

## Nuclear Tests in Diagnosis of Respiratory and Cardiac Pathology

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**What follows is an overview for a series of nuclear tests that can be used to diagnose pulmonary, vascular, and cardiac pathology. It will focus on nuclear scans and not on X-rays, CT and MRI. While not high yield for the USMLE, it is good to familiarize yourself with these modalities as you may get a random question on your actual USMLE test (although rare). You are likely to find these tests while working in hospital wards.**



### Overview

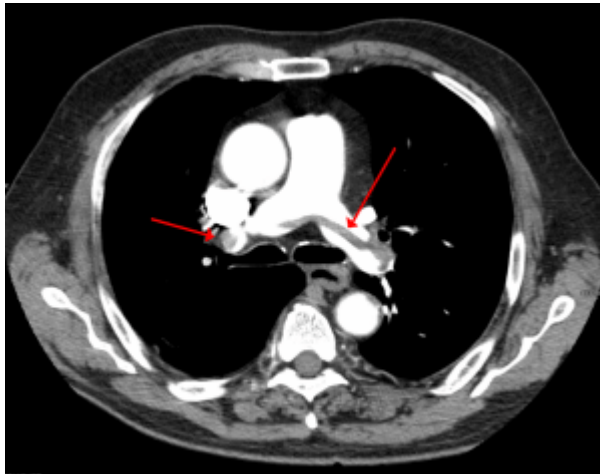
Radiographic techniques used in the diagnosis of **pulmonary embolisms** (PE) and **myocardial infarctions** (MI) are not limited to X-ray, CT, and MRI. In PEs, a **ventilation perfusion scan** can be used for diagnosis.

MI and post-MI states can be evaluated using **SPECT, PET, Perfusion** and **MUGA scans**. These scans rely on radio-labeled tracers to emit energy that can be viewed using a Gamma camera to generate a very accurate picture of organ health.

### Lung Scans

Lung scans are often used to **diagnose PEs** as they require **serious medical intervention**. PEs result in a change in the ventilation (V) and perfusion (Q) of the lung tissue. PEs are caused most often by **thrombi** that originate in the lower extremities with

the most common sites being the deep veins that travel in the hip and pelvis.



[Image](#): "A large pulmonary embolism at the bifurcation of the pulmonary artery (saddle embolism)." by James Heilman, MD.  
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While thrombi are the most likely cause, there are several other sources that can cause a PE that include **fat**, **air**, **bacteria**, **amniotic fluid**, and **tumor**. The major risk factors for developing a PE include **CHF**, **obesity**, **post-surgical**, and **immobility** such as being on a flight.

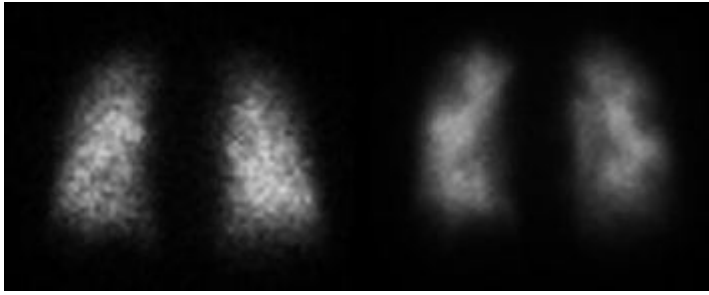
Signs and symptoms of a PE are **tachypnea**, **chest pain**, and **rapid onset dyspnea**. The most common symptom is dyspnea. Other relevant findings are **elevated D-dimer** on labs and **S1Q3T3 pattern** on ECG.

Rapidly diagnosis of a PE can be done using several modalities with the most sensitive and reliable one being the **CT pulmonary angiogram (CTPA)**. For patients who have contraindications to a CTPA, a **VQ scan** is recommended. Contraindications include having **renal impairment** that does not allow for contrast to be used. Another common reason is due to **pregnancy** where radiation is a teratogen.

For USMLE, it is important to know that while D-dimers are seen during a PE; they are only sensitive and not specific, meaning that while they occur with PEs they also occur with many other conditions. If you suspect a PE but the patient does not have an elevated D-dimer, then it is very unlikely that the patient is experiencing a PE and another pathology should be considered. Other causes of an elevated D-dimer can include **sepsis**, **stroke**, and **renal disease**.

## Ventilation Perfusion Scans

Ventilation perfusion scans (**VQ scans**) rely on **scintigrams**, a technique where a radioactive isotope with Technetium-99 DTPA is inhaled after which multiple images are taken using a Gamma camera. This is then followed by an injection of Technetium-99 MAA which lodges in arterioles of the lung after which Gamma camera images are taken.



[Image](#): "Posterior views from ventilation (left) and perfusion (right) scans of a patient's lungs. Generated using OsiriX." by Kieran Maher – <http://en.wikibooks.org/wiki/Image:VentPerfPost.jpg>. License: [Copyrighted free use](#)

Both image sets are compared and if there is a PE there will be ventilation but no perfusion. Oftentimes, there are **multiple perfusion defects**. V/Q scans are done using a **chest X-ray** to rule out other pathologies such as **atelectasis**. Due to the V/Q scan protocol and poorer sensitivity and specificity, a CTPA is a much better choice to rapidly diagnose a PE.

## Cardiography

Cardiography can be done using **nuclear tests** to diagnose cardiac pathology and usually focuses on two areas: ischemia/infarct or with heart failure.

**Cardiac ischemia** in a chronic form can present as **angina** which results from luminal narrowing. If the stenosis continues to grow, or if it breaks off and occludes a distal part of the vessel tissues, ischemia will rapidly occur resulting in **MI**. The most common coronary arteries to occlude are the **left anterior descending, right coronary, and left circumflex**.

Common symptoms you will see in a patient include **retrosternal pain** that can radiate to the left arm or up the neck to the jaw, **shortness of breath, diaphoresis, nausea,** and **vomiting**.

**ECG** is the best way to diagnose a MI with changes normally seen in the ST region for a transmural infarct. On laboratory exam, **Troponin I** is the most specific marker. Immediate treatment in the ED includes **oxygen, aspirin, morphine** and **sublingual nitroglycerin**.

**MI complications** can occur during or post infarct and can have serious morbidity and mortality. **Cardiac arrhythmias** are very common and you should remember that only **ventricular tachycardia** and **ventricular fibrillation** are shockable rhythms.

Cardiogenic shock where the heart cannot pump enough blood can occur and lead to death rapidly.

Depending on tissue death, **free wall rupture** can occur leading to **cardiac tamponade**. Also, papillary muscles can rupture which lead to **valve regurgitation** with the most common being the **mitral valve**. Finally, several weeks after the MI, **Dressler's syndrome** can occur which is an **autoimmune reaction** that leads to **fibrinous pericarditis**.

For the USMLE, it is important to know the **time course for changes on the microscopic level** in cardiac tissue related to ischemia. Cardiac tissue undergoes **coagulative necrosis** which results in maintenance of cell architecture for a few

days.

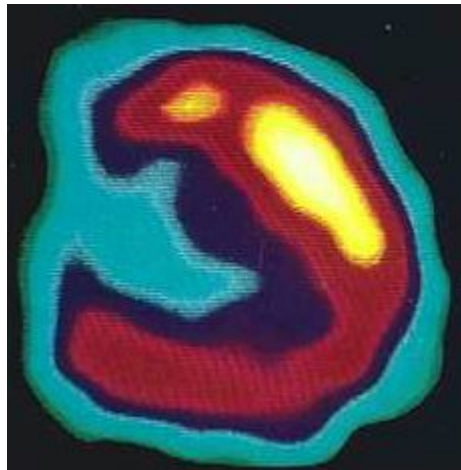
- Initially, within the **first four hours** there will be **few visible changes** to the cardiac tissue.
- Between **four to twelve hours**, **edema** and **wavy fibres** can be seen.
- **Twelve to twenty-four hours** will see the arrival of **neutrophils** to primary infarct site.
- **One to three days** shows surrounding tissue with **inflammation** and **neutrophils**.
- Up to **two weeks later** will show **granulated tissue with macrophages**.
- **After two weeks** the infarction site will show **scar** tissue formation.

**Heart failure** is a condition that can be caused by cardiac ischemia, [alcohol abuse](#), vitamin deficiencies, and drug use. It is usually broken down into two distinct categories of left and right-sided heart failure.

**Left-sided heart failure** will present with symptoms of [pulmonary edema](#), orthopnea, paroxysmal nocturnal dyspnea, and patients can cough up pink frothy sputum.

**Right-sided heart failure** will present with symptoms that include jugular venous distension, peripheral edema, and hepatomegaly. Diagnostics tests usually begin with a chest X-ray and echocardiogram. For an even more accurate picture, nuclear tests can be performed which will allow for a better representation of myocyte health, ventricular function, and ejection fraction. **Ejection fraction** is measured as the stroke volume divided by the end diastolic volume. The normal range is somewhere around ~60% and the classification for heart failure is when it reaches ~40% or less.

## Ventricular Function Studies



[Image](#): "A SPECT slice of a patient's heart." by Kieran Maher – <http://en.wikibooks.org/wiki/Image:SPECT-Heart.jpg>. License: Copyrighted free use.

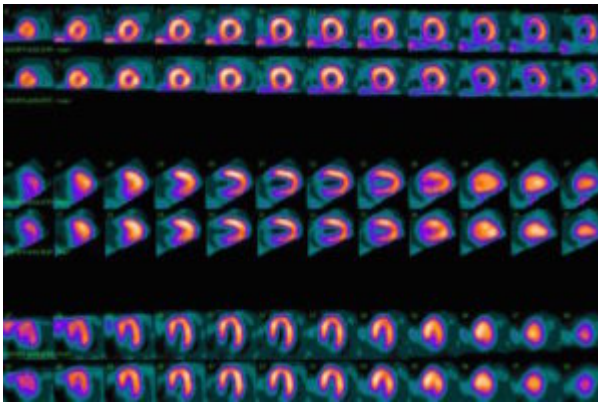
Ventricular function studies are most commonly done as **single photon emission computed tomography (SPECT)** test. SPECT tests show **signs of CAD** and **ventricular function**. The test uses Technetium-99m to visualize the heart in states of rest and during activity. Viewing the function of the heart during activity can be done with the patient walking on a treadmill or, in some cases, by pharmacologically induction. **Adenosine** is often given to facilitate this.

# Positron Emission Tomography

Positron emission tomography (**PET scan**) is an imaging technique that utilizes **radiopharmaceuticals**. The radiopharmaceuticals are usually **radio-labeled sugars** that can be injected into the bloodstream that then build up in certain tissues and can be used to detect cancer, neurologic disease and activity, and cardiac function.

In conditions such as **hibernating myocardium**, a PET scan can be used to visualize cardiac activity. Hibernating myocardium occurs after cardiac ischemia where loss of blood flow results in a decreased contractile ability of myocardium but not of viability. A PET scan can be used to visualize if the tissue is still viable as the radio-isotopes would still be taken up by the myocardial tissue.

## Resting Myocardial Perfusion Scan



[Image](#): "Nuclear medicine myocardial perfusion scan showing normal heart muscle with no defects." by Sincefalastrum - Own work. License: [GFDL](#)

Resting myocardial perfusion scan studies are often referred to as **myocardial perfusion imaging**. This is done to see perfusion of myocardial tissue in the heart and improve on the accuracy of cardiac stress test results.

The test uses a **radioactive agent** such as **Thallium** to readily uptake into cardiac myocytes. A **photon camera** is used to take the images of the heart. Areas of reduced signal are likely due to ischemia or a past infarct. If done with exercise, this can distinguish areas that are at risk of becoming ischemic.

## Multigated Acquisition Scan (MUGA)

Multigated acquisition scan (MUGA), also known as **radionuclide angiography**, utilizes the patient's own red blood cells that are tagged with **technetium-99 pertechnetate**.

This **labeling of the red blood cells** allows for visualization of the function of both the left and right ventricles. This test is useful in the **diagnosis of heart failure**. Like in many of the other tests, a **Gamma camera** will record and generate a picture of cardiac function. This technique can give a very accurate EF.

# References

[Clinical presentation, evaluation, and diagnosis of the adult with suspected acute pulmonary embolism](#) via uptodate.com

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[V/Q scan](#) via radiopaedia.org

[Positron emission tomography](#) via radiopaedia.org

[Multigates Acquisition Scan \(MUGA\)](#) via my.clevelandclinic.org

[Causes of Elevated D-Dimer](#) via em.umaryland.edu

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