Implementing VQ SPECT/CT

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Introduction

Planar VQ imaging has been used for more than three decades for imaging pulmonary embolism. Although it is fast, widely available and technically simple, it has disadvantages such as insufficient detail due to overlapping of lungs on each other and inability to visualise some segments which can cause reduction in sensitivity of the technique. The other interpretational difficulties arise in patients with chronic obstructive airways disease, heart failure and pneumonia.

In the last decade, multiple studies described use of single photon emission tomography (SPECT) in imaging ventilation (V) and perfusion (Q) imaging of lungs. Based on this evidence, the European Association of Nuclear Medicine (EANM) has published guidelines promoting use of SPECT for assessing patients with pulmonary embolism (PE) in 2009. The same logic can also be extended to patients who are undergoing functional imaging of lungs for non PE applications. The guidelines have also encouraged use of holistic principles for diagnosis of PE (when mismatch of more than one sub-segment is found) than using the complicated probabilistic PIOPED criteria. This simplifies interpretation for reporting and treating physicians.

The most important advantage of switching from planar to SPECT is slight increase in radiation dose to patients, but it remains much smaller than alternative techniques such as computed tomographic pulmonary angiogram (CTPA) (table 1). The ability to produce planar images from SPECT during the transitional phase is useful to build confidence and understand patterns on SPECT. The acquisition times are not longer than planar and it can identify smaller and a greater number of mismatches than planar, with reduced interobserver variability.

Stein et al. published a meta analysis of studies that used SPECT and compared it with other established techniques, ranging from conventional angiography to a combination of lab tests and CT angiography that showed sensitivity and specificities above 90% and less interobserver variability.

Gutte et al. prospectively studied the diagnostic ability of VQ SPECT, VQ SPECT combined with low dose CT, and pulmonary multi-detector CT (MDCT) angiography obtained simultaneously using a combined SPECT/MDCT scanner in patients suspected of having PE. A total of 81 simultaneous studies were analysed, of which 38% were from patients with PE. VQ SPECT had a sensitivity of 97% and a specificity of 88%. When low dose CT was added, the sensitivity was still 97% and the specificity increased to 100%. Perfusion SPECT with low dose CT had a sensitivity of 93% and a specificity of 51%. MDCT angiography alone had a sensitivity of 68% and a specificity of 100%. The authors suggest VQ SPECT with low dose CT as first-line imaging in work-up for suspected PE.

At our institution, we have been using SPECT with low dose CT (LDCT) using a GE Infinia Hawkeye for co-registration of V and Q data and for attenuation correction. The other advantages of LDCT are easier fusion with MDCT data when required and the ability to correlate gross findings such a large mass or pleural effusion with the V and Q data in 3D format which helps to make more conclusive interpretation.

Requirements for SPECT

Changing from planar to SPECT is not just a change in how the images are acquired or having the new software for analysis but more a change of the mindsets of reporting physicians. The shift from two dimensions to three dimensions and the ability to see in-depth changes in different slices of the lungs is revolutionary from a nuclear medicine perspective but not so difficult for radiologists who are used to seeing images in transaxial planes. Acquiring 2D and 3D images sequentially and building up confidence is a useful and achievable step. Longer time slots should be allocated initially and compliant patients should be chosen. Planar images can be derived from the SPECT data which will be discussed in the following sections. Once the technical and diagnostic confidence is established, the entire imaging can be completed with LDCT in under 25 minutes.

Radiopharmaceuticals

Perfusion agent

99mTc-macroaggregated albumin is the agent of choice for lung perfusion imaging. The particle size of 15-100μm micro-emulsifies a small proportion of the pulmonary capillaries and pre-capillary arterioles and reflects the overall pulmonary perfusion. The ARSAC guidelines recommend twice the dose at 200MBq for SPECT as compared to planar of 100MBq but smaller doses can be given for SPECT in special cases and can be compensated by increasing acquisition time per frame. The usual precautions of slow injection in supine position during tidal breathing without withdrawal of blood in the syringe are to be observed.

Ventilation agents

A wider choice of ventilation agents is available, such as 99mTc-DTPA, 99mTc-Technegas and 81mKr. Although DTPA is a widely available, inexpensive aerosol, it gets deposited in central airways in patients with airways disease, making it less suitable for SPECT. 99mTc-Technegas is a finer aerosol and has better penetration and is widely available in Europe. The distribution of particles remains fixed for the duration of study. Technegas is hydrophobic but tends to grow by aggregation, and should be used within 10 minutes of generation. An optimal V:Q activity ratio of 1:4 should be used in case both agents are labelled with 99mTc.

81mKr is a true gas and has a very short half life of 13 seconds. Inhaled 81mKr disappears from the alveolar space at a much faster rate by decay than by exhalation. Regional alveolar 81mKr concentration is closely proportional to regional ventilation during steady breathing. Limited access, high cost and need for a daily generator are its disadvantages. However, it is the best ventilation tracer among the available agents.

New imaging protocols

SPECT is simple to set up and takes less manual intervention than planar. However, if CT is used in conjunction,
appropriate training of staff is necessary. The EANM procedure guidelines have described the acquisition parameters for SPECT in detail. At Royal Brompton Hospital we use dual head camera with low dose CT with fixed tube voltage and tube current. 360° acquisition with 120 projections (projection time of 5 seconds for Krypton and 10 seconds for MAA) in a 128 x 128 matrix is acquired.

If aerosols are used for ventilation, V is performed first and then Q with 1:4 ratio of activity. If Kr-81m is used for V, the order does not matter. Simultaneous dual isotope study can be performed with Krypton but it is important to check for downscatter.

Additional scatter window method has been developed by Bailey et al that helps in creating synthetic maps. Respiratory gating may help but it is not available on most SPECT systems.

**SPECT reconstruction and analysis**

Analysis of SPECT data is important and various commercially available softwares, eg Hermes, can be used. The basic use of software is to create planar images from SPECT during the planar to SPECT transition. Various methods have been described in literature for achieving this. Reinartz et al have described angular sampling method and Bailey et al have described reprojection with scatter window attenuation correction method for SPECT. When CT is acquired with SPECT, it can provide a true attenuation map with reprojections. These are available from commercial vendors.

The other method is comparing and co-registering Q with V and also to CT. Triangulation and display of images in three orthogonal planes with VQ quotient images can assist in identifying smaller areas of mismatches. The 3D interactive segmental maps are available for exact localisation of segments from SPECT images.

The software can also assist in fusion of diagnostic CT images with the VQ SPECT which can help in interpreting functional impact of tumours, parenchymal changes and avoiding false positive interpretations in cases with emphysema (figure 1), pleural effusion, pneumonia etc. However, at each step, a quality check is essential to avoid artefacts related to acquisition, patient motion, Krypton wafting (exhaled Krypton from patient in the field of view can cause reconstruction artifacts) and mis-registration.

**Image interpretation**

Like any other SPECT, the raw data should be checked for artifacts and if present, their impact on image quality should be weighed before interpretation. Adequate co-registration of V with Q and CT data should be inspected. History, concurrent lab and imaging findings should be reviewed for additional information. If reprojected or dedicated planar images are available, preliminary impression can be made. The maximum intensity projection (MIP) images also help in focussing on sites of abnormal tracer distribution. The co-registered V and Q slices in three orthogonal planes are then compared for locating sites of mismatch (figure 2). Each of the mismatched sites is compared with CT for structural abnormalities that could explain the defects. Explanation for matched defects can also be found here. With the help of a 3D interactive segmental map, site, extent and nature of defects can be described in the findings.

At RBH, in collaboration with Hermes medical solutions, the authors have developed 3D individual and lobar quantification by fusing diagnostic CT with V and Q SPECT. This is useful in preoperative assessment of patients undergoing lung resection surgery for cancers. This is thought to be more accurate than the conventional 2D method with arbitrary lobes.

**Conclusion**

There is a resurgence of VQ SPECT imaging in diagnosis of PE and non-PE applications. This has been possible due to the wide availability of multi-detector cameras and increased computing ability. New software availability to assist with interpretation and quantification has led to a substantial increase in the diagnostic accuracy, reduction in non-diagnostic rates and ability to quantify with SPECT/CT. However, it is not available 24 hours, except in emergency departments. Although round-the-clock availability of CTPA is advantageous, high radiation dose, especially to female breast, contrast allergy and reduced diagnostic accuracy in sub-segmental embolism makes CTPA a less favoured technique and VQ SPECT should be considered as the first-line investigation by the referring clinicians.

**References**


### Table 1

<table>
<thead>
<tr>
<th>Tracer</th>
<th>Administered activity-(MBq)</th>
<th>Total effective dose</th>
<th>Suitability for SPECT</th>
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<tbody>
<tr>
<td>99mTc-MAA</td>
<td>200</td>
<td>2mSv</td>
<td>★★★★</td>
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<td>Tc-DTPA</td>
<td>80</td>
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<td>Technegas</td>
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<td>81Kr</td>
<td>6000</td>
<td>0.2mSv</td>
<td>★★★★</td>
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Values from ARSAC Notes for Guidance 2006

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<thead>
<tr>
<th>Technique</th>
<th>Effective dose (mSv)</th>
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<tr>
<td>Single slice LDCT</td>
<td>1mSv</td>
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<td>CTPA 4 slice</td>
<td>4.2 mSv</td>
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<td>CTPA 16 slice</td>
<td>14.4 mSv</td>
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<tr>
<td>CTPA 64 slice</td>
<td>19.9 mSv</td>
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Hurwitz et al 2006, ICRP 53, ICRP 80

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Figure 1
A 56-year-old patient with known emphysema showing perfusion abnormalities in bullous emphysema but with normal ventilation. Hybrid SPECT/CT helps in avoiding false positive interpretation of scan for pulmonary embolism.
**Figure 2**
A 67-year-old lady with history of chronic pulmonary embolism and pulmonary hypertension. Images demonstrate multiple mismatched abnormalities that are clearly shown as bright yellow colour on quotient images.