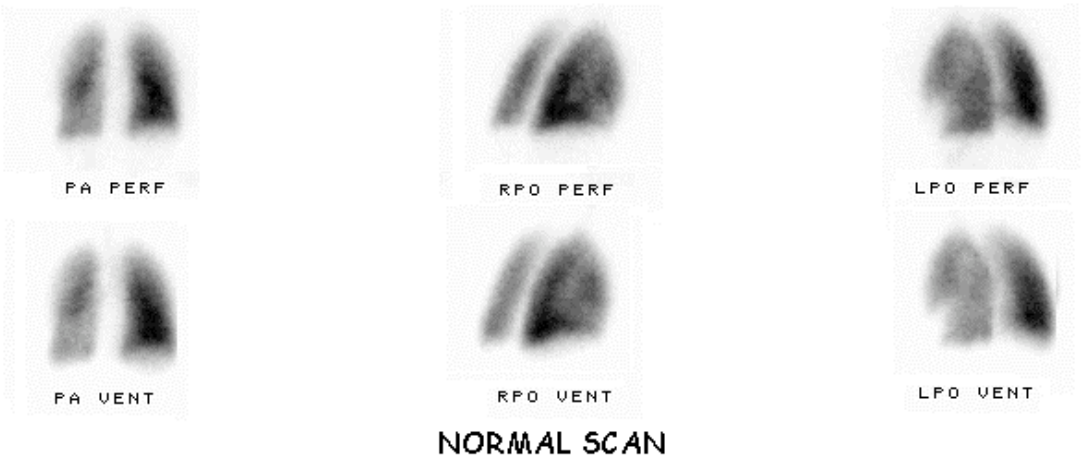
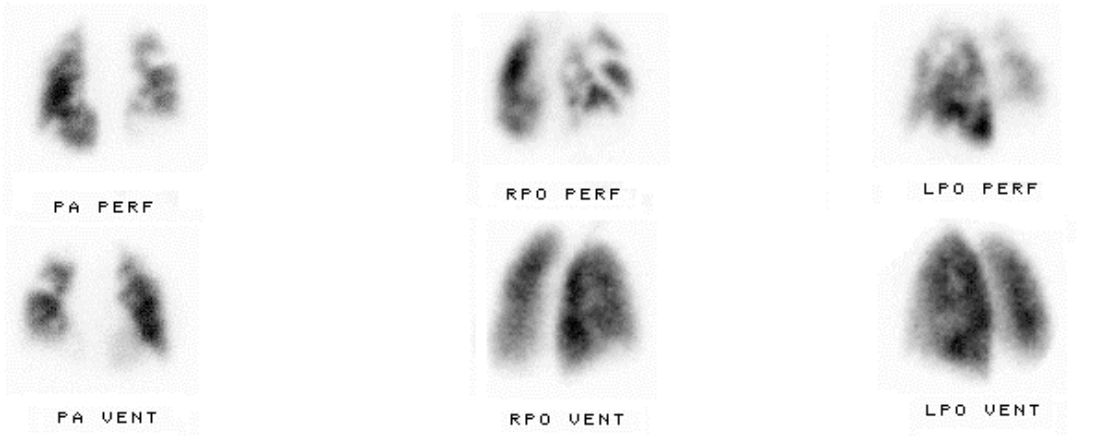
Belgian Society of Nuclear Medicine

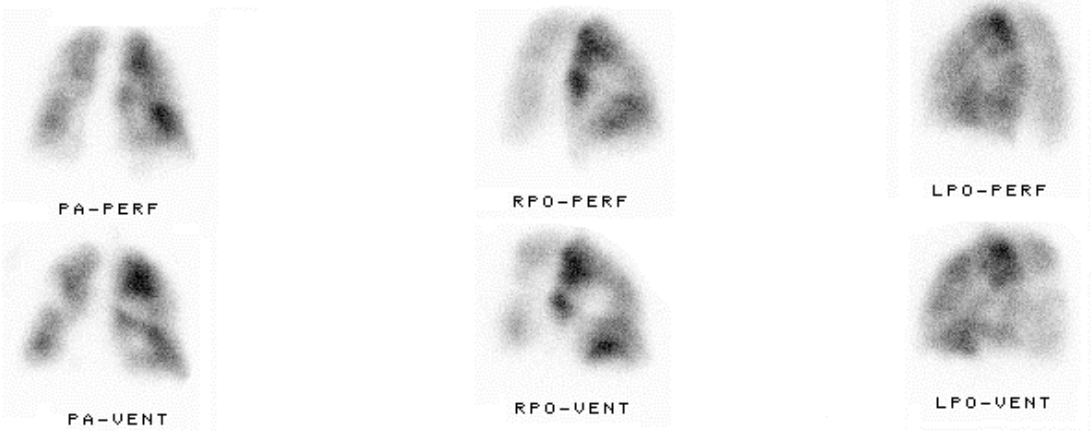
Procedure Guidelines for Lung Scintigraphy



NORMAL SCAN



PULMONARY EMBOLISM



OBSTRUCTIVE PULMONARY DISEASE

Images courtesy of AZ Sint-Jan AV Brugge

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Procedure Guideline for Lung Scintigraphy

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I. Purpose

The purpose of this guideline is to assist nuclear medicine practitioners in recommending, performing, interpreting, and reporting the results of lung scintigraphy.

II. Background Information and Definitions

Perfusion scintigraphy is a diagnostic imaging test that records the distribution of pulmonary arterial blood flow.

Ventilation scintigraphy is a diagnostic imaging test that records the bronchopulmonary distribution of a gas or an inhaled radioactive aerosol within the lungs.

III. Common Indications

The most common indication for lung scintigraphy is to determine the likelihood of pulmonary embolism.

Other indications include evaluation of lung perfusion and ventilation after treatment for pulmonary embolism, lung transplantation, preoperative evaluation, right-to-left shunt evaluation and pediatric indications.

IV. Lung Scintigraphy

A. Patient Preparation

1. In patients with acute obstructive lung disease, the use of bronchodilator therapy before lung scintigraphy may decrease ventilatory defects and improve the accuracy of the study. Because perfusion defects often change as acute ventilation obstruction resolves, patients are best imaged when bronchospasm has been cured.

2. Perchlorate can be given prior to injection in order to limit thyroid exposure, although it is not common practice.

B. Information Pertinent to Performing and Interpreting the Procedure

1. In pregnant or lactating women, the indication must be carefully discussed and the procedure performed only in case of life threatening conditions. When the indication is fully established, the procedure should be adapted in order to lower the exposition.

2. Previous history of hypersensitivity to albumin should be sought. Perfusion study should not be performed in patients with a known history of hypersensitivity to human albumin.

3. Pertinent clinical history includes, but is not limited to: right-to-left shunt; severe pulmonary hypertension; chest pain; dyspnea; hemoptysis; syncope; symptoms of deep venous thrombosis; oral contraceptive use; recent surgery; prior pulmonary embolism; cancer; congestive heart failure; antecedent illness; smoking; intravenous drug abuse, and prolonged immobilization.

4. Pertinent findings on physical examination include, but are not limited to: vital signs (including oxygen saturation), chest examination; cardiac examination; and leg findings.

5. Review of prior lung scintigraphy.

6. A chest radiograph should be obtained before lung scintigraphy. A routine chest radiograph obtained in both the posterior-anterior and lateral projections is preferred. In patients who have no changes in signs or symptoms, a chest

radiograph within 1 day of scintigraphy is adequate. A more recent chest radiograph (preferably within 1 hr) is necessary in patients whose signs and symptoms are changing.
Pertinent chest radiographic findings include, but are not limited to: consolidation; atelectasis; effusions; masses; cardiomegaly; and decreased pulmonary vasculature.

7. Results of the D-dimer assay should be known when interpreting the scintigraphy.

8. Treatment with anticoagulant or thrombolytic therapy should be noted, as well as its efficacy.

9. Results of tests for deep venous thrombosis, e.g. compression ultrasonography, should be noted when available.

10. The referring physician's estimate of the prior probability of pulmonary embolism may be helpful.

C. Procedure

Perfusion

1. The radiopharmaceutical most commonly used for perfusion imaging is Tc-99m MAA.

The biological half-life of the macroaggregated albumin in the lungs varies (usually 1.5 to 3 hr).

The usual adult administered activity is 40 – 150 MBq (1 – 4 mCi).

The number of particles should be in the range of 200,000 –700,000.

Radiochemical purity and particle size determination of Tc-99m MAA should be performed. .

Reduced numbers of macroaggregated albumin (MAA) particles should be considered for patients with pulmonary hypertension or right-to-left shunting, and in infants and children. In adults, the number may be reduced to 100,000 –200,000 particles without altering the quality of the

images for detection of perfusion defects. Inhomogeneous distribution of activity may result from a reduction of the number of particles below 100,000 in adults.

2. Image Acquisition

Both ventilation and perfusion studies require the following projections: anterior, posterior, left and right posterior obliques. Lateral and anterior obliques may also be helpful.

Labeled MAA particles will settle in the vial with time. Vials should be agitated prior to withdrawing a dose.

Before intravenous administration of the pulmonary perfusion radiopharmaceutical, the patient should be instructed to cough and to take several deep breaths. The patient should be in the supine position during injection, or in the case of a patient with orthopnea, as close to supine as possible.

A well-flushed indwelling line can be used if venous access is difficult. Do not administer in the distal port of a Swan-Ganz catheter or any indwelling line or port that contains a filter, e.g. chemotherapy line. The syringe should be inverted prior to injection. Make sure no blood refluxes into the syringe before injecting the tracer.

Imaging in the upright position increases chest cavity size and minimizes diaphragmatic motion, thus allowing for better correlation with chest X-ray. On the other hand, imaging in the supine position may provide images with less motion artifacts.

Usual count rates reach 400 Kcnts per projection.

Ventilation

1. Krypton-81m

Krypton-81m is obtained from a rubidium-81/krypton-81m generator.

The usual administered activity of krypton-81m is 40 – 400 MBq (1– 10 mCi).

The patient breathes continuously from the Rb-81/Kr-81m generator. Due to the short half-life of Kr-81m, the distribution of radioactivity approximates single-breath gas distribution.

The collimator is chosen so that it insures no significant septal projection.

Typical count rates range from 200 to 400 Kcnts per projection.

Perfusion/ventilation scintigraphy with Kr-81m as a ventilation agent can be performed sequentially or simultaneously.

During the sequential procedure, acquisition of Tc-99m and Kr-81m images is obtained alternately by turning the gas flow on for ventilation imaging and off during perfusion imaging. The patient does not move during both tracers acquisition of each projection.

Simultaneous acquisition using the dual isotope procedure allows to shorten the imaging time. However, the scattered activity of the Kr-81m into the Tc-99m window may hide some perfusion defects, particularly if the activity of the Kr-81m generator is too high (>300 MBq). Typically, the count rate of the perfusion study must be at least four times the count rate of the cross-talk of Kr-81m into the window of Tc-99m.

The disadvantage of Kr-81m is that the short half-life of the generator decreases availability and increases cost.

2. Technegas

Technegas is an ultrafine dispersion of ^{99m}Tc-labelled carbon, formed by burning of ^{99m}Tc pertechnetate in a carbon crucible at 2500° C in the presence of argon gas. The particles produced are of the order of 20 nm in diameter and are inhaled by the patient via a mouthpiece. Technegas has properties shared by both gases and aerosols. Its penetration characteristics are gas-like, as it has a smaller and more uniform particle size than other aerosols.

The usual administered activity of ^{99m}Tc-pertechnetate in the carbon crucible is 260-370 MBq (7-10 mCi), from which the patient receives approximately 37 MBq (1 mCi) to the lungs.

Technegas is slowly inhaled through a mouthpiece with the nose occluded, from residual volume to total lung capacity, followed by breath-hold for about 5 seconds with the patient in a sitting position. If a count rate of 2 Kcounts/s is not obtained, further breaths can be taken.

Standard views are obtained with 200 Kcounts per view in 256 x 256 matrix size.

Technegas imaging is usually performed before perfusion imaging because it is more difficult to deliver a larger dose of Technegas than it is to deliver a larger dose of Tc-99m macroaggregated albumin (MAA). Because both agents are labeled with Tc-99m, it is extremely important that the count rate of the second study is at least four times the count rate of the first study.

3. Aerosols

Technetium-99m-diethylenetriamine-pentaacetic acid (DTPA) is the preferred radiopharmaceutical.

The patient should drink a glass of water prior to administering the tracer.

The usual administered activity of Tc-99m DTPA is 900 – 1300 MBq (25 – 35 mCi) in the nebulizer, from which the patient receives approximately 20 – 40 MBq (0.5 – 1.0 mCi) to the lungs.

Aerosol imaging is usually performed before perfusion imaging because it is more difficult to deliver a larger dose of the Tc-99m aerosol than it is to deliver a larger dose of Tc-99m macroaggregated albumin (MAA). Because both agents are labeled with Tc-99m, it is extremely important that the count rate of the second study is at least four times the count rate of the first study.

The aerosol is administered through a mouthpiece with the nose occluded and the patient performing tidal breathing.

It is preferable to have the patient inhale the aerosol in the upright position, but the supine position can be used if necessary.

The collimator is chosen so that it insures no significant septal projection.

4. Xenon-133 Ventilation Imaging

Information regarding this procedure can be found in the SNM guidelines.

Advantages and inconvenient for the various ventilation tracers are listed in table 1.

	Advantages	***Disadvantages***
Krypton	Photon energy > 140keV Multiple views possible No environmental contamination	Ultra-short T1/2 Cost very high No equilibrium or washout phases
Technegas	Good tissue penetration Require few breaths Small particle size Reaches deep lung tissue well Complete deposition in lungs Multiple views possible Readily available	Same energy photon as perfusion agent Special generator device needed - one-time high cost No washout phase Possible artifact with COPD patients Possible environmental contamination
DTPA aerosol	Good tissue penetration Low cost Multiple views possible Readily available Useful to evaluate alveolar-capillary membrane	Same energy photon as perfusion agent Special nebulizer apparatus No washout phase Large droplet, particle size Poor penetration to lung periphery High deposition in central airway No washout phase Possible artifact with COPD patients Possible environmental contamination

D. Processing

After completing the ventilation study, it should be verified that the maximum pixel value is located inside the lungs.

E. Interpretation

1. It is suggested to read the study according to the following sequence:

When both V and Q scans are performed, read the perfusion scan first.

Note the presence or absence of perfusion defect(s).

Note the number, location and severity of the defect.(s)

Note the segmental or lobar distribution of the defect(s).

Compare the perfusion scan to the ventilation study and chest X-ray when available.

2. Interpretation criteria

a) Modified PIOPED criteria: The following modified PIOPED criteria were derived from a retrospective analysis of the PIOPED database.

High Probability (≥80%, in the absence of conditions known to mimic pulmonary embolism)

≥2 large mismatched segmental perfusion defects or the arithmetic equivalent in moderate or large and moderate defects. (A large segmental defect, >75% of a segment, equals 1 segmental equivalent; a moderate defect, 25 – 75% of a segment, equals 0.5 segmental equivalents; a small defect, <25% of a segment, is not counted.)

Two large mismatched segmental perfusion defects, or the arithmetic equivalent, are borderline for "high probability."

Individual readers may correctly interpret individual images with this pattern as "high probability." In general, it is recommended that more than this degree of mismatch be present for the "high probability" category.

Intermediate Probability (20% - 79%)

One moderate to two large mismatched perfusion defects or the arithmetic equivalent in moderate or large and moderate defects.

Single-matched ventilation-perfusion defect with clear chest radiograph. Very extensive matched defects can be categorized as "low probability."

Single ventilation-perfusion matches are borderline for "low probability" and thus should be categorized as "intermediate" in most circumstances by most readers, although individual readers may correctly interpret individual scintigrams with this pattern as "low probability."

Difficult to categorize as low or high or not described as low or high.

Low Probability (<20%)

Nonsegmental perfusion defects (e.g. cardiomegaly, enlarged aorta, enlarged hila, elevated diaphragm).

Any perfusion defect with a substantially larger chest radiographic abnormality.

Perfusion defects matched by ventilation abnormality provided that there are: a) clear chest radiograph; and b) some areas of normal perfusion in the lungs.

Any number of small perfusion defects with a normal chest radiograph.

Normal

No perfusion defects or perfusion exactly outlines the shape of the lungs seen on the chest radiograph (note that hilar and aortic impressions may be seen and the chest radiograph and/or ventilation study may be abnormal).

The combination of the PIOPED criteria with clinical data such as risk factors for PE increases the diagnostic accuracy of the test, as shown in table 2.

V/Q scan interpretation	Proportion of pts with PE and 0 risk factors	Proportion of pts with PE and 1 risk factor	Proportion of pts with PE and 2 risk factors
High	82%	84%	97%
Intermediate	25%	37%	45%
Low	4%	12%	21%
Normal	0%	0%	0%

Risk factors = immobilization for 3 days or more, surgery, trauma to the lower extremities or central venous instrumentation within 3 months of presentation.

The stripe sign (activity at the periphery of a perfusion defect) lowers the chance of pulmonary embolism in the zone of the perfusion defect that shows the stripe.

b) PISA-PED Criteria

Image analysis according to the PISA-PED criteria is based on the perfusion scan and the chest X-ray

Normal

No perfusion defect of any kind

Near-normal

Perfusion defects smaller or equal in size and shape to the following radiographic abnormalities: cardiomegaly, enlarged aorta, hila or mediastinum, elevated diaphragm, blunting of the costophrenic angle, pleural thickening, intrafissural collection of liquid

PE +: Abnormal scan compatible with pulmonary embolism

Single or multiple wedge-shaped perfusion defects of any size, overperfusion of single or multiple wedge-shaped areas of various size, resulting from the diversion of blood flow away from unperfused regions.

PE -: Abnormal scan not compatible with pulmonary embolism

Single or multiple non wedge-shaped perfusion defects

The final interpretation combines these criteria with the clinical data. For instance, the positive predictive value of a PE + scan was 99% in patients with a high (very likely) or intermediate (possible) likelihood of PE after clinical assessment. Conversely, a near normal or a PE – scan combined with a low clinical likelihood of PE had a negative predictive value of 97%.

c) Gestalt Interpretation

The experienced nuclear medicine physician may be able to provide a more accurate interpretation of the ventilation-perfusion study than is provided by the criteria alone; however, his/her opinion is usually informed by detailed knowledge of the various lung image interpretive criteria.

d) Further Interpretive Considerations

Ventilation-perfusion mismatch can result from any cause of pulmonary arterial blood flow obstruction. Although there is a very long differential diagnosis for ventilation-perfusion mismatch, there are few common causes: acute pulmonary embolism, old pulmonary embolism, obstruction of an artery by tumor; and radiation therapy.

On perfusion scintigraphy, extrapulmonary activity (which may be seen at the edges of lung images in the thyroid or kidneys) may be due to either right-to-left shunt, to free Tc-99m pertechnetate or reduced technetium compounds, or to a recent nuclear medicine procedure. An image of the head can be used to differentiate free pertechnetate/reduced technetium from shunt.

F. Reporting

1. The report should include a description of the lung scintigraphy findings, diagnostic category and an overall assessment of the likelihood of pulmonary embolism based on the scintigraphic findings

2. The report should include an assessment of the post-test probability of pulmonary embolism based on the result of lung scintigraphy and an estimate of the prior probability of disease.

G. Sources of Error

1. Perfusion images can show "hot spots" in the lung if clotting of blood occurs in the syringe during the injection, or if the injection is made through an indwelling catheter that is not well-flushed.

2. Ventilation scintigraphy is obtained at a different point in time than the perfusion scintigraphy. In the intervening time, there can be changes in ventilation and perfusion. Similarly, ventilation scintigraphy may be obtained in an upright position and perfusion scintigraphy injected in the supine position. These changes in position may also affect the comparability of the two scintigrams.

3. Injection of Tc-99m MAA through a central line can result in inadequate mixing of activity in the pulmonary artery. This inadequate distribution of activity is especially true if the activity is injected through a pulmonary artery line.

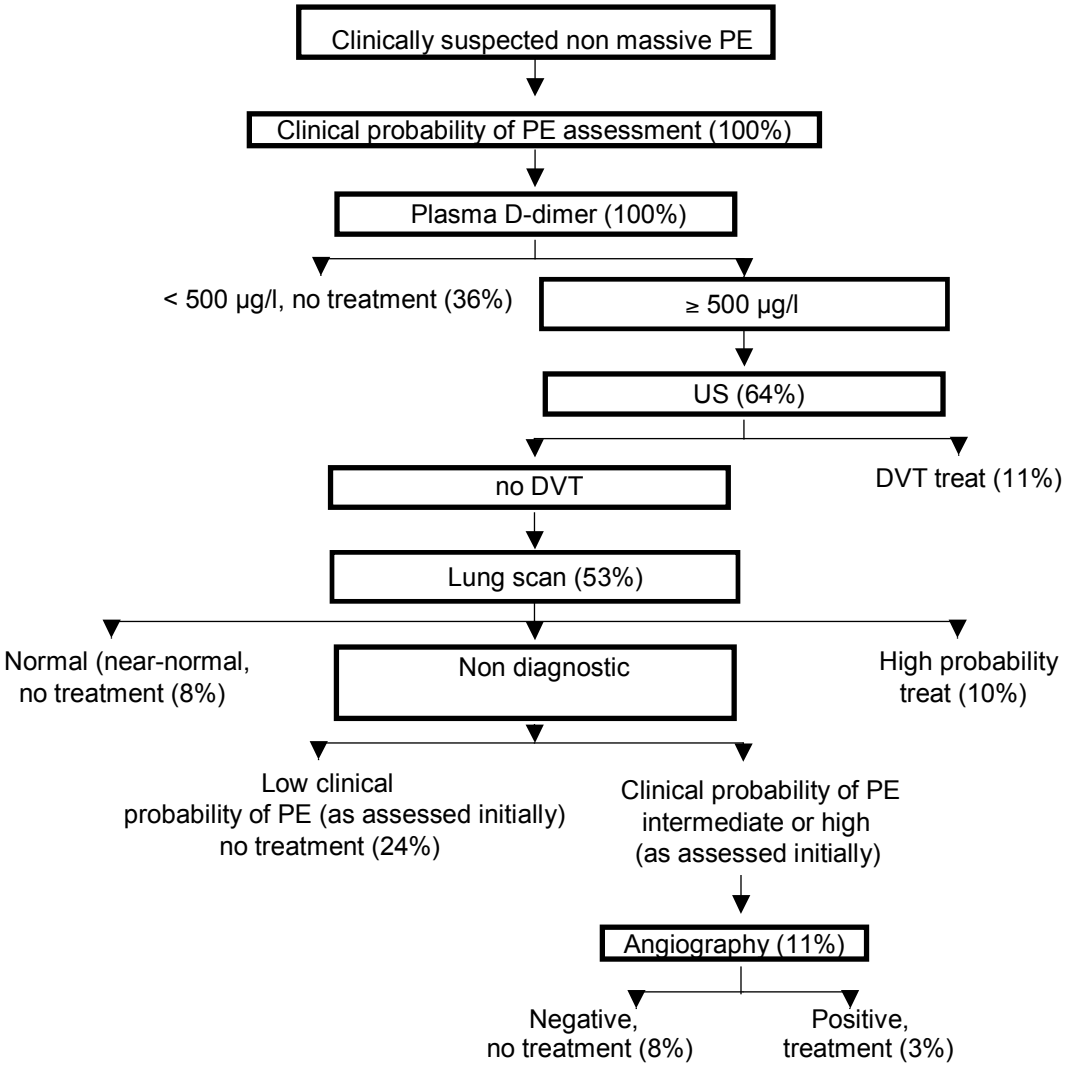
4. A decubitus or oblique patient position can markedly affect the distribution of ventilation and perfusion. If the injection for perfusion scintigraphy or if ventilation scintigraphy is performed in the decubitus or oblique position,

mismatched patterns can result. Accordingly, any nonstandard patient positioning should be recorded and considered during subsequent interpretation.

5. Attenuation artifacts can occur from various sources (medals, pacemaker device, etc.)

H. Diagnostic strategies

Various diagnostic strategies have been suggested. The following algorithm was reported by the Task Force on the Diagnosis and Management of acute pulmonary Embolism.



PE=pulmonary embolism, US=leg ultrasonography, DVT=deep vein thrombosis. The percentages represent the proportion of patients in each situation.

H. Issues Requiring Further Clarification

SPECT images may be useful along with planar images but currently there are no definite interpretation criteria.

V. Remarks

A. When quantitation is needed (i.e. evaluation prior to partial pneumonectomy), patients should be injected while in the upright position. Anterior and posterior planar views are sufficient. ROIs are drawn around each lung and divided into three regions: apical, middle and basal regions. The geometric mean of counts for each region is then calculated
(√ant. x post.). The ratio of left to right lung activity can thus be computed.

B. Evaluation of right to left shunting

In patients with right to left (R-L) shunting, part of the intravenously administered Tc-99m MAA will pass through the shunt to the systemic circulation. The detection of an important R-L shunting is therefore straightforward, with the visualization of organs like brain or kidneys as characteristic signs. No adverse reactions have been reported from intravenous administration of Tc-99m MAA. Nevertheless, the use of a small number of particles is advocated (10.000 to 50.000 have been reported in the literature). Also, freshly prepared Tc-99m MAA should be used.

The detection of small R-L shunt is more difficult. Indeed, after labeling, a small proportion of Tc-99m is not fixed on the particles. This « free » Tc-99m does not require the presence of R-L shunting to enter the systemic circulation. Moreover, the breakdown of Tc-99m MAA in the lung capillary occurs quite rapidly. In less than 10 minutes, some of the Tc-99m previously blocked in the pulmonary capillary can already be found outside the lung. For these reasons, for the detection of a small right to left shunt, a dynamic data acquisition is preferable. It should be performed directly after the I.V. administration of the tracer. The camera's field of view should include the head and the upper part of the lung. The shape of the time-activity curve of the brain area allows to differentiate Tc-99m MAA activities to the free Tc-99m. This early data acquisition also allows to avoid contamination from the degraded Tc-99m MAA.

For quantitative study, one possibility is to acquire high-speed images of the entire body in both anterior and posterior projection. The magnitude of the shunt could then be estimated using the geometric means of total body and total lung counts.

C. These guidelines are valid for studies performed in adults only. Readers are invited to consult the literature for information about pediatric studies (for instance Treves, ST. *Pediatric Nuclear Medicine,* 2nd ed. New York, NY: Springer-Verlag; 1995, p.168).

VI APPENDIX

Radiopharmaceuticals

Radionuclide	Physical half-life	Energy (kev)
Tc-99m	6 hrs	140
Kr-81m	13 sec	190

Radiation Dosimetry in Adults

Radiopharmaceuticals	Administered Activity MBq (mCi)	Organ receiving the largest radiation dose mGy/MBq (rad/mCi)	Effective dose mSv/MBq (rem/mCi)
Tc-99m MAA	40-150 (1-4)	Lung: 0.067 (0.25)	0.012 (0.044)
Tc-99m DTPA	20-40 (0.5-1)	Bladder: 0.047 (0.17)	0.007 (0.026)
Kr-81m	40-400 (1-10)	Lung: 0.0068 (0.025)	0.0007 (0.026)

VII REFERENCES

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