SPECT or SPECT/CT as First Line Imaging Modality for Pulmonary Embolism

Pulmonary embolism (PE) is a blockage of an artery in the lung that originates commonly as a blood clot in the leg. It is estimated that approximately 430,000 people in Europe and between 300,000 and 600,000 people in the US are afflicted each year by a PE, with a mortality rate between 20%-30%.[1,2]

In 2009, the European Association of Nuclear Medicine published new guidelines recommending the use of tomography (V/P_{SPECT}) as a first-line procedure in patients with suspected PE. Professor Marika Bajc, MD, PhD, Senior Consultant and Associate Professor, Department of Clinical Physiology, at Skåne University Hospital, Lund (Lund, Sweden) was the lead author of the guidelines.[3,4]

Professor Bajc and Berit Olsson, research technologist in the department of Clinical Physiology and Nuclear Medicine, Skåne University Hospital, Lund, had previously published in 2004 a study of 53 patients with suspected PE comparing V/P_{SPECT} (tomography) with V/P_{PLANAR} imaging. The study demonstrated that V/P_{SPECT} had a higher sensitivity in revealing more perfusion defects, less interobserver variability and better quantitation than V/P_{PLANAR}.[5] The authors noted a significant difference between the two methods. V/P_{SPECT} demonstrated a 53% higher mismatch rate than V/P_{PLANAR}.[3]

"Our clinic in Lund performs anywhere from 1,300-1,500 V/P_{SPECT} studies each year. In the hospital, two-thirds of patients with suspected PE receive a V/P_{SPECT} study first; the other third are referred to CT (on Saturdays, Sundays and holidays) and to address additional questions beyond the PE," Professor Bajc explains.

It is with patients that have other clinical conditions—such as lung cancer or COPD—where Professor Bajc sees the greatest benefit for hybrid SPECT/CT imaging. "For these groups of patients there is added value to identify morphology," she adds.

With three SPECT/CTs, one SPECT and two dedicated cardiac gamma cameras, the Clinical Physiology and Nuclear Medicine Department at Lund is actively involved in pulmonary physiology research in addition to its long standing research in respirology and cardiology.

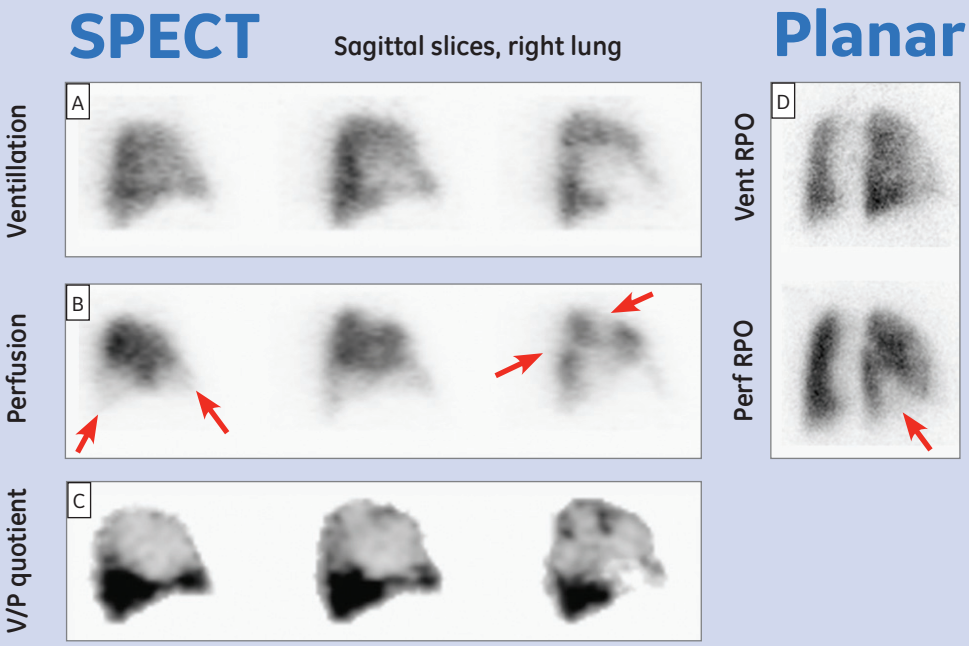

Figure 1. Patient with massive PE treated with thrombolysis; control images acquired the next day. On planar images only one perfusion defect is seen (D, arrow). On SPECT images (sagittal slices, right lung) segmental perfusion defects are still present in whole lower lobe as well as sub-segmental defects in upper lobe (B, arrows).

"Even in early onset of PE, we can see the reduction in perfusion using V/P_{SPECT}," Professor Bajc explains. With V/P_{SPECT} the clinician has both ventilation and perfusion information for evaluating total lung volume and lung function. This information provides the opportunity to quantify and measure

the extent of ventilation and perfusion defects and see how they match, mismatch and reverse mismatch in terms of total lung function. A segmental chart (not pictured) facilitates recognition of segmental and sub-segmental perfusion defects (conforming pulmonary circulation) on SPECT images that are typical for PE.

"I look at V/P$_{SPECT}$ as the most essential physiological exam while with planar the structure could be covered and you may miss what is going on. Since 2004, we are using quantitation for estimation of the PE extent at our facility because our clinicians want it. These measurements serve to choose the type of treatment the patient receives," Professor Bajc says. Clinically stable patients with PE less than 40% and ventilation defects less than 20% are treated as outpatients, saving €2,000 per patient.[6]

Professor Bajc believes it is easier to acquire a SPECT exam than a planar exam. She says it's not only faster—20 minutes for a complete examination—but unlike other imaging exams, patient motion is not a problem with SPECT.

Ventilation information primarily helps clinicians with lung delineation; also important is its use to detect and interpret other functional changes, such as pneumonia.[3,4]

This is particularly important in patients presenting with both pneumonia and PE. Professor Bajc explains that a patient can have a perfusion defect from PE and in another area have pneumonia with reduced ventilation. Yet it can take time for the perfusion to change; therefore, pneumonia patients may not be treated effectively because of an underlying PE. It is in this group of patients, having underlying pneumonia but examined on a CT for suspected PE, where PE could be missed.[7]

"In patients developing pneumonia, we can see physiological changes on the ventilation scan first," Professor Bajc explains. "It takes three to four days before you see morphological changes on CT or a chest X-ray, so tomography ventilation is an enormous advantage.

"CT is a fantastic examination, but it is very demanding on how to perform and adjust changes in hemodynamic conditions. It is not automatic. We don't have this issue with SPECT," Professor Bajc adds.

V/P$_{SPECT}$ can also be performed in all patients with suspected PE, as there are no definitive contraindications, whereas pulmonary CT angiography (CTPA) cannot be performed in 40%-50% of patients due to kidney impairment, cardiac problems or allergy to contrast media.[8,9] The emergence of hybrid SPECT/CT systems can also enhance PE diagnosis; a recently published study found that SPECT/CT had the best diagnostic accuracy for PE compared to CTPA, planar and SPECT alone.[9] However, V/P$_{SPECT/CT}$ reported the best accuracy based on the fact that EANM guidelines for the interpretation of V/P mismatches were not implemented. This study and another found that V/P$_{SPECT}$ and V/P$_{SPECT/CT}$ can provide an alternative diagnosis if PE is negative.[9, 10]

"This can start a discussion with the clinician that there may be another clinical condition. That is really important, and we can't get this information from planar imaging," Professor Bajc adds.

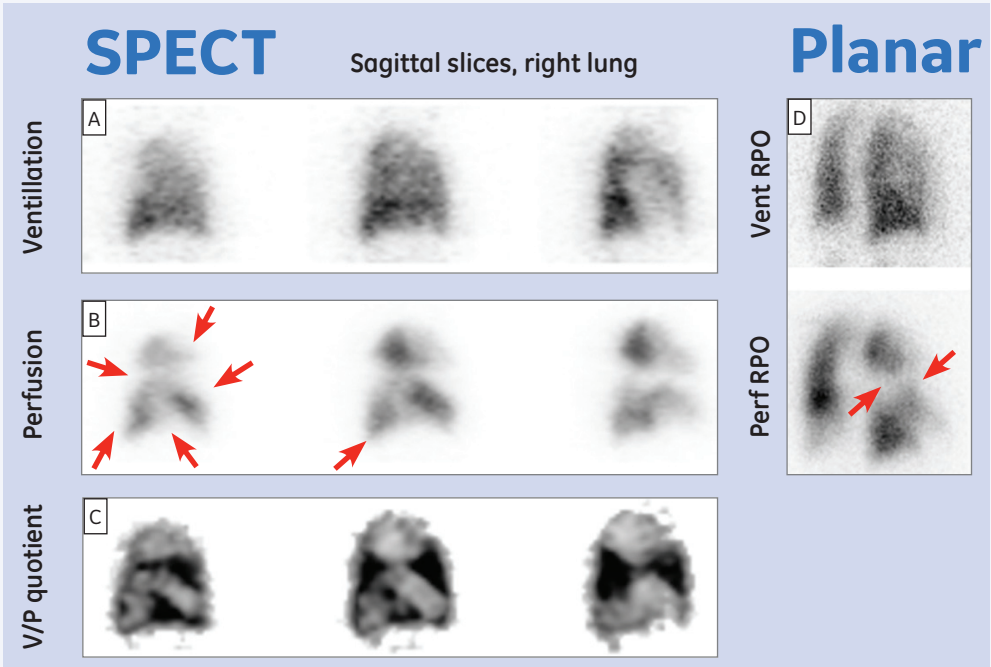

Figure 2. Patient with clinically suspected PE, showed perfusion defects on planar images (D, arrows); however, more segmental defects are seen on SPECT (B, arrows). Patient was treated six months for PE.

For example, at Lund V/P$_{SPECT}$ is also used on all patients with suspected heart failure and pulmonary arterial hypertension (PAH) to identify patients who have developed PAH due to chronic PE. Professor Bajc says that this is crucial to identify patients with chronic thromboembolic pulmonary hypertension who can be potentially cured. If these conditions are left untreated, the patient can develop left heart failure. The disease is similar in clinical presentation to PE, yet has a completely different treatment regimen.

V/P$_{SPECT}$ can also play an important role in diagnosing chronic obstructive lung disease/chronic obstructive pulmonary disease (COPD).

"We see these changes before spirometry, which is still the gold standard," says Professor Bajc. "Obstructive disease starts in the small airways and there is no resistance so you cannot measure this by spirometry. But we can see this when using ventilation."[11]

The type of gas used also makes a difference, Professor Bajc says. "I find Technegas[12] to be the best agent to study ventilation because of its size, 0.01 micrometers, which allows the particle to reach the periphery to enable diagnosis in most PE patients who also have obstructive (COPD) disease."

While ^{99m}Tc-diethylenetriaminepentaacetic acid (^{99m}Tc-DTPA) is a viable option, Professor Bajc recommends that in markets where Technegas is not available that DTPA should be used. In an obstructed (COPD) patient, she says Xenon doesn't enable good visualization of the ventilation due to its inherent poor penetration. According to Professor Bajc, Xenon as a gas is not recommended by EANM Guidelines. Since nearly 50% of patients referred to Lund have COPD, the clinic has never used Xenon. On the contrary, Professor Bajc says that Technegas can be used successfully with V/P$_{SPECT}$ in nearly all patients; there are only very few cases—one or two patients each year (out of 1,300 to 1,500 V/P$_{SPECT}$)—where this exam fails.

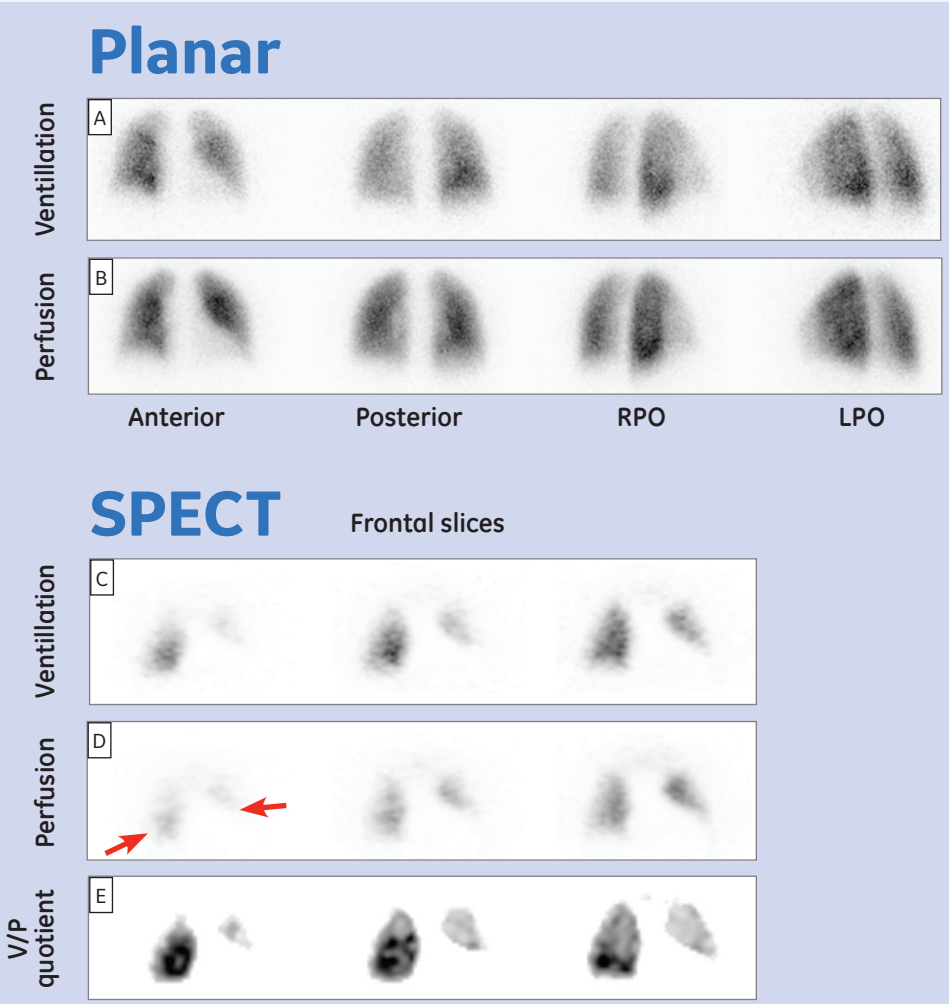

Figure 3. Patient with clinically suspected PE. Planar images showed normal ventilation and perfusion. On frontal slices perfusion defects are seen in medial lobe and lingula (D, arrows). Patient was controlled after two weeks and showed normalization of perfusion defects; treatment for PE continued for three months.

Advancements in technology help increase the adoption of V/P$_{SPECT}$ in many centers across Europe. Professor Bajc says almost every hospital in Sweden has a SPECT system and facilities in Germany, UK and France are growing in numbers.

Professor Bajc believes that V/P$_{SPECT}$ and V/P$_{SPECT/CT}$ can play an important diagnostic role in the evaluation of lung diseases, such as PE, pneumonia, COPD and lung cancer.

"I cannot stress enough how important it is for nuclear medicine physicians to work together with other clinicians so they know what diagnostic information they can get from you," she says. ■

1. Centers for Disease Control and Prevention. Venous Thromboembolism: A Public Health Concern. Available at: http://www.ncbi.nlm.nih.gov/pubmed/20331949.
2. Belohavek J, Dytrych V, Linhart A. Pulmonary embolism, part I: Epidemiology, risk factors and risk stratification, pathophysiology, clinical presentation, diagnosis and nonthrombotic pulmonary embolism. Exp Clin Cardiol, 2013 Spring; 18(2): 129–13.
3. Bajc M, Neilly JB, Miniati M, Schuemichen C, Meignan M, Jonson B. EANM Committee. EANM guidelines for ventilation/perfusion scintigraphy: Part 1. Pulmonary imaging with ventilation/perfusion single photon emission tomography. J Nucl Med Mol Imaging. 2009; 36(9):1528-38.
4. Bajc M, Neilly JB, Miniati M, Schuemichen C, Meignan M, Jonson B. Eur EANM guidelines for ventilation/perfusion scintigraphy : Part 2. Algorithms and clinical considerations for diagnosis of pulmonary emboli with V/P(SPECT) and MDCT. J Nucl Med Mol Imaging. 2009 Sep; 36(9):1528-38.
5. Bajc M, Olsson CG, Olsson B, Palmer J, Jonson B. Diagnostic evaluation of planar and tomographic ventilation/perfusion lung images in patients with suspected pulmonary emboli. Clin Physiol Funct Imaging, 2004; 24:249–256.
6. Elf JE, Jögi J, Bajc M. Home treatment of patients with small to medium sized acute pulmonary embolism. J Thromb Thrombolysis. 2015 Feb; 39(2):166-72.
7. Bajc M. Value of ventilation/perfusion SPECT detecting extensive pulmonary embolism in a patient with pneumonia. Thromb Haemost. 2005 May;93(5):993-4).
8. Stein PD, Fowler SE, Goodman LR, et al. PIOPED II Investigators. Multidetector computed tomography for acute pulmonary embolism. N Engl J Med. 2006 Jun 1; 354(22):2317-27.
9. Mortensen J, Gutte H. SPECT/CT and pulmonary embolism. Eur J Nucl Med Mol Imaging, 2014; 41 (Suppl 1):S81-S90.
10. Begic A, Opankovic E, Cukic V, Lindqvist A,Miniati M, Bajc M. Ancillary findings assessed by ventilation/perfusion tomography. Impact and clinical outcome in patients with suspected pulmonary embolism. Nuklearmedizin, 2015; 54(5):223-30.
11. Bajc M, Markstad H, Jarenbäck L, Tufvesson E, Bjermer L, Jögi J. Grading obstructive lung disease using tomographic pulmonary scintigraphy in patients with chronic obstructive pulmonary disease (COPD) and long-term smokers. Ann Nucl Med. 2015 Jan; 29(1):91-9.
12. Not US FDA approved. Not available for sale in the United States.