

Original Article

Acute pulmonary embolism detection with ventilation/perfusion SPECT combined with full dose CT: What is the best option?

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ABSTRACT

Aim: To compare diagnostic accuracy of Ventilation/Perfusion (V/P) single-photon emission computed tomography (SPECT) combined with simultaneous full-dose CT with a hybrid SPECT/CT scanner versus planar ventilation/perfusion (V/P) SPECT and CT angiography (CTA) in patients suspected with acute pulmonary embolism (PE).

Methods: Between 2009 and 2011, consecutive patients suspected of acute PE were referred for V/P SPECT/CT (reviewed board approved study). A contrast agent was administered to patients who had no contraindications. Non-contrast V/P SPECT/CT was performed on the remaining patients. All patients were followed-up for at least 3 months.

Results: A total of 314 patients were available during the study period, with the diagnosis of PE confirmed in 70 (22.29%) of them. The overall population sensitivity and specificity was 90.91% and 92.44%, respectively for V/P SPECT, 80% and 99.15%, respectively, for CTA, and 95.52% and 97.08% for V/P SPECT/CT. SPECT/CT performed better than V/P SPECT (AUC differences = 0.0419, $P = 0.0043$, 95% CI: 0.0131–0.0706) and CTA (AUC differences = 0.0681, $P = 0.0208$, 95% CI: 0.0103–0.1259). Comparing imaging modalities when contrast agent could be administered, sensitivity and specificity increased and V/P SPECT/CT was significantly better than CTA (AUC differences = 0.0681, $P = 0.0208$, 95% CI: 0.0103–0.1259) and V/P SPECT (AUC differences = 0.0659, $P = 0.0052$, 95% CI: 0.0197–0.1121). In case of non-contrast enhancement, there was non-significant increase of specificity. Secondary findings on CT impacted patient management in 14.65% of cases.

Conclusion: Our study shows that combined V/P SPECT/CT scanning has a higher diagnostic accuracy for detecting acute PE than V/P SPECT and CTA alone. When feasible, V/P SPECT/CT with contrast enhancement is the best option.

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SPECT/TC de ventilación-perfusión pulmonar en el diagnóstico del tromboembolismo pulmonar agudo

RESUMEN

Objetivo del estudio: Valorar la exactitud diagnóstica de la SPECT/TC de ventilación-perfusión (V/P) pulmonar de alta dosis mediante un equipo híbrido SPECT/TC frente a la SPECT de V/P pulmonar y a la angiografía por TC (CTA) en pacientes con sospecha de tromboembolismo pulmonar (TEP) agudo.

Metodología: Entre 2009 y 2011, se estudiaron de forma consecutiva con SPECT/TC de V/P pulmonar los pacientes con sospecha de TEP agudo que acudieron a nuestro centro (estudio aprobado por el comité de ética hospitalaria). A los pacientes que no presentaban contraindicaciones se les administró contraste yodado (CI) por vía intravenosa. En el resto se realizó un estudio SPECT/TC de V/P pulmonar sin CI. Los pacientes fueron seguidos durante un período de 3 meses.

Resultados: Se estudiaron un total de 314 pacientes. En 70 (22,29%) se confirmó el diagnóstico de TEP. La sensibilidad y especificidad para la población global fue: 90,91 y 92,44% respectivamente para la SPECT de V/P; 80 y 99,15% para la CTA; y 95,52 y 97,08% para la SPECT/TC de V/P pulmonar. La SPECT/TC presentaba una exactitud diagnóstica superior a la SPECT de V/P (diferencias AUC = 0,0419; $p = 0,0043$; IC95%: 0,0131–0,0706) y la CTA (diferencias AUC = 0,0681, $p = 0,0208$; IC95%: 0,0131–0,1259). Comparando las diferentes modalidades cuando se administró CI, observamos un aumento de la sensibilidad y la especificidad de

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la SPECT/TC de V/P superior a la CTA (diferencias AUC = 0,0681; $p = 0,0208$; IC95%: 0,0131-0,1259) y a la SPECT de V/P (diferencias AUC = 0,0659; $p = 0,0052$; IC95%: 0,0197-0,1121). En el caso de no administrar CI se observó un aumento no estadísticamente significativo de la especificidad. Los hallazgos secundarios de la TC provocaron un cambio en el manejo del paciente en un 14,65% de los casos.

Conclusión: Nuestro estudio demuestra que el estudio combinado SPECT/TC de V/P pulmonar tiene una mayor exactitud diagnóstica para detectar el TEP agudo que la SPECT de V/P pulmonar o la CTA por sí solos. Cuando es factible, la SPECT/TC de V/P pulmonar con CI es la mejor opción diagnóstica.

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Introduction

Pulmonary embolism (PE) is a relatively common and potentially fatal disorder in inpatients as well as in some outpatients, with an incidence of 100 per 100.000 individuals per year.¹ Prevalence in hospital patients is roughly 1%.² PE is known to be associated with a considerable risk of mortality: autopsy studies have shown PE in 34% of hospital deaths.³ Early diagnosis is essential in order to treat patients immediately, and thus to decrease mortality.⁴ Patients with acute PE may present with a wide spectrum of symptoms and signs, but none of them proved to be useful to diagnose PE.⁵ Therefore, a diagnostic image technique is needed. Planar ventilation/perfusion (V/P) scintigraphy has been the pivotal diagnostic test for over thirty years.⁶ However, in spite of its high sensitivity,⁷ it has important limitations, namely low specificity and worrisome rates of indeterminate studies, around 30%.⁸⁻¹¹

Helical CT Angiogram (CTA) has become the first diagnostic test in many institutions. Among advantages are short acquisition times, wide availability, high specificity, holistic result and the disclosure of alternative diagnoses. However, some studies have shown a rather low sensitivity of 83% for a screening test.^{10,11} In addition, CTA is contraindicated in patients with renal insufficiency, contrast agent allergy or multiple myeloma, all of which may be commonly encountered in everyday practice.

The advent of SPECT techniques in the nuclear medicine field has meant a real milestone, especially in brain and heart studies.¹² Several investigations have shown a significant improvement in lung V/P scanning with SPECT, owing to increased sensitivity, specificity and accuracy, as well as lower rates of indeterminate studies and better intra and inter observer correlation.¹³⁻¹⁸ Hybrid SPECT/CT equipment has opened a new perspective in both anatomical and functional imaging but only few studies have focused on the potential role of SPECT/CT in the diagnosis of acute PE,¹⁹⁻²² all of which used low-dose CT. Based on a prospective design of unselected patients suspected for acute PE, we aimed to assess diagnostic performance of V/P SPECT combined with full-dose CT with or without contrast enhancement, simultaneously obtained on a hybrid SPECT/CT scanner.

Materials and methods

Patient eligibility

Our investigation was duly approved by our institutional Scientific Ethics Committee (Project Approval number EO-09-081). Written informed consent was obtained from all patients. The study protocol complied with the guidelines of the Helsinki Declaration on human experimentation. The study included consecutive patients suspected of acute PE from April 2009 through April 2011. Patients were included if they had acute symptoms suggesting PE, defined as acute onset of new or worsening shortness of breath or chest pain without any obvious cause, combined with a intermediate or high pre-test probability according to the Wells score or a low

pre-test probability with raised D-dimer results (>255.00 ng/dL). Patients with previous PE and pregnant women were excluded.

Imaging protocols

For ventilation imaging, patients inhaled a radioactive aerosol of ^{99m}Tc-DTPA (Effective dose (mSv): 5.64, (ICRP 60)). If the count rate was superior to 0.5 kcounts/s SPECT ventilation images were acquired with a Siemens Symbia T2 SPECT/CT system, 15 s/step, continuous mode rotation, on a 128 × 128 matrix. If the rate was lower, planar images were recorded as standard planar views.

Following the ventilation study, SPECT images of the chest (10 s/step, continuous mode rotation, in a 128 × 128 matrix) were recorded after intravenous (IV) injection of 6.0 mCi (222 MBq) of ^{99m}Tc-MAA with the patient supine during tidal breathing (Effective dose (mSv): 2.44, (ICRP 60)). Following perfusion SPECT, a CT scan was acquired (80 mAs, 110 Kv (average), 3 mm slice, 2 × 2.5 mm collimation, 1.2 pitch, 0.8 s rotation) in deep inspiration. IV iodinated contrast agent was administered with 10 s delay (3 mL/s, 100 mL/300 mg Iodine, Iomeron 300®) if serum creatinine was <2 mg/dL in patients younger than 70 years or normal in older patients (Effective dose (mSv): 4.4 for the topogram and CTA, (Ctdosimetry v.1.0.4)). Other causes of contrast agent contraindications were metformin use, contrast allergy, inability to obtain a correct venous catheterization, a recent chest CT angiography and/or other known contraindications.

Ventilation and perfusion SPECT imaging data were rebuilt using an iterative ordered subset expectation maximization algorithm with scatter and attenuation correction. The resulting images were displayed in transaxial, coronal, and sagittal planes and fused V/P SPECT and P-SPECT/CT images were obtained.

Image interpretation and final diagnosis

Two independent experienced physicians (a radiologist and a nuclear medicine physician of 20 and 5 years of experience respectively) reviewed V/P SPECT, CT, and V/P SPECT/CT images. V/P SPECT, CT and V/P SPECT/CT scan datasets were read on separate occasions to avoid recall bias (15 days lapse period). The physicians were unaware any of clinical information.

V/P SPECT images were interpreted following criteria recommended by the European Association of Nuclear Medicine (EANM) guidelines,²⁵ as in our own clinical routine. PE was reported if there was V/P mismatch with at least one segmental or two subsegmental defects.²⁶ CTA was reported positive for PE based on the presence of acute-looking intravascular clots. Hybrid V/P SPECT/CT studies were reported positive for PE if mismatched V/P defects were not associated with airway or mediastinal conditions that could be responsible for such mismatch and/or there were acute-looking intra-arterial clots on CTA images. Patients were classified in three groups for each technique (V/P SPECT, CTA and V/P SPECT/CT): positive, negative and indeterminate.

A chest radiologist independently reviewed the CT scans and recorded all pulmonary, mediastinal, pleural, thoracic and extra

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