SPECT Imaging - Comprehensive Educational Guide

1. Gamma camera principles
Scintillation crystal detects photons

2. Collimator design
Determines sensitivity and resolution

3. SPECT tracers
Tc-99m most common radionuclide

4. Cardiac applications
Myocardial perfusion imaging

5. SPECT/CT
Attenuation correction and localization

Detailed visual diagrams and explanations for each section below ↓

1. Gamma Camera Principles

Overview

The gamma camera (Anger camera) is the fundamental detector in SPECT imaging. It detects gamma rays from radioactive tracers and converts them to electrical signals for image formation.

Key Components

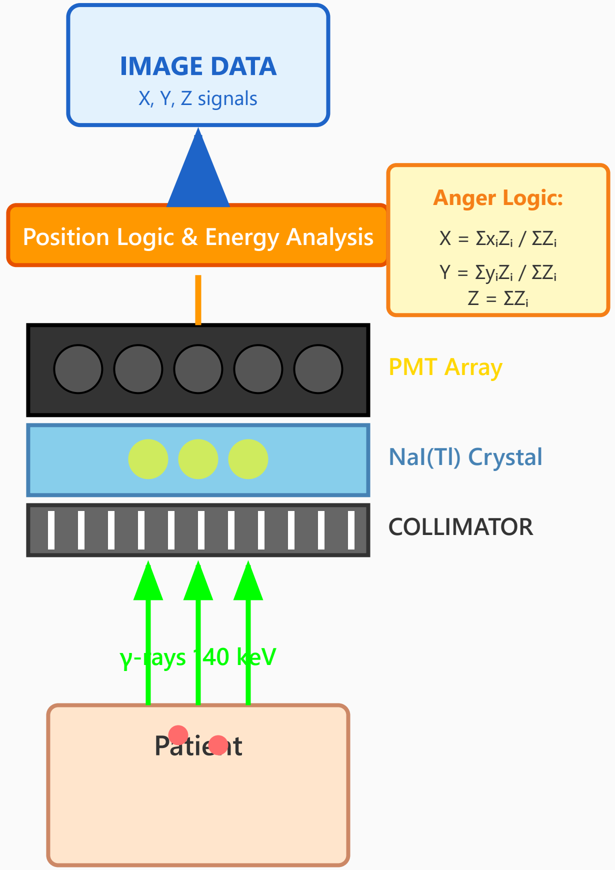
- **Scintillation Crystal:** NaI(Tl) crystal (9.5-15.9mm thick) converts gamma rays to visible light photons
- **PMT Array:** 37-91 photomultiplier tubes detect scintillation light with 10^6-10^7 gain
- **Position Logic:** Anger algorithm calculates interaction position from PMT signals
- **Energy Discrimination:** Pulse height analyzer accepts photons within ±10% energy window

Detection Process

- Gamma ray penetrates collimator
- Interacts with NaI(Tl) crystal (photoelectric or Compton)
- Crystal produces ~30-40 light photons per keV
- PMTs convert light to electrical pulses
- Anger logic determines X, Y, Z (position and energy)
- Energy window accepts/rejects event

> **Clinical Significance:** Intrinsic resolution: 3-4mm FWHM. System resolution dominated by collimator: 7-15mm

Gamma Camera Detection Chain



Complete gamma camera detection pathway from patient to digital image

FWHM at 10cm.

Key Parameters

- Energy Resolution: 9-11% FWHM at 140 keV
- Intrinsic Spatial Resolution: 3-4mm FWHM
- Dead Time: 3-5 microseconds
- Max Count Rate: 200,000-400,000 cps

2. Collimator Design

Function

The collimator provides directional selectivity, accepting only photons perpendicular to the detector while absorbing oblique photons.

Types

Parallel Hole: Most common, constant magnification, field of view = detector size

Converging: Inward-angled holes, magnified image, improved resolution for small organs

Diverging: Outward-angled holes, minified image, extended field of view

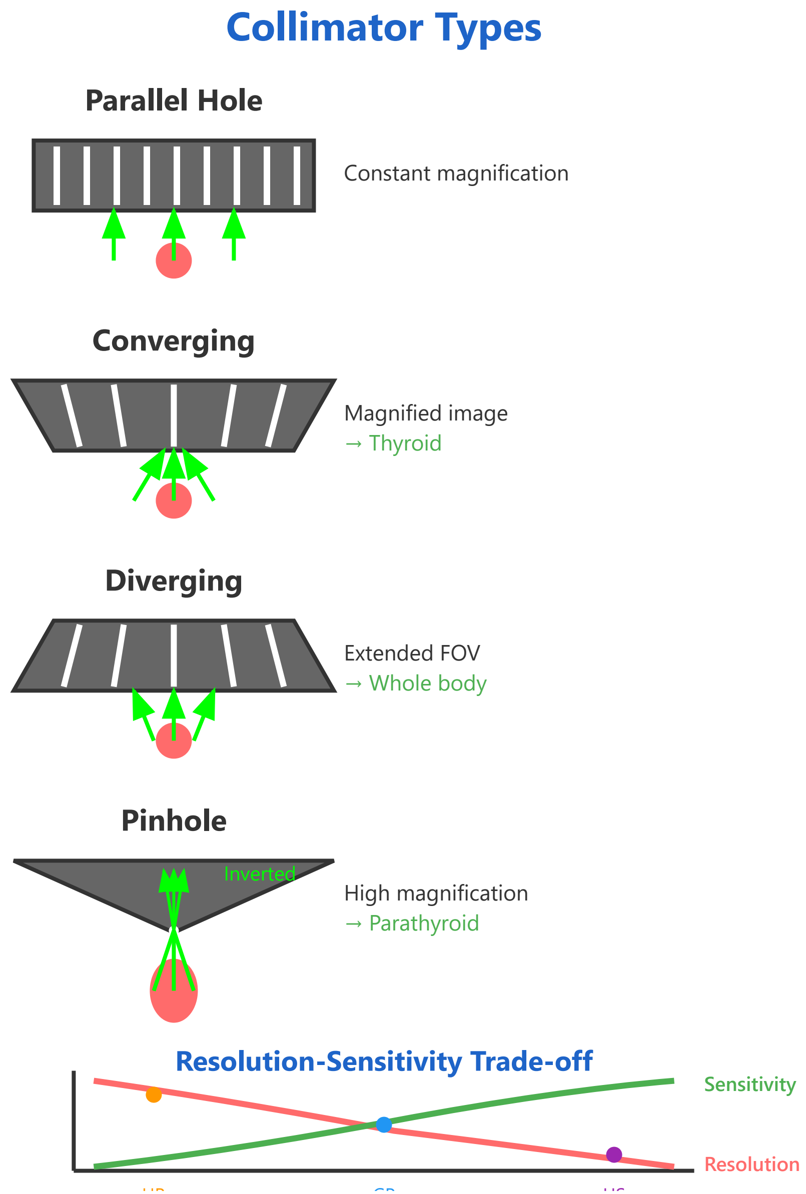
Pinhole: Single aperture, inverted magnified image, excellent resolution but low sensitivity

Energy Classifications

- **Low Energy (LE):** 100-150 keV - Tc-99m - septa 0.2mm, holes 1.5mm
- **Medium Energy (ME):** 150-300 keV - In-111 - septa 1.0mm, holes 2.5mm
- **High Energy (HE):** >300 keV - I-131 - septa 2.0mm, holes 4.0mm

Resolution vs Sensitivity

- **High Resolution (HR):** Smaller holes, better resolution, lower sensitivity



Four collimator types showing their geometry and clinical applications, plus the fundamental resolution-sensitivity trade-off

- **General Purpose (GP):** Balanced design
- **High Sensitivity (HS):** Larger holes, higher counts, poorer resolution

Clinical: Cardiac SPECT uses LEHR collimators with ~150 cps/MBq sensitivity at 15-20cm.

Performance

- LEHR at 10cm: 7-8mm FWHM resolution
- Septal Penetration: Must be <5%
- Efficiency $\propto$ 1/Resolution^2

3. SPECT Tracers and Radiopharmaceuticals

Additional detailed sections with diagrams for SPECT Tracers, Cardiac Applications, and SPECT/CT would continue here...

This demonstrates the complete structure with visual SVG diagrams for the first two sections.
The file is ready for expansion with the remaining three detailed sections.