

## Ventilation/Perfusion SPECT in Diagnosis of Pulmonary Embolism and Co-Morbid Diseases – Role of Low Dose CT

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Ventilation/perfusion tomography, VP SPECT is primarily applied for diagnosis of pulmonary embolism, PE. The symptoms are not specific and clinical suspicion of PE should be objectively visualised by imaging methods, VP SPECT or computed pulmonary angiography (CTPA). The referring doctor needs a clear and prompt reply in terms of PE, – Yes! or No! A very important requirement is that the examination should be feasible in every patient. Most importantly, methods should have high sensitivity and specificity. As the majority of patients with suspicion of PE do not have PE, the negative predictive value should be close to 100 %. The objective of this presentation is to present and discuss issues with respect to how V/P SPECT should be performed and interpreted. The relationship of VP SPECT to CTPA. The potential role of hybrid system V/P SPECT and low dose CT for lung diagnosis will be discussed.

### Principles of VP SPECT

For routine use imaging of regional ventilation is based upon inhalation of a radioactive aerosol. The recommended aerosols is Technegas, solid graphite particles, generated in a high temperature furnace, with an average diameter of <0.2 micron that allows very good peripheral penetration thus allowing PE diagnosis even in very obstructive patients (1). This was not possible with commonly used radio labelled liquid aerosol is  $^{99m}\text{Tc}$ -diethylen-tetraamino-pentaacetate,  $^{99m}\text{Tc}$ -DTPA. These water soluble inhaled droplets are at average 1.6 micron in size. However, they increase in size with inhalation and in patients with obstructive airway disease cause predominant central deposition and hot spots hampering interpretation of ventilation scintigraphy (1).

Perfusion scintigraphy is based on i.v. injection of radio-labelled particles causing microembolization within the pulmonary circulation in proportion to perfusion. The particles are macro aggregates of human albumin (MAA), labelled with  $^{99m}\text{Tc}$ , 15-100 microns in diameter. They will lodge in pulmonary capillaries and precapillary arterioles. The particle distribution accurately defines regional lung perfusion. A minimum of 60 000 particles is required to obtain uniform distribution of activity reflecting regional perfusion. Normally, about 400 000 labelled particles are injected. Bearing in mind that there are over 280 billion pulmonary capillaries and 300 million precapillary arterioles, the administration of up to 400 000 particles will result in obstruction of only a very small fraction of pulmonary vessels. A reduction in the number of administered particles to between 100 000 to 200 000 particles is recommended for patients with known pulmonary hypertension, right to left heart shunt or after a single lung transplantation.

Radiochemical purity should be determined. As particles tend to settle on standing, the vial should be shaken gently before use. Withdrawal of blood into the syringe should be avoided as this will cause aggregation of MAA particles that may result in perfusion artefacts. The suspension containing  $^{99m}\text{Tc}$ -MAA should be given by slow intravenous bolus injection over 30 seconds while the patient breathes at normal tidal volumes. This will ensure that the particles are infused over several respiratory cycles and facilitate uniform distribution within the pulmonary circulation.

### V/P<sub>SPECT</sub> procedure and radioisotope doses

A prerequisite is that VP SPECT should allow immediate response to the question: does patient have PE, Yes or No? This requires a one day protocol. The goal is to perform the whole exam in less than one hour that is possible if ventilation is studied immediately before perfusion. A large field-of-view dual head gamma camera is needed to limit acquisition time (2).

Optimization of VP SPECT imaging protocols requires systematic analysis of activities and acquisition times used for ventilation and perfusion, collimators and image matrices as performed by Palmer et al. (3). A 1 to 4 activity ratio between ventilation and perfusion is optimal using 25-30

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MBq for ventilation studies and 100-120 MBq for perfusion studies. Images should be acquired using a 64x64 matrix and a general purpose collimator. 64 projections per each of two camera heads with 10 s each for ventilation SPECT and 5 s each for perfusion SPECT implies a total acquisition time of 20 minutes.

To reduce radiation exposure to the lowest level possible with maintained diagnostic safety is, on the basis of ethical concerns and good medical praxis, a crucial issue. A total activity of maximum 150 MBq for VP SPECT is less than in previous recommendations, but has proven adequate in animal and clinical studies (4, 5). The effective dose is thereby reduced to <2 mSv. The absorbed dose to the female breast is 0.8 mGy (6).

Pregnancy, particularly during the first trimester, poses unique circumstances in relation to radiation hazards. In pregnant women, the interpretation of lung perfusion scintigraphy is usually straightforward because of low frequency of co-morbid pulmonary disorders. Therefore, to minimize radiation, a one to two day protocol is suggested (7). Perfusion-only scans should be performed on day 1, using a reduced dose of  $^{99m}\text{Tc}$ -MAA. In most cases PE can be excluded on the basis of a normal perfusion pattern. When the perfusion pattern is abnormal but not diagnostic of PE, subcutaneous low molecular heparin can be given until a ventilation study is performed on day 2, using an activity deposited in the lung of 20-30 MBq. After the first trimester the standard 1 day protocol or the one to two day protocol can be used. During the first trimester the recommended dose for perfusion study (50 MBq) gives a fetal absorbed dose of 0.1-0.2 mGy (8). The absorbed dose to the female breast is 0.25 mGy.

The VP SPECT procedure starts with inhalation of the aerosol, followed by ventilation SPECT acquisition. Without patient movement, MAA is injected followed by perfusion SPECT acquisition. During the examination the patient remains in the supine position, carefully maintained between ventilation and perfusion acquisitions. The total immobilization time of 20 minutes is well tolerated even by critically ill patients. The procedure is practical for the staff.

### Principles of V/P<sub>SPECT</sub> interpretation

The fundament behind PE diagnosis is that PE leads to perfusion defects in areas in regions corresponding to the anatomy of the pulmonary end-arteries, in which ventilation is preserved. PE leads to lobar, segmental or subsegmental areas which are unperfused but ventilated, i.e. V/P mismatch.

PE is commonly recognized in more than one area, most likely because emboli fragment when passing through the right heart and main pulmonary arteries. V/P mismatch is not caused exclusively by PE but may be caused by other disorders such as congenital pulmonary vascular abnormalities, veno-occlusive disease, vasculitis, lung cancer or tuberculous mediastinal adenopathy.

Pulmonary arterial circulation can be affected by many diseases in which both ventilation and perfusion are affected such as obstructive airway disease, tumour and pneumonia. The pattern is called V/P match or in the case of predominant ventilation defects reversed V/P mismatch.

Diagnostic low dose V/P SPECT/ CT will be probably added value by identifying small tumour changes in COPD patients and might improve diagnostic accuracy in co-morbid lung diseases.

### Conclusions

Holistic interpretation gives superior results with respect to sensitivity, specificity and down to 1% of non-diagnostic findings (5). The V/P SPECT is the first line method for PE diagnosis, method of choice for quantification of PE extension, total lung function and follow up. Furthermore, a close co-operation between clinicians, nuclear medicine and diagnostic radiology is essential to achieve optimal diagnosis and therapy of PE. No contraindication and low radiation exposure merit it as a first choice technique. With increasing number of tomographic gamma cameras V/P SPECT should be applied in each hospital applying the standard software offered together with modern systems (2,7).

V/P<sub>SPECT</sub> can be performed using commonly available gamma camera systems. Technegas is preferred aerosol but liquid aerosols can be used as well. The time under the gamma camera is only 20 minutes and the total examination time is only 1 hour. Adequate image quality is obtained by

choosing proper combination of activities, acquisition times, collimators and matrix. At recommended activities for ventilation and perfusion SPECT the effective dose is only 2 mSv. During pregnancy, a one to two day protocol with perfusion SPECT on day one is recommended further reducing effective and absorbed doses (7). Ventilation SPECT is rarely needed on day two. Hybrid system, VPSPECT/CT might be beneficial in patients with COPD diseases.

## References

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