Original

Contribution of V/Q SPECT to planar scintigraphy in the diagnosis of pulmonary embolism


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A B S T R A C T

Aim: To evaluate the feasibility of V/Q SPECT and analyze its contribution to planar V/Q lung scintigraphy in the diagnosis of pulmonary embolism (PE).

Material and methods: A total of 109 patients with suspected PE showing Wells score > 2 and elevated D-dimer were studied. The V/Q could not be completed in 7 patients, so they were excluded. Ventilation and perfusion scans were done using Technegas and 99mTc-MAA. Planar study included 8 projections on a 256 × 256 matrix and 128 projections on a 128 × 128 matrix were acquired for the SPECT study, applying an iterative method. Planar images were interpreted according to modified PIOPED criteria, and SPECT by the guidelines of the EANMNI. The results with both techniques were compared.

Results: V/Q planar scintigraphy and SPECT could be performed in 102 patients. V/Q planar scintigraphy was considered “diagnostic” in 39 of the 102 patients, and “non-diagnostic” in 63. Of the 39 “diagnostic” studies, 31 were reported as high probability of PE and 8 as normal. Of the 63 “non-diagnostic”, 26 corresponded to intermediate, 29 to low, and 8 to very low probability. The SPECT study was “diagnostic” in 97 and indeterminate in only 5. All patients with a high probability planar scintigraphy had a positive SPECT. In the 8 patients with a normal planar scintigraphy SPECT was negative in 5 and positive in 3. In the 63 patients with a “non-diagnostic” planar scintigraphy SPECT was “diagnostic” in 58 of them, positive in 17 and negative in 41.

Conclusion: V/Q SPECT is a feasible technique as it was performed in 102 of the 109 patients who were enrolled in the study (94%). The addition of V/Q SPECT to planar V/Q decreases the number of “non-diagnostic” reports from 62% in planar scintigraphy to 4.9% in SPECT. Therefore, V/Q SPECT should be included in the diagnosis approach of PE due to its high diagnostic yield.

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Contribución de la SPECT V/Q a la gammagrafía planar en el diagnóstico del tromboembolismo pulmonar

R E S U M E N

Objetivo: Evaluar la factibilidad de la SPECT V/Q y analizar su contribución a la gammagrafía planar en el diagnóstico del tromboembolismo pulmonar (TEP).

Material y métodos: Estudio en 109 pacientes con sospecha de TEP, con escala de Wells > 2 y dímero D elevado. Se excluyeron 7 pacientes porque no pudieron completar el estudio. Para la gammagrafía de ventilación se empleó Technegas y para el estudio de perfusión 99mTc-MAA. El estudio planar incluyó 8 proyecciones en matriz 256 × 256, en la SPECT se adquirieron 128 proyecciones en matriz 128 × 128, aplicándose una reconstrucción iterativa. Las imágenes planares fueron interpretadas según criterios PIOPED modificados y la SPECT según la guía de la EANMNI. Se compararon los resultados obtenidos entre ambas técnicas.

Resultados: Fue posible realizar el estudio V/Q planar y la SPECT en 102. La gammagrafía planar V/Q fue considerada “diagnóstica” en 39 de los 102 pacientes, y “no diagnóstica” en 63. De las 39 gammagrafías “diagnósticas”, 31 fueron de alta probabilidad para TEP y 8 fueron normales. De las 63 gammagrafías “no diagnósticas”, 26 fueron probabilidad intermedia, 29 baja y 8 muy baja probabilidad. La SPECT fue diagnóstica en 97 e indeterminada solo en 5. En todos los pacientes con alta probabilidad en la gammagrafía planar la SPECT fue positiva. En los 8 pacientes con gammagrafía planar normal la SPECT fue negativa en 5 y positiva en 3. En 63 pacientes con gammagrafía planar «no diagnóstica», la SPECT fue «diagnóstica» en 58 de ellos, siendo positiva en 17 y negativa en 41.

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Introduction

Venous thromboembolism, which includes deep venous thrombosis and pulmonary embolism (PE), is the third most common cause of death from cardiovascular disease after heart attack and stroke. Its clinical presentation may be very variable and this makes the evaluation of the likelihood of PE in an individual patient according to the clinical presentation, of utmost importance. The assessment of the clinical probability is the first step to the diagnostic process of the disease. When a clinical suspicion of PE has been established, non-invasive imaging techniques must be performed. Planar V/Q scintigraphy was the non-invasive imaging technique of choice and was generally applied for the diagnosis of PE for decades, despite the high number of “non-diagnostic” scans. In this setting the introduction of CT angiography was a breakthrough and it has been in the last decade generally applied in the clinical practice when a PE is suspected. Therefore, planar V/Q remained restricted to specific circumstances, especially when angiography was not appropriate or had contra indications or side effects.

Some authors even suggested the use of ultrasonography in these cases as the technique to replace planar V/Q due to the low diagnostic yield. However, beyond the contra indications of CT such as renal insufficiency and iodine allergy, evidence has been found that CT angiography may have some other limitations. In fact, it has been found that CT may have a relatively low sensitivity with regard to subsegmental embolisms, one of the strong points of V/Q scintigraphy.

In this context, some authors decided to evaluate the contribution of SPECT techniques to the diagnosis of PE as it was done in other clinical applications of scintigraphy with outstanding results. As a consequence the contribution of the V/Q SPECT to diagnosis of PE was reported by demonstrating an increase of the diagnostic yield of the V/Q scintigraphy.

Nevertheless, despite the described advantages, the technique is not of general use in the daily clinical practice, perhaps because not sufficient evidence is available and hence, as suggested by some authors, more research needs to be done to confirm the value of V/Q SPECT in the hospital clinical setting. Therefore, the aim of the present study was to evaluate the feasibility of V/Q SPECT and to analyze its diagnostic yield compared to the V/Q planar scintigraphy when applied in a routinely way to patients with clinical suspicion of PE.

Material and methods

Patients

The study, prospectively designed, included 109 consecutive patients (67 women, 42 men; mean age: 76.9 years; age range: 33–96 years). In all V/Q lung scan was requested because of clinical suspicion of PE by the Internal Medicine, Respiratory, and Emergency Departments of our hospital (80 hospitalized and 29 outpatients) between November 2011 and February 2013. The 109 patients had an elevated serum D-dimer and a Wells score of higher than 2 (85 intermediate risk/Wells score 3–6 and 17 high risk/Wells score > 6). In 7 patients V/Q could not be done and were excluded due to impossibility to complete the scans.

V/Q lung scintigraphy

The study protocol included the evaluation of ventilation and perfusion with planar and tomographic (SPECT) images for both scans.

Ventilation scintigraphy: The scan was done after inhalation of the aerosol 99mTc Technegas over 3–5 respiratory cycles with the patient in supine position. For preparation of the aerosol 700 MBq of 99mTc were used in order to accumulate an approximate activity of 37 MBq in the lung. Images were acquired using a dual head gamma-camera equipped with low-energy, high-resolution collimators (ECAM Siemens). Planar images in 8 projections (anterior, posterior, right oblique anterior, right oblique posterior, left oblique anterior, left oblique posterior, right lateral, left lateral) on a 256 × 256 matrix were acquired. This was followed by the SPECT acquisition on a 128 × 128 matrix and 128 projections at 20 s each.

Perfusion scintigraphy: Immediately after the ventilation scan and with the patient in supine position 150 MBq of 99mTc-MAA were administered by slow intravenous injection, under inspiration. Planar images in 8 views were acquired in the same way as ventilation projections. A perfusion SPECT was also acquired with the same parameters, a 128 × 128 matrix and 128 projections, but 10 s each.

Reconstruction and image analysis

V/Q SPECT data were reconstructed using an iterative method OSEM (Ordered-subset expectation maximization) with 8 subsets and 2 iterations. Reconstructed images were displayed in axial, sagittal and coronal slices. No image processing software was applied to planar images.

The scans were visually analyzed by two experienced readers in V/Q lung studies. Modified PIOPED criteria (high probability, intermediate probability, low probability, very low probability and normal) were applied to the V/Q planar Images. The scan was considered “diagnostic” when the probability was high, or normal. Otherwise the scan was considered “non-diagnostic”. EANM guide line (positive, negative or indeterminate) was applied for reporting the V/Q SPECT scan. Discrepancies were overcome by consensus.

Interpretation of results

Planar and SPECT lung scintigraphy results were analyzed independently and in correlation.

Results

In Table 1, the contribution of SPECT in the “diagnostic group” is shown. Of the 31 with high probability planar scans SPECT was positive in all of them; and of the 8 normal on planar, 3 were positive and 5 negative (Fig. 1). Likewise, Table 2 shows the contribution...
V/Q planar scintigraphy

![V/Q planar scintigraphy images]

Table 1
SPECT V/Q in the 39 “diagnostic” planar V/Q scans.

<table>
<thead>
<tr>
<th>Planar scintigraphy</th>
<th>SPECT (+)</th>
<th>SPECT (-)</th>
<th>SPECT indeterminate</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>High probability</td>
<td>31</td>
<td>0</td>
<td>0</td>
<td>31</td>
</tr>
<tr>
<td>Normal</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>34</td>
<td>5</td>
<td>0</td>
<td>39</td>
</tr>
</tbody>
</table>

Table 2
SPECT V/Q in the 63 “non-diagnostic” planar V/Q scans.

<table>
<thead>
<tr>
<th>Planar scintigraphy</th>
<th>SPECT (+)</th>
<th>SPECT (-)</th>
<th>SPECT indeterminate</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermediate</td>
<td>13</td>
<td>9</td>
<td>4</td>
<td>26</td>
</tr>
<tr>
<td>Low</td>
<td>3</td>
<td>25</td>
<td>1</td>
<td>29</td>
</tr>
<tr>
<td>Very low</td>
<td>1</td>
<td>7</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>41</td>
<td>5</td>
<td>63</td>
</tr>
</tbody>
</table>

Fig. 1. Normal V/Q planar scintigraphy in 8 views and normal V/Q SPECT in axial, right sagittal, left sagittal and coronal slices (ANT: anterior; POST: posterior; ROA: right oblique anterior; LOP: left oblique posterior; RL: right lateral; LL: left lateral; ROP: right oblique posterior; LOA: left oblique anterior).

Table 3
Pre-test clinical probability Wells score > 6. Planar V/Q and SPECT V/Q scintigraphy.

<table>
<thead>
<tr>
<th>Planar scintigraphy</th>
<th>SPECT (+)</th>
<th>SPECT (-)</th>
<th>SPECT indeterminate</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Intermediate</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Low</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Very low</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Normal</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>2</td>
<td>0</td>
<td>17</td>
</tr>
</tbody>
</table>

of SPECT in the “non-diagnostic” group. Of the 26 patients with intermediate probability on the planar views, SPECT was positive in 13 (Fig. 2), negative in 9, and only in 4 remained indeterminate; of the 29 with low probability, the SPECT was negative in 25, positive in 3, and remained indeterminate in 1; of the 8 with very low probability, SPECT was negative in 7 and positive in 1. Overall, 63 “non-diagnostic” scans on planar V/Q turned into 58 diagnostic on SPECT, 17 positive and 41 negative, and only 5 remained indeterminate.

Table 3 shows the planar V/Q probabilities and the V/Q SPECT according to the clinical pre-test probability. When the Wells score was >6, of the 17 patients in this group, SPECT was positive in all the 12 which also had a high probability of PE on planar views (Fig. 3). On the other hand, of the 4 with intermediate and low probability on planar V/Q, 2 were turned into positive and 2 into negative by SPECT.

When the same analysis is applied to the Wells score 3–6 the distribution of the results is very different, as shown in Table 4, revealing a high number of intermediate and low probability planar V/Q scans, 51 in total. Of them, 14 became positive with SPECT and 32 negative, therefore only 5 remained indeterminate.

Table 4
Pre-test clinical probability Wells score 3–6. Planar V/Q and SPECT V/Q scintigraphy.

<table>
<thead>
<tr>
<th>Planar scintigraphy</th>
<th>SPECT (+)</th>
<th>SPECT (-)</th>
<th>SPECT indeterminate</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>19</td>
</tr>
<tr>
<td>Intermediate</td>
<td>13</td>
<td>9</td>
<td>4</td>
<td>26</td>
</tr>
<tr>
<td>Low</td>
<td>1</td>
<td>23</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>Very low</td>
<td>1</td>
<td>7</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Normal</td>
<td>2</td>
<td>5</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>36</td>
<td>44</td>
<td>5</td>
<td>85</td>
</tr>
</tbody>
</table>
Many physicians prefer CT angiography over V/Q scintigraphy due to the availability 24 h and also to the dual report style performed as positive or negative, leading to higher rates of conclusive results. However, evidence has shown a relatively low sensitivity for subsegmental embolisms, and in addition the technique is not indicated in certain diseases or situations. In these circumstances and also when CT angiography is “non-diagnostic”, other diagnostic tests are needed to confirm or exclude PE. It is in this situation where V/Q scintigraphy has its role, not only as an alternative technique but also as the technique of choice.9,16

Since the development of CT angiography and publication of PIOPED criteria in 1990, scintigraphic equipment evolution as well as new radiotracers and new scintigraphic criteria update guideline changed the V/Q role.

When PIOPED investigation was published, the SPECT technology was not generally available and dual or triple-head gamma cameras were still under evaluation. The current availability of V/Q SPECT offers the possibility of reporting as positive or negative according to the recommendations of the European Association of Nuclear Medicine.13

The introduction of new 99mTc radiolabeled micro-particles in the ventilation scans, provides a better definition of peripheral lung structures and have eased the interpretation of the studies in patients with pre-existing pulmonary disease such as chronic obstructed pulmonary disease patients.17

Over the years, V/Q results have been evaluated and re-evaluated with the aim to improve and specify diagnostic criteria. It has led to the proposal of new diagnostic criteria trying to cut down the number of inconclusive reports. The publication of different papers such as the review of the scintigraphic criteria and interpretations PIOPED12 and the results of the Prospective Investigative Study of Acute Pulmonary Embolism Diagnosis (PISA-PED)18 are good examples of this. All this work has led to a better interpretation of the inconclusive results, the very low probability and the interpretation of the mismatch defect of previous interpretation criteria. Furthermore, new concepts are added, such as the clinical stratification, cardiopulmonary risk,19 and comparison to the chest radiography.

Before getting into the detailed analysis of the results of the study, we can notice an outstanding finding, that is, in spite of the advanced age of many of the patients, most of them hospitalized, it was possible to perform the V/Q SPECT study in 102 of the 109 patients. Therefore we can conclude that V/Q SPECT is a feasible technique for the diagnosis of PE. Only 34 of the 102 patients had a CT angiography, and although it is not the aim of this study to compare with this technique, it is anyway a remarkable fact.

Regarding the interpretation of our diagnostic results, it is striking the great difference in the incidence of inconclusive studies between planar scintigraphy and SPECT. Our data showed that 63 of 102 planar examinations (62%) were non-diagnostic. This percentage is within the ranges reported when PIOPED and modified PIOPED criteria are applied.3,12 The high incidence in our study of inconclusive studies is explained by the interpretation criteria applied. If only the intermediate probability studies were considered “non-diagnostic”, the figure would decrease to 26 of 102 (25%), but the inclusion of modified PIOPED criteria in our study has added the low and very low probability studies, 37 of the 102 examinations (36%).

By contrast, when V/Q SPECT is used, the incidence of “non-diagnostic” studies in our series is only 5% (5 of 102 examinations), a percentage in accordance with the published studies.7,10,21 This lower incidence can be explained by the interpretation criteria applied, as some guidelines13 recommend a dual interpretation as positive or negative resembling the CT angiography criteria. As result, the number of the inconclusive studies which limited the use of planar scintigraphy as a diagnostic tool, decrease when SPECT is

**Discussion**

Until the 1990s with the introduction of CT angiography, V/Q lung scintigraphy was the method of choice for studying patients with suspected PE. V/Q scintigraphy is a robust and well established diagnostic test for suspected PE with a high negative predictive value (NPV). The test has been proved extremely safe to apply and few adverse reactions have been described. The radiation exposure from a lung scan is significantly lower than that of a CT angiography.14,15 Its main disadvantage is the lack of specificity, which leads to a high number of non-diagnostic examinations.3

![Fig. 2](image-url) V/Q planar scintigraphy in anterior and left lateral views, showed a single wedge shaped perfusion defect in the antero basal segment of the lower lobe corresponding to an intermediate probability (arrow). In the axial slices of V/Q SPECT this defect was observed and in addition another mismatched defect in the medial segment of the middle lobe was discovered in the contralateral lung (arrows).
V/Q planar scintigraphy

Perfusion

Anterior  Posterior  Right lateral  Left lateral

Ventilation

V/Q SPECT

Perfusion

Axial  Left sagittal  Right sagittal  Coronal

Ventilation

AngioCT

Fig. 3. V/Q planar scintigraphy and SPECT in patient with multiple PE. Several mismatched defects are evident although the definition of the defects is better in SPECT study. CT angiography was negative and did not show underlying structural abnormalities.

applied. But the most important development in the SPECT technique, already reported, is the improvement in the quality of the image and the definition of the ventilation and perfusion defects resulting in images easier to interpret, as well as a lower inter- and intra-observer variability.\textsuperscript{5,22–24}

The better and easier reading of the images provided by the SPECT technique allows for an improvement in the sensitivity of the scintigraphic technique. In our series planar scintigraphy was able to diagnose PE in only 31 of the 51 patients with a final diagnosis of PE (61%). This diagnostic yield is also explained by the current imaging technology and the new compounds, as Technegas, for ventilation studies. This radiotracer provided better results than those reported in previous work, by Palla 1988,\textsuperscript{25} with a sensitivity of 32% in planar scintigraphy. However the diagnostic yield remains lower than the already published studies comparing planar scintigraphy and SPECT.\textsuperscript{6,7,26}

The low diagnostic yield of the planar scintigraphy in our series, when compared to those reported by those groups, might be explained by the characteristics of the population studied, the older age and that they were in a great proportion hospitalized patients.
We must also take into account that 85 of the 102 patients (83%) presented an intermediate pre-test probability (Wells score 3–6), which included most of the “non-diagnostic” planar examinations (Table 4) and all of the 5 inconclusive SPECT scans.

Therefore, from the results of the study showed in Table 2, we can conclude that the SPECT technique makes an important diagnostic contribution by decreasing the number of inconclusive examinations. Moreover, in our series it was able to detect PE in 3 patients with normal planar scintigraphy, 2 of them with an intermediate pretest probability (Table 4); this is a relevant finding since any other diagnostic test it is not usually indicated, when V/Q scintigraphy is normal.27,28

With regard to the impact of the V/Q SPECT on the PE diagnosis and its contribution to the scintigraphy reporting, the recent proposal of using only the perfusion SPECT instead the V/Q SPECT by Bajc et al. is of great interest and deserves some research work.29

**Limitations**

The main limitation of our study is that the lack of a gold standard as diagnosis must be made based on clinical outcome and follow up of the patients. In our series of patients the final report was based on the joint interpretation of the findings in the planar scintigraphy and the SPECT scan. And the clinical decision of the referring physicians was based on our report, as this examination had been requested with diagnostic purposes, to confirm or exclude PE. Furthermore in many patients CT angiography could not be performed or the results were inconclusive.

Therefore, in our study all patients reported as scintigraphic diagnosis of PE were clinically diagnosed of PE and anticoagulant therapy started, unless it was contraindicated.

**Conclusions**

Taken into account the results presented and discussed in this work we can conclude that V/Q SPECT scan is a feasible technique which can be easily applied in the daily clinical practice for the diagnosis of PE.

V/Q SPECT allows a better segmental definition of perfusion and ventilation defects and therefore a better correlation between them. It helps to significantly reduce the number of inconclusive results from 62% to planar scintigraphy to 4.9% for SPECT and it also reduces the number of potential false negative results of the technique due to the improvement in the sensitivity. In addition it allows a dual report as positive or negative.

**Conflict of interest**

The authors declare no conflict of interest.

**References**