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The American College of Radiology will periodically define new practice parameters and technical standards for radiologic practice to help advance the science of radiology and to improve the quality of service to patients throughout the United States. Existing practice parameters and technical standards will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

Each practice parameter and technical standard, representing a policy statement by the College, has undergone a thorough consensus process in which it has been subjected to extensive review and approval. The practice parameters and technical standards recognize that the safe and effective use of diagnostic and therapeutic radiology requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published practice parameter and technical standard by those entities not providing these services is not authorized.

Revised 2018 (Resolution 30)\*

## **ACR–SPR–STR PRACTICE PARAMETER FOR THE PERFORMANCE OF PULMONARY SCINTIGRAPHY**

### **PREAMBLE**

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care<sup>1</sup>. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner in light of all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of this document is to assist practitioners in achieving this objective.

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<sup>1</sup> *Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing*, \_\_\_ N.W.2d \_\_\_ (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, *Stanley v. McCarver*, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

## I. INTRODUCTION

This practice parameter was revised collaboratively by the American College of Radiology (ACR), the Society for Pediatric Radiology (SPR), and the Society of Thoracic Radiology (STR).

It is intended to guide physicians performing pulmonary scintigraphy in adult and pediatric patients. Properly performed ventilation imaging with aerosolized or gaseous radiopharmaceuticals and perfusion imaging with technetium-99m-labeled perfusion radiopharmaceuticals that localize by temporary capillary blockade are sensitive tools for detecting certain pulmonary abnormalities. The interpretation of pulmonary scintigraphy may be optimized by incorporating clinical data and relevant correlative imaging, including current chest radiography and computed tomography (CT).

Application of this practice parameter should be in accordance with the [ACR–SPR Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals](#) [1].

The goal of pulmonary scintigraphy is to detect and, in some cases, to quantify abnormalities of pulmonary perfusion and/or ventilation.

## II. INDICATIONS AND CONTRAINDICATIONS

Clinical indications for pulmonary scintigraphy include, but are not limited to, the following:

### A. Indications

1. Assessment of the probability of acute or chronic pulmonary thromboembolic disease, including the evaluation of unexplained pulmonary arterial hypertension [5-7]. It may be used as an alternative examination or a follow-up examination to CT pulmonary angiography in various clinical settings, including pregnancy [2,4,8].
2. Quantification of differential or regional pulmonary function (eg, in predicting postoperative function)
3. Evaluation of transplanted lungs
4. Evaluation of pulmonary or cardiac right-to-left shunts
5. Evaluation of the effects of structural abnormalities of the chest, such as pectus excavatum and congenital diaphragmatic hernia
6. Confirmation of the presence of bronchopleural fistulae
7. Evaluation of chronic pulmonary parenchymal disorders such as cystic fibrosis

### B. Contraindications

There are no absolute contraindications for pulmonary scintigraphy. Potential benefits must outweigh the minor risks of the procedure.

The [ACR–SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation](#) provides useful information on radiation risks to the fetus regardless of source. Information on managing pregnant or potentially pregnant patients undergoing nuclear medicine procedures is available from the International Commission on Radiological Protection [9-11].

## III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the [ACR–SPR Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals](#) [1].

## IV. SPECIFICATIONS OF THE EXAMINATION

The written or electronic request for pulmonary scintigraphy should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient's clinical problem or question and consistent with the state's scope of practice requirements. (ACR Resolution 35 adopted in 2006 – revised in 2016, Resolution 12-b)

#### A. Pulmonary Perfusion Imaging

##### 1. Radiopharmaceutical – Technetium-99m–labeled macroaggregated albumin (MAA) [12,13]

- a. Administered Activity – Perfusion After Ventilation
  - i. Adult: 3.0 to 5.0 mCi (111 to 185 MBq)
  - ii. Pediatric: 0.07 mCi/kg (2.6 MBq/kg)
    - a. Minimum 0.4 mCi (14.8 MBq)
    - b. Maximum 5.0 mCi (185 MBq)
- b. Administered Activity – Ventilation After Perfusion or Perfusion Only
  - i. Adult: 1.0 to 3.0 mCi (37 to 111 MBq)
  - ii. Pediatric: 0.03 mCi/kg (1.11 MBq/kg)
    - a. Minimum 0.4 mCi (14.8 MBq)
    - b. Maximum 3.0 mCi (111 MBq)
- c. MAA Particle Size and Administered Number of Particles

The range of particle sizes should be between 10 and 90 microns in diameter and should not exceed 150 microns. Typically between 200,000 and 700,000 particles should be injected. The administered activity must be sufficient to allow acquisition of diagnostic quality images.

For adult patients with known pulmonary arterial hypertension, a right-to-left shunt, previous pneumonectomy, or pregnancy, the number of particles injected, and, if necessary, administered activity may be decreased to between 100,000 and 150,000 particles.

For pediatric patients, administered activity should be as low as practically achievable for appropriate image quality. The number of particles administered to infants, small children, and children with right-to-left shunts or pulmonary hypertension should depend on the patient's age and the severity of involvement. In these cases, the reduced particle number is based on age and usually ranges from 10,000 up to the adult number of particles.

##### d. Radiopharmaceutical Administration

The patient should be supine for 10 minutes, if possible, prior to injection. To minimize settling and clumping of technetium-99m–labeled MAA, the vial should be agitated gently before the radiopharmaceutical is withdrawn into the syringe, and then the syringe should be agitated gently prior to intravenous administration of the radiopharmaceutical. A 22-gauge or larger needle is preferred to help reduce the chance of damage to the particles. During intravenous injection, extreme care must be taken not to draw blood back into the syringe to avoid formation of clots, which may produce focal areas of increased radiopharmaceutical activity (“hot spots”) on the lung perfusion images. When possible, injection should be directly intravenous, avoiding intravenous tubing and use of indwelling catheters. The patient should remain supine for injection, and infusion should be slow (10 to 15 seconds). If possible, the patient should cough or take several deep breaths prior to and during the injection. If the perfusion examination is performed after an aerosol ventilation study, then

the technologist should verify a 3- to 4-fold increase in the perfusion count rate when compared with the ventilation count rate.

e. Imaging

Imaging with single-detector systems should be performed with the patient in the upright (sitting) position, if possible, because doing so provides improved visualization of the costophrenic angles. With dual-detector systems, both the injection and imaging are performed with the patient in the supine position. Imaging may begin immediately after the radiopharmaceutical has been administered. Preferably 8 views (anterior, posterior, bilateral posterior oblique, bilateral anterior oblique and both lateral images) should be obtained for 500,000 to 1,000,000 counts per image. Counts per image may be reduced in infants and small children. For critically ill patients undergoing pulmonary perfusion scintigraphy, a minimum of one anterior view and bilateral anterior oblique views is an acceptable alternative to the usual 8 views.

For the diagnosis of pulmonary embolism, single photon emission CT (SPECT) or SPECT-CT imaging may be used as a supplemental or alternative examination that can aid diagnosis [8,13-21]. Typical acquisition parameters would be low-energy, high-resolution collimator, a 360-degree orbit with 120 projections (3 degree intervals), and 8 seconds per projection for perfusion imaging. SPECT-CT may provide anatomic correlation that can aid diagnosis.

B. Pulmonary Ventilation Imaging

1. Radiopharmaceutical – Technetium-99m-labeled diethylene-triamine pentacetic acid (DTPA) aerosol

Diethylene-triamine pentacetic acid (DTPA) is most often used because of favorable characteristics that include a relatively fast clearance and rapid renal excretion, which lowers patient radiation exposure.

a. Administered Activity – Perfusion After Ventilation

- i. 30 to 50 mCi (1,110 to 1,850 MBq) is placed in a nebulizer and agitated with oxygen.
- ii. Patient inhales to a count rate of 1,000 to 1,600 counts per second (which deposits approximately 1 mCi (37 MBq) in the lungs.

b. Administered Activity – Ventilation After Perfusion

- i. 30 to 50 mCi (1,110 to 1,850 MBq) is placed in a nebulizer and agitated with oxygen
- ii. Patient inhales to a count rate of 3 to 4 times that of the perfusion scan count rate.

c. Radiopharmaceutical Administration

The flow rate should be adjusted to deliver the aerosol droplet size at or below about 1 micron in diameter. Patient cooperation is required for success of the examination. Care should be exercised to prevent spillage of the aerosol into the environment.

d. Imaging

Ventilation images should be acquired in the same projections and with the same collimator used for the perfusion examination.

If SPECT or SPECT-CT is used for perfusion imaging, ventilation imaging would use similar acquisition parameters, but the time per projection may increase by 50% to account for the lower count rate.

2. Radiopharmaceutical – Xenon-133

Xenon-133, a radioactive gas, is administered by mask and requires a delivery and trapping system or external exhaust system.

- a. Administered Activity
  - i. Adults: 10 to 30 mCi (370 to 1,110 MBq)
  - ii. Pediatrics: 0.3 mCi/kg (11.1 MBq/kg)
    - a. Minimum: 3.0 mCi (111 MBq)

A room with negative pressure ventilation is desirable and is also dependent on the individual state regulatory requirements. Patient cooperation is very important for success of the examination. Care should be exercised to prevent leakage of the radiopharmaceutical into the environment; a xenon trap should be used. Patients who are severely dyspneic or who are on ventilator support may not be able to undergo xenon-133 ventilation imaging. Special adapters may be available to administer xenon-133 through an endotracheal tube. If available, aerosol ventilation imaging may be an alternative for these patients.

- b. Imaging

The ventilation phase is usually, but not always, performed before the perfusion phase. Three sets of images are usually obtained, nearly always in the posterior projection with the same collimator used for the perfusion examination. These may be performed as 3 separate image acquisitions or may be acquired as parts of a single dynamic image acquisition. The first is a breath-holding view of the first deep breath after introduction of the radiopharmaceutical (“single breath image”). The second is an “equilibrium” phase, during which the patient rebreathes the xenon-133 and oxygen, usually for 2 to 3 minutes, after which 2 static images at 90 seconds are acquired. The third is the “wash-out phase,” during which the patient inhales room air, possibly mixed with oxygen, but exhales into the xenon-133 trap. Serial images are obtained at 15- to 60-second intervals for 3 to 5 minutes or until wash-out is complete, whichever comes first. Right and left posterior oblique equilibrium images may also be obtained early in the “equilibrium phase” and/or during wash-out (typically obtained during the third and fourth minutes of wash-out) to provide additional information about the location of ventilation abnormalities.

## V. EQUIPMENT SPECIFICATIONS

A single or multidetector planar or SPECT gamma camera may be used. Low-energy all-purpose/general-purpose (LEAP/GAP) or high-resolution parallel hole collimators may be used. Optionally, a SPECT-CT camera may be used

## VI. OTHER CONSIDERATIONS

For examinations performed to assess for acute pulmonary thromboembolic disease, several sets of interpretive criteria have been validated and may be used for guidance, such as the modified PIOPED II criteria (either with or without ventilation imaging), PISAPED criteria, Trinary system, or modified Biello criteria. The overall interpretation of the examination should also take into account the clinical pretest likelihood of pulmonary embolism and the results of any previously performed imaging studies, laboratory tests, or other clinical evaluations.

For patients being studied for acute pulmonary embolic disease, current chest radiographic images, preferably posteroanterior and lateral, should be obtained and inspected by the interpreting physician to ascertain whether confounding conditions (eg, pneumonias, tumors, congestive heart failure, pleural effusions, pneumothoraces) are present. Optimally, chest radiographic images should be obtained immediately before or after scintigraphy or, after any change in cardiopulmonary status, usually within 24 hours of the scintigraphic examination.

If available, prior pulmonary scintigrams, chest CT images, or abdominal CT images (if the abdominal CT examination includes the lower lungs) should be reviewed to evaluate for chronic unresolved pulmonary emboli or other persistent abnormalities.

Quantitative measures of differential or regional lung perfusion (comparing lungs or dividing each lung into halves or thirds and calculating the percentage of total counts in each region) may be useful in nonembolic and

preoperative disease assessment and evaluation of post–lung transplant patients. Quantitative comparison of regional perfusion and ventilation may also be useful.

If a patient with an abnormal lung scan is diagnosed as having pulmonary emboli, a follow-up perfusion lung scan should be considered to establish a baseline for continued evaluation, particularly in patients with comorbid cardiopulmonary disease and/or a large initial perfusion deficit. Preferably, this follow-up examination should be performed 1 to 3 months following the initial thromboembolic episode.

## **VII. DOCUMENTATION**

Reporting should be in accordance with the [ACR Practice Parameter for Communication of Diagnostic Imaging Findings](#) [22].

The report should include the radiopharmaceutical, administered activity, and route of administration, as well as any other pharmaceuticals administered, also with dosage and route of administration.

## **VIII. RADIATION SAFETY**

Radiologists, medical physicists, registered radiologist assistants, radiologic technologists, and all supervising physicians have a responsibility for safety in the workplace by keeping radiation exposure to staff, and to society as a whole, “as low as reasonably achievable” (ALARA) and to assure that radiation doses to individual patients are appropriate, taking into account the possible risk from radiation exposure and the diagnostic image quality necessary to achieve the clinical objective. All personnel that work with ionizing radiation must understand the key principles of occupational and public radiation protection (justification, optimization of protection and application of dose limits) and the principles of proper management of radiation dose to patients (justification, optimization and the use of dose reference levels)  
[http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1578\\_web-57265295.pdf](http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1578_web-57265295.pdf).

Facilities and their responsible staff should consult with the radiation safety officer to ensure that there are policies and procedures for the safe handling and administration of radiopharmaceuticals and that they are adhered to in accordance with ALARA. These policies and procedures must comply with all applicable radiation safety regulations and conditions of licensure imposed by the Nuclear Regulatory Commission (NRC) and by state and/or other regulatory agencies. Quantities of radiopharmaceuticals should be tailored to the individual patient by prescription or protocol.

Nationally developed guidelines, such as the ACR’s [Appropriateness Criteria](#)<sup>®</sup>, should be used to help choose the most appropriate imaging procedures to prevent unwarranted radiation exposure.

Additional information regarding patient radiation safety in imaging is available at the Image Gently<sup>®</sup> for children ([www.imagegently.org](http://www.imagegently.org)) and Image Wisely<sup>®</sup> for adults ([www.imagewisely.org](http://www.imagewisely.org)) websites. These advocacy and awareness campaigns provide free educational materials for all stakeholders involved in imaging (patients, technologists, referring providers, medical physicists, and radiologists). Radiation exposures or other dose indices should be measured and patient radiation dose estimated for representative examinations and types of patients by a Qualified Medical Physicist in accordance with the applicable ACR Technical Standards. Regular auditing of patient dose indices should be performed by comparing the facility’s dose information with national benchmarks, such as the ACR Dose Index Registry, the NCRP Report No. 172, Reference Levels and Achievable Doses in Medical and Dental Imaging: Recommendations for the United States or the Conference of Radiation Control Program Director’s National Evaluation of X-ray Trends. (ACR Resolution 17 adopted in 2006 – revised in 2009, 2013, Resolution 52).

## **IX. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION**

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control,

and Patient Education appearing under the heading *Position Statement on QC & Improvement, Safety, Infection Control, and Patient Education* on the ACR website (<https://www.acr.org/Clinical-Resources/Practice-Parameters-and-Technical-Standards>).

Equipment performance monitoring should be in accordance with the [ACR–AAPM Technical Standard for Nuclear Medical Physics Performance Monitoring of Gamma Cameras](#) [23].

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