arm with the IV line is lying besides the supine patient and the opposite arm is abducted horizontally. All subjects received 100 ml contrast media (non-ionic contrast medium, 350 mg/ml) in antecubital vein via 18 to 20 gauge catheter over 25 seconds with a rate of 4 ml per second. MDCTPA image acquisition was started within 14 to 20 seconds after commencement of administration of contrast medium and was completed in 25 seconds. Investigation parameters were predetermined as 120 kV, 150 mAs, pitch 1.25, slice thickness 4X1.3 mm, scan time 0.5 s. The acquired images were reconstructed using 180 degree linear-interpolation algorithm and matrix 512X512 pixel, C filter with 0.6 mm spaces. MDCTPA images were interpreted with respect to main lobar, segmental and subsegmental vasculature using the criteria developed and modified by Remy-Jardin et al (6). Two experienced radiologists evaluated the images in accord with these criteria, with special regard to presence of occlusive or nonocclusive emboli, adequacy of vascular contrast enhancement, and presence of associated mediastinal and parenchymal pathologies. Contradictory interpretations were reexamined and reached to a consensus.

Technique of Doppler ultrasonography investigation: The patients' lower extremities were examined by an experienced radiologist using ATL 5000 (Philips Medical Systems), in a frequency interval of 12-5 mHz, with a 5-cm superficial probe. Venous USG examination comprised the area between the inguinal level and popliteal vein. In the first stage, gray scale was employed to assess venous wall structure, intraluminal echogenicity, luminal size, vascular response to compression and inspiratory changes. The second stage consisted of assessment of color filling and flow forms via color Doppler USG, and documentation of deep vein thrombosis (DVT).

V-P scan studies were elicited with gamma camera (XR/T GE Medical Systems, Milwaukee, Wis) following intravenous administration of 5 mCi Tc 99m-labeled 'macro- aggregated' serum albumin. The images were obtained with three-minute intervals in anterior, posterior, right posterior oblique, left posterior oblique, right lateral and left lateral positions. Then ventilation scan images were recorded in the same positions and intervals following inhalation of nebulized 40 mCi Tc-99m DTPA (diethylenetriaminepentaacetic acid).

This study employed a matrix of 256X256 pixels. V/P scan images were evaluated by an experienced nuclear medicine specialist in accord with PIOPED criteria and were assigned to one of four categories: 1. high probability, 2. moderate probability, 3. low probability, 4. normal (7).

Clinical Course

Patients with consistent diagnostic tests who were diagnosed with PE were treated with anticoagulant agents. Those without anticoagulant treatment were subjected to chart follow-up with respect to PE and DVT for three months.

Final diagnosis of PE

Definitive diagnosis of PE was established when a positive MDCTPA is coupled with a high probability V/P scan result. Absence of PE was confirmed by negative

MDCTPA, normal- to low-probability V/P scan findings and three-month file follow-up. The diagnosis was clarified in case of inconsistent MDCTPA and V/P scan with empirical clinical scoring and lowers extremity Doppler USG results. There is no consensus in the literature on which clinical probability model is to be used in case of suspected PE. The most widely used clinical scoring systems are the standard clinical scoring system developed by Hyers and empirical clinical scoring system (8-10). Empirical clinical scoring is the most widely employed technique with its ease of use and comprehensibility. In the current study, patients were assigned to high, moderate and low-scored groups in accord with the empirical clinical scoring system.

Analysis: Sensitivity, specificity, PPV and NPV were calculated for MDCTPA and V/P scan. Only the high-probability scan results were considered as 'positive scan' for purposes of sensitivity. On the other hand, normal and low-probability results were taken as 'negative scan' to calculate specificity. Differences between the results of MDCTPA and V/P scan were analyzed with McNemar test. This test was also performed to compare empirical clinical scoring results with MDCTPA results.

Results

Twenty patients out of 39 (51%) who were suspected to have PE were diagnosed with the entity. Of these, 12 (60%) received the diagnosis with MDCTPA demonstrating the thromboemboli concurrent with high-probability V/P scan results. The diagnoses of two patients (10%) were established after high-probability clinical score, DVT identified in Doppler USG, and thromboemboli shown in MDCTPA. V/P scan results were interpreted as low-probability in one of these patients and moderate in the other. Another patient (5%) was diagnosed with high probability clinical and V/P scan results. This patient also had DVT, while thromboembolus was not visualized in MDCTPA. Four patients (20%) had the diagnosis with high clinical score and MDCTPA demonstrating thromboemboli. Three of them had received low probability V/P scan and the other had moderate probability. Another patient (5%) had a low probability V/P scan, however received the diagnosis after MDCTPA showing thromboembolus along with a moderate probability clinical score (Table 1). In 11 patients (58%) out of 19 without PE the diagnosis was ruled out with absence of thromboembolus in MDCTPA associated with normal- to low-probability V/P scan results (Table 2).

Pulmonary arterial emboli were visualized in central and peripheral vasculature in ten patients' (50%) MDCTPA interpretations, while only segmental or subsegmental arterial emboli were demonstrated in the other ten (50%). Among these, four patients harbored isolated subsegmental emboli.

MDCTPA has led to the correct diagnosis in 19 out of 20 (sensitivity=95%). The only patient with the false negative result received the diagnosis with high probability clinical score associated with high probability V/P scan result. MDCTPA images were interpreted as negative in all 19 patients without PE (specificity=100%). None of these with negative MDCTPA developed thromboembolic event within the three-month follow-up period. In 11 patients out of 19 patients without PE, MDCTPA provided data supporting the definitive diagnoses besides ruling out PE. These included pneumonia (n=5), pulmonary edema (n=1), pleural effusion (n=1), radiation fibrosis (n=1), bronchiectasis (n=1), chronic obstructive pulmonary disease (n=1) and metastatic breast cancer (n=1).

V/P scan yielded high-probability results in 13 out of 20 patients with PE (sensitivity=65%). Scans missed PE in seven patients including two with subsegmental emboli, 2 segmental, 2 main pulmonary, lobar and segmental, and one with lobar and segmental arterial emboli. Normal to low- probability scans were recorded in 11 out of 19 patients without PE (specificity=58%). MDCTPA had a NPV of 95% and a PPV of 100%, while V/P scan had a NPV of 93% and a PPV of 69%.

Thirty-four out of 39 patients undergoing investigation for PE with MDCTPA and V/P scan were also examined with Doppler USG. PE was identified in 7 out of 9 with DVT, while DVT was ruled out in 12 with PE documented in MDCTPA. PE was visualized in the right lung in 5 patients, in the left in four and bilateral in 11. MDCTPA ruled out PE in all 6 patients (100%) with low-probability clinical scores while 17 (89%) out of 19 with high clinical scores turned out to have PE. Two (14%) out of 14 patients with moderate clinical scores were diagnosed with PE (Tables 3 and 4).

When the results of MDCTPA were compared to those of V/P scan using Mc Nemar test, there was a statistically insignificant difference ($p=0.180$, $p>0.05$). The results obtained from the empirical clinical scoring model used in this study were compared with MDCTPA interpretations using McNemar test, and no statistical difference was found ($p=0.5$).

Discussion

PE is a leading cause of death with a mortality rate of 30% in untreated victims. Expedient diagnosis and prompt treatment reduce the rate to 3% (11-13). Absence of specific symptoms, radiographic and laboratory findings render the diagnosis elusive. Certain diseases such as pneumonia and congestive heart failure do not only boost the risk of PE, they also masquerade as PE. While only one third of the patients are suspected of having the disease, a substantial percentage of patients go undiagnosed (14,15).

Chest radiographs have a limited diagnostic yield in

PE. It is useful in differentiating entities that mimic PE, and comparing them with V/P scan results (16). V/P scan is also a commonly used technique in the diagnosis of PE, although perfusion defects are not unique to the entity. PIOPED enrolled 1493 patients and showed that high-probability scan results predicted significant PE, while normal and low-probability scan ruled out the disease in 98% of the cases. On the other hand, scans were not helpful to establish or rule out the diagnosis in 73%. Perfusion scan is most useful in ruling out PE in selected cases. Thus PIOPED researchers recommend use of ventilation scan when deemed necessary. Therefore ventilation scan was not included in the current study protocol due to concerns regarding cost-effectiveness (17).

Conventional pulmonary angiography is considered the gold standard diagnostic modality(14,18,19) with its sensitivity and specificity above 95%. In PIOPED, its morbidity and mortality is reported to be 6% and 0.1%, respectively. However, its sensitivity and interrater reliability drops significantly in subsegmental emboli (18-21). The technique was not employed in the current study due to its retrospective design.

Spiral CTPA was compared to pulmonary angiography in diagnosis of PE and found to be 100% sensitive and 96% specific (22). A couple of newer studies reported its sensitivity between 97% and 53%, specificity 100% and 81% (6,23). The sensitivity and specificity of MDCTPA were found to be 95% (19/20) and 100% (19/19), respectively, in the diagnosis of PE.

The results from the current study indicate that MDCTPA is an appropriate method to verify or rule out PE in suspected cases. The sensitivity and specificity figures are somewhat higher than similar studies. It may have resulted from usage of single-detector spiral CT in previous studies. Advanced technologies optimized contrast enhancement, allowed thin-section analysis and finally, improved resolution quality in MDCTPA (6,22,23). Section thickness is reduced up to 1 mm in the recent studies which allowed evaluation of subsegmental arteries in 70% of the cases and increased interrater reliability (14).

V/P scan was found 65% sensitive and 58% specific in this study. Corresponding figures were reported as 86% and 88% by Coche et al. and 80.8%, and 82% by Blachere et al., respectively (19,24). A factor that may have contributed to the lower sensitivity and specificity values compared to the previous studies is the higher rate of moderate-probability results.

The most remarkable finding in the current study is that the diagnostic accuracy of MDCTPA was found superior to V/P scan. Cross et al. showed that SCTPA and V/P scan was able to visualize PE in 90% and 54%, respectively (26).

Although body mass indices (BMI) were not recorded in the current study, we have not noticed any difficulty imaging the obese and/or dyspneic patients which could mandate performing a modified spiral CT protocol. Other potential limitations of CTPA studies such as known allergy to contrast media, renal failure, hemodynamic instability and pregnancy were not recorded in any of our study patients.

Sixteen patients were found to harbor right-sided PE, while 15 had emboli on the left. The most commonly involved site was segmentary branches of the lower lobe (15/20). This finding was consistent with previous data. On the other hand, there was not any significant difference between right- and left-sided emboli in contrast to the literature data (26,27).

The prevalence of PE was found 51% in the present study, which is higher than the literature data (26,28). A major cause of this difference might have been the retrospective design of the study and recruitment of only the patients undergoing V/P scan in 48 hours. Four (20%) out of 20 patients with emboli suffered from isolated subsegmental thromboembolism, which falls within the range previously reported (6-34%) (29,30). Recent studies put forth that MDCTPA is the imaging study of choice to visualize isolated subsegmental thromboembolism (24,31,32).

NPV of an imaging study is judged in three-month period with respect to recurring PE (33). MDCTPA had a NPV of 95% in the present study, similar to the rates previously reported (34, 35). MDCTPA has a higher NPV compared to that of single-detector spiral CT due to higher resolution. Three-month incidence of PE has been found as 5%, which is higher than literature data (21, 34, 35). Small sample size may have contributed in this discrepancy.

CTPA has been useful in 11 out of 19 patients without PE in establishing diagnoses of other conditions such as pneumonia, pulmonary edema, pleurisy, metastatic cancer etc. These findings were not recorded in V/P scan studies (36).

The empirical clinical scoring model had a significant consistency with MDCTPA results. None of the six patients with low probability clinical score turned out to have PE in MDCTPA, while 17 (89%) out of 19 patients with high probability scores had PE in MDCTPA. The consistency values were higher in patients with high- and low-probability clinical scores than in those with moderate probability.

Lower extremity DVT was visualized in eight (40%) out of 20 patients with PE. This finding was similar to the study by Hull et al (37). Fifteen patients without PE underwent lower extremity venous Doppler USG and only one were diagnosed with DVT. A combination of clinical probability model, V/P scan, outcomes in three-month follow up and MDCTPA were used in the assessment of the patients in the current study. The definitive diagnosis was considered to be established in cases with consistent MDCTPA and V/P scan results. In patients with inconsistent results, further evaluation was performed with Doppler USG, clinical scoring and three-month follow-up to approach the diagnoses.

Some limitations applied to the present study. First of all, it has not enrolled 'all' patients suspected to have PE. Only patients who underwent MDCTPA and V/P scan within 48 hours were recruited. A second limitation is that pulmonary angiography- gold-standard imaging study in PE- was not performed in any patient. This drawback was compensated by employing clinical scoring, three-month follow-up of charts, lower extremity venous Doppler USG, MDCTPA and V/P scan in the diagnostic armamentarium. A recent study compared pulmonary angiography and MDCTPA and found no difference between the two techniques in diagnosing PE (38). Another study pointed out that spiral CT was superior to pulmonary angiography (39). The indications of PA is subject to an ongoing debate nowadays and it is generally thought that pulmonary angiography can be considered in case of negative spiral CT, negative lower extremity DVT and high clinical probability.

A third limitation is small sample size which is unable to represent a clinical group. The sample consisted of patients from the ED, ICU and wards. Well-designed trials conducted with broader, selected and homogeneous samples are needed to extrapolate the results of this study.

Clinical scoring and noninvasive tests are commonly performed as the first step in the contemporary approach to diagnose PE. The present results support MDCTPA over V/P scan with respect to predictive values and accuracy as an initial imaging study. It can also be foreseen that MDCTPA can reduce the need to catheter pulmonary angiography which is an invasive procedure. Nonetheless, catheter pulmonary angiography is still indicated in cases with normal MDCTPA in the presence of high clinical probability of PE.

MDCTPA is an important diagnostic tool with its ability to visualize pulmonary arteries up to subsegmental levels. The technique has a higher accuracy and reliability when compared to V/P scan in establishing a diagnosis of PE.

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References

1) Moser KM. Venous thromboembolism. Am Rev Res Dis 1990; 141:235-249.

2) Henschke CI, Mateescu I, Yankelevitz DE. Changing practice pattern in the workup of pulmonary embolism. Chest 1995; 107:940-945.

3) Worsley DF, Alavi A. Comprehensive analysis of the results of the PIOPED study. J Nucl Med 1995; 36:2380-2387

4) Remy-Jardin M, Remy J, Deschildre F, et al. Diagnosis of pulmonary embolism with spiral CT: comparison with pulmonary angiography andscintigraphy. Radiology 1996; 200:699–706

5) Ghaye B, Szapiro D, Mastora I, et.al. Peripheral pulmonary arteries: how far in the lung does multi-detector row spiral CT allow analysis? Radiology 2001; 219:629–636

6) Remy-Jardin M, Louvegny S, Remy J, et al. Acute central thromboembolic disease: posttherapeutic follow-up with spiral CT angiography. Radiology 1997; 203:173-180.

7) The PIOPED investigators. Value of the ventilation/perfusion in acute pulmonary embolism: Results of the prospective investigation of pulmonary embolism diagnosis (PIOPED). JAMA 1990; 263:2753.

8) Hatipoglu ON, Durak H, Ucan ES et al. Combination of clinical and scintigraphicgrading in pulmonary embolism. First International Congress of Nuclear Oncology and 8th. Annual Meeting of Turkish Society of Nuclear Medicine Abstract book. **İstanbul 1994**;3:17

9) Hatipoglu ON, Durak H, Ucan ES et al. [Combinations of clinical and scintigraphic scoring in pulmonary embolism]. (Turkish) Journal of Trakya Univ. School of Medicine 1995; 12(1,2,3):165-169.

10) Hyers T. Diagnosis of pulmonary embolism. Thorax 1995; 50:930-932

11) Carson JL, Kelley MA, Duff A, et al. The clinical course of pulmonary embolism. N Engl J Med 1992; 326:1240-1245.

12) Duwe KM, Shiau M, Budorick NE, et al. Evaluation of the lower extremity veins in patients with suspected pulmonary embolism: Retrospective comparison of helical CT venography and sonography. AJR 2000; 175:1525-1531.

13) Prevention of venous thrombosis and pulmonary embolism. NIH Consensus Development. JAMA 1986; 256:744-9

14) Peterson KL. Acute pulmonary thromboembolism: Has its evolution been redefined? Circulation 1999; 99:1280-1283

15) Arseven O. Acute pulmonary embolism. In: Turktas H, Ekim N eds. Emergencies in Pulmonary diseases Turkish: Ankara, 2000, pp:247-262

16) Fraser RS, Müler NL, Colman N, Pare PD. Thrombosis and thromboembolism. In: Fraser RS, Müler NL, Colman N, Pare PD, eds. Diagnosis of disease of the chest. 4th ed. Philadelphia: W.B Saunders company 1999:1773-1483.

17) Miniati M, Pistolesi M, Marini C, et al. Value of perfusion lung scans in the diagnosis of pulmonary embolism: results of the prospective investigate study of acute pulmonary embolism diagnosis (PISAPED). Am J Resp Crit Care Med 1996; 154:1387-1393.

18) Spritzer CE, Norconk JJ, Sostman HD, Coleman RE. Detection of deep venous thrombosis by magnetic resonance imaging. Chest 1993; 104:54.

19) Blachere H, Latrabe V, Montaudon M, et al. Pulmonary embolism revealed on helical CT angiography: comparison with ventilation-perfusion radionuclide lung scanning. AJR2000; 174:1041-1047.

20) Gotway MB, Patel RA, Webb WR. Helical CT for the evaluation of suspected acute pulmonary embolism. Diagnostic pitfalls. J Comput Assist Tomogr 2000; 24:267-273

21) Kavanagh EC, O'Hare A, Hargaden G, Murray JG. Risk of pulmonary embolism after negative MDCT pulmonary angiography Findings. AJR 2004; 182:499-504.

22) Coche E, Muller NL, Kim KI, et al. Acute pulmonary embolism: ancillary findings at spiral CT. Radiology 1998; 207:753-758.

23) Remy-Jardin M, Remy J, Wattinne L, et al. Central pulmonary thromboembolism: diagnosis with spiral volumetric CT with the single-breath-hold technique-comparison with pulmonary angiography. Radiology 1992; 185:381-387.

24) Coche E, Verschuren F, Keyeux A et al. Diagnosis of acute pulmonary embolism in outpatients: comparison of thin-collimation multi-detector row spiral CT and planar ventilation-perfusion scintigraphy. Radiology 2003; 229(3):757-65.

25) Cross JJ, Kemp PM, Walsh CG, Flower CD, Dixon AK. A randomized trial of helical CT and ventilation perfusion radionuclide lung scanning for the diagnosis of pulmonary embolism. Clin Radiol 1998;53:177–182

26) Mayo JR, Remy-Jardin M, Muller NL, et al. Pulmonary embolism: prospective comparison of helical CT with ventilation–perfusion radionuclide lung scanning. Radiology 1997; 205:447–452

27) Ferretti GR, Bosson JL, Buffaz PD, et al. Acute pulmonary embolism: role of helical CT in 164 patient with intermediate probability at ventilation-perfusion scintigraphy and normal results at duplex US of the legs. Radiology 1997; 205:453-458.

28) Krivec B, Voga, Zuran I, et al. Diagnosis and treatment of shock due to massive pulmonary embolism. Approach with transesophageal echocardiography and intrapulmonary thrombolysis. Chest 1997; 112:1310 1316.

29) Oser RF, Zuckerman DA, Gutierrez FR, Brink JA. Anatomic distribution of pulmonary emboli at pulmonary angiography: Implications for cross-sectional imaging. Radiology 1996; 199:31–35.

30) de Monye W, van Strijen MJ, Huisman MV, et al. Suspected pulmonary embolism: prevalence and anatomic distribution in 487 consecutive patients. Radiology 2000; 215:184–188.

31) Schoepf UJ, Holzknecht N, Helmberger TK,et al. Subsegmental pulmonary emboli: improved detection with thin-collimation multi– detector row spiral CT. Radiology 2002; 222:483–490.

32) Ghaye B, Szapiro D, Mastora I, et al. Peripheral pulmonary arteries: how far in the lung does multi–detector row spiral CT allow analysis? Radiology 2001; 219:629-636.

33) Tillie-Leblond I, Mastora I, Radenne F, et al. Risk of pulmonary embolism after a negative spiral CT angiogram in patients with pulmonary disease: 1-year clinical follow-up study. Radiology 2002; 223:461–467

34) Lomis NN, Yoon HC, Moran AG, Miller FJ. Clinical outcomes of patients after a negative spiral CT pulmonary arteriogram in evaluation of acute pulmonary embolism. J Vasc Interv Radiol 1999; 10:707–712

35) Bourriot K, Couffinhal T, Bernard V, et al. Clinical outcome after a negative spiral CT pulmonary angiographic finding in an inpatient opulation from cardiology and pneumology wards. Chest 2003; 123:359–365.

36) Kim KI, Muller NL, Mayo JR. Clinically suspected pulmonary embolism: utility of spiral CT. Radiology 1999; 210:693–697.

37) Perrier A, Miron MJ, Desmarais S et al. Combining clinical probability and lung scan in suspected pulmonary embolism. Arch Intern Med 2000; 160:512-516

38) Baile EM, King GG, Muller NL, et al. Spiral computed tomography is comparable to angiography for the diagnosis of pulmonary embolism. Am J Respir Crit Care Med 2000; 161:1010-1015.

39) Herold CJ, Sostman HD, Weber M, Fleishman D, Hahne J. Determination of retrospective gold standart in patients with suspected PE and discordant results between spiral CT and pulmonary angiography. Radiology 2000; 217:294.