Comparison of planar and SPECT perfusion lung scintigraphy in the diagnosis of pulmonary embolism

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Aims and objectives

Introduction

Pulmonary embolism (PE) is a severe and potentially fatal disease and therefore needs to be diagnosed as early as possible [1]. PE is caused when an embolus travels to the lungs, and gets lodged within the arteries in the lungs, resulting in lack of blood supply to the area supplied by that blocked artery [2]. A lung scintigraphy scan is performed to diagnose PE. There are two parts to a lung scintigraphy scan: ventilation and perfusion.

A ventilation scan is performed to assess the air distribution within the lung, after inhalation of a radioactive aerosol. The particles are suspended in air and remain within the lung. The clearance is then used for diagnostic purposes [3].

A perfusion scan is performed to assess the blood flow within the lung, after the intravenous administration of technetium-99m macroaggregated human albumin ($^{99m}$Tc-MAA). The micorembolisation of radiolabelled particles of trapped $^{99m}$Tc-MAA within the pulmonary capillaries defines regional lung perfusion [1].

Planar two-dimensional (2-D) scintigraphy scans have the following limitations: images result in high levels of image noise, image registration difficulties due to superimposition of structures and poor contrast. Single photon emission computed tomography (SPECT) provides three-dimensional (3-D) images, with more accurate data. Therefore, SPECT has been shown to be more sensitive and specific than planar (2-D) scintigraphy in the clinical diagnosis of PE and this has been supported by many studies, which determine an increase in sensitivity and specificity to detect PE with the use of SPECT imaging [4-7].

SPECT ventilation/perfusion (V/Q) imaging is considered a quick and easy scan to perform. Bailey et al., (2010), state that SPECT V/Q images have reduced inter-observer variability and improved the detection of small perfusion defects [8]. Bajc et al., (2009), stated that SPECT V/Q imaging is preferred over planar (2-D) studies as it allows a more accurate diagnosis of PE, even when other diseases such as chronic obstructive pulmonary disease (COPD) and pneumonia are present [1]. However, many centres still find it difficult to make the transition from planar imaging to SPECT imaging, the reason being the need to implement a new imaging protocol [9-11].

The purpose of this study was to compare the clinical utility and work load efficacy between planar perfusion lung scintigraphy and SPECT perfusion lung imaging in the
implementation of a SPECT imaging protocol within a nuclear medicine department in Malta.

**Methods and materials**

The study was approved by the University of Malta Research Ethics Committee (UREC no. 079/2013) and all participating patients gave written informed consent.

This study consisted of the evaluation of images obtained from adult patients (n=40) who had undergone a lung perfusion scan with an acute onset of new or worsening shortness of breath or chest pain with any apparent cause;# with a positive D-dimer test (>0.5mg/l);# with a request for a perfusion lung scan by their referring doctor, together with a chest x-ray reported by a radiologist.

Each participating patient underwent a supine perfusion lung scintigraphic scan consisting of a planar (2-D) acquisition followed by a SPECT (3-D) acquisition. The current planar imaging protocol in use within the local department was followed for image acquisition, however a new protocol for the acquisition of the SPECT scan was set up.

Planar perfusion images were acquired in six standard views (anterior, posterior, left anterior oblique, left posterior oblique, right anterior oblique, right posterior oblique), aiming for 500,000 counts in each view, using a 256 x 256 matrix.

The SPECT protocol was developed based on literature findings [12-16] and the European Association of Nuclear Medicine (EANM) guidelines [1]. The imaging protocol was finalised and agreed upon by all parties following discussions with nuclear medicine physicians as well as experienced radiographers. Participating patients underwent a supine SPECT perfusion acquisition using 6° steps through a 360° acquisition, allowing 20s on each step, resulting in 60 projections. The SPECT images were acquired in a 128 x 128 matrix.

Both planar and SPECT scans were performed on a general purpose, dual detector Infinia General Electric (GE) gamma camera. The gamma camera was loaded with low-energy general purpose (LEGP) collimators. Data was acquired for the emission photopeak of 140keV ± 10%.

Once the images for both techniques were acquired, they were transferred to a workstation for processing. All six views acquired during the planar study were displayed as one image and saved in that manner (Fig. 1). The SPECT data was processed...
using the same reconstruction method as in the study by Harris et al., (2007), whereby iterative reconstruction using 3-D Butterworth filters were applied, smoothening the post reconstruction [4] (Fig. 2-4).

ViewDEX, a Java-based, DICOM-compatible software was used for the presentation and evaluation of the acquired images. ViewDEX enables the possibility to perform observer performance studies using the same display properties as is generally used in a clinical environment [17]. This software also enabled the calculation of the time spent by the observer to evaluate the images for each case.

Nuclear medicine physicians (n=2) were presented with two image data sets on ViewDEX. They were asked to rate their confidence in identifying PE within each lobe of the lung. The two image data sets consisted of: the planar image data set (n=40) which also included the chest x-ray of each patient, and the SPECT image data set (n=40) of the same patients consisting of transverse, coronal and sagittal images, together with the chest x-ray of that same patient. The planar and SPECT image data sets were presented separately to the nuclear medicine physicians after a one-week interval to limit the physicians from correlating the data sets. The images within each data set were presented in random order to avoid bias and only the researcher knew which planar image corresponded to which SPECT image. ViewDEX ensured that there was no indication linking the planar image to the corresponding SPECT image as all images were anonymously presented.

The nuclear medicine physicians were asked to rate their confidence in identifying the presence or absence of a defect implying PE in each of the three lobes of the right lung and the two lobes in the left lung. The following rating scale was used: 1 - suggested no defect, 2 - suggested possible no defect, 3 - suggested an inconclusive study whereby a ventilation scan was recommended, 4 - suggested a probable defect, 5 - suggested a definite defect [13] (Fig. 5, Fig. 6). The rating scores were evaluated using receiver operating characteristic (ROC) analysis.

Accurate timing of the entire procedure was necessary to assess any time difference between a planar and SPECT lung scintigraphic study. Timing of each procedure was divided into three aspects: scanning time, processing time and reporting time. Mean time was compared for both techniques using a paired samples t-test.

**Images for this section:**
Fig. 1: Normal planar perfusion lung scan
Fig. 2: Normal Transverse SPECT perfusion lung scan
Fig. 3: Normal Sagittal SPECT perfusion lung scan
Fig. 4: Normal Coronal SPECT perfusion lung scan
Fig. 5: Planar (2-D) presentation in ViewDEX

Fig. 6: SPECT (3-D) Transverse image presentation in ViewDEX
Results

Reliability

Intra-observer reliability was 100% for both nuclear medicine physicians when assessing planar data. When assessing SPECT data, one nuclear medicine physician had a reliability of 60%, whereas the other physician had a reliability score of 90%, indicating excellent internal consistency for each observer.

Inter-observer reliability using Pearson's correlation ($r$) ranged from 0.63 to 0.83, indicating a strong correlation of inter-observer reliability. Paired samples t-test was also performed which concluded that the mean rating scores provided by the two nuclear medicine physicians for the same lobe images were comparable. One may conclude, that a strong correlation between both raters was evident and therefore both nuclear medicine physicians were reliable.

Statistical Analysis

Receiwer Operating Characteristic (ROC) analysis was performed to evaluate the quality or performance of the two imaging techniques. ROC analysis is based on the sensitivity (true positive rate) and specificity (true negative rate) of the imaging technique [18]. SPECT data was considered as the gold standard, based upon a number of studies stating that V/Q SPECT is of superior diagnostic capability [10, 15, 12, 9, 5]. SPECT data was categorised into two groups: 0 and 1. Category - 0 included all cases with a negative result ('possibly no defect'; 'no defect'). Category - 1 included all cases with an inconclusive or positive result ('inconclusive'; probable defect'; 'defect'). This was the cut off point used to define positive and negative test results.

ROC Curves

An ROC curve for the determination of the presence or absence of a defect in relation to PE as reported by both nuclear medicine physicians for the collective lobes of both lungs was plotted for the planar versus SPECT data.

The area under the ROC curve ($AUC_{ROC}$) was calculated from the graph to determine the diagnostic accuracy of the test [19]. An $AUC_{ROC}$ value of 0.93 was measured (Fig. 7). The closer the value is to 1, the better the overall diagnostic performance of the test [20]. Table 1 was generated to determine the sensitivity and specificity of the planar
study in comparison to the SPECT study. The specificity for planar imaging was found to be 90.8%, whereas the sensitivity for planar imaging was found to be 77.4%. From the findings, one may conclude that planar perfusion imaging had a lower sensitivity in comparison to SPECT imaging, however the specificity of planar imaging was still relatively high.

*Time difference between both techniques*

Work load efficacy is dependant upon: the scanning time of the patient for a perfusion lung scan; the processing time for the radiographer to process the acquired images and the time taken for the nuclear medicine physicians to report the images. Every part of the planar and SPECT scans were timed precisely to accurately compare the total time for a planar and SPECT perfusion scan. A paired samples t-test was used to compare the mean times for both imaging techniques (Table 2). Results show a significant reduction ($p<0.05$) in total mean time for a SPECT study in comparison to a planar study, deeming SPECT as being more work load efficient.

*Images for this section:*
**Fig. 7:** ROC curve plotted for planar imaging test sensitivity (y-axis) versus false positive rate (1-specificity) (x-axis)

<table>
<thead>
<tr>
<th>Total number of cases</th>
<th>420</th>
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<tbody>
<tr>
<td>Number of correct cases</td>
<td>373</td>
</tr>
<tr>
<td>Accuracy</td>
<td>88.8%</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>77.4%</td>
</tr>
<tr>
<td>Specificity</td>
<td>90.8%</td>
</tr>
<tr>
<td>Positive cases missed</td>
<td>14</td>
</tr>
<tr>
<td>Negative cases missed</td>
<td>33</td>
</tr>
<tr>
<td>Area under the curve (AUC$_{ROC}$)</td>
<td>0.93</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>0.015</td>
</tr>
</tbody>
</table>

**Table 1:** Sensitivity and Specificity of Planar versus SPECT imaging for all the lobes of both lungs
### Table 2: Paired samples t-test for timing for both planar and SPECT studies

<table>
<thead>
<tr>
<th></th>
<th>Mean Time (s)</th>
<th>N</th>
<th>Std. Deviation</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scanning</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planar</td>
<td>928.14</td>
<td>84</td>
<td>210.35</td>
<td>0.000</td>
</tr>
<tr>
<td>SPECT</td>
<td>724.00</td>
<td>84</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td><strong>Processing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planar</td>
<td>19.19</td>
<td>84</td>
<td>5.91</td>
<td>0.000</td>
</tr>
<tr>
<td>SPECT</td>
<td>110.60</td>
<td>84</td>
<td>11.25</td>
<td></td>
</tr>
<tr>
<td><strong>Reporting</strong></td>
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<td></td>
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<td></td>
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<tr>
<td>Planar</td>
<td>33.62</td>
<td>84</td>
<td>27.69</td>
<td>0.001</td>
</tr>
<tr>
<td>SPECT</td>
<td>62.76</td>
<td>84</td>
<td>78.46</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL Time</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planar</td>
<td>980.95</td>
<td>84</td>
<td>210.93</td>
<td>0.001</td>
</tr>
<tr>
<td>SPECT</td>
<td>897.36</td>
<td>84</td>
<td>79.94</td>
<td></td>
</tr>
</tbody>
</table>
Conclusion

Since currently, planar perfusion lung scintigraphy is the mode of detection of PE within the local nuclear medicine department, a protocol was set up prior to the start of the study for the acquisition of SPECT perfusion lung images requiring changes to processing and display protocols on the gamma camera.

From the results obtained it was concluded that SPECT perfusion lung scintigraphy has an overall higher sensitivity and specificity in comparison to planar imaging for both lungs. Based on SPECT images, more decisive reports were issued by the nuclear medicine physicians on the presence or absence of a defect indicating the presence of PE. Therefore, SPECT has aided in the clinical utility and improved work load efficacy within the department. #Work load efficacy was assessed through the timing duration of the SPECT scan in comparison to planar imaging and statistical tests confirmed that there was a significant reduction in time for SPECT over planar imaging. This total time is also thought to be reduced even further once nuclear medicine physicians are more acquainted with reporting SPECT lung perfusion images.

Through evidence-based practice, a change in work practice within the local nuclear medicine department was successfully implemented to the benefit of patients and the hospital.

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