Quality Control in Medical Imaging System

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Introduction

- **Quality Assurance (QA)** embraces all aspects of the diagnostic imaging process including a visual check of the equipment and confirmation of careful preparation prior to every patient procedure.

- **Quality control (QC)** in medical imaging is crucial to ensuring accurate diagnoses and treatment plans. It involves a systematic process of monitoring and evaluating the performance of imaging equipment and techniques.

- **Acceptance testing** is a quality assurance (QA) process that determines to what degree an application meets end users' approval.

- **Calibration** is a procedure for detecting and fixing the uncertainties in measurements and bringing them to an acceptable level.

Importance of Quality Control in Medical Imaging

1 **Accurate Diagnoses**

Ensures precise interpretation of medical images leading to accurate diagnoses.

2 **Effective Treatment**

Provides reliable data for treatment planning and monitoring patient progress.

3 **Patient Safety**

Minimizes risks associated with faulty equipment or procedures, safeguarding patient well-being.

4 **Efficient Operations**

Optimizes workflow, reduces errors, and improves overall efficiency of imaging departments.

Quality Control in Computed Tomography

Quality control (QC) is essential in CT imaging. It ensures reliable, accurate, and safe scans for patients.

Importance of Quality Control in CT Imaging

CT imaging provides detailed anatomical information, enabling accurate diagnosis and treatment planning.

1 Patient Safety

QC safeguards patients from potential harm by minimizing radiation exposure and ensuring accurate results.

2 Diagnostic Accuracy

Consistent image quality improves the reliability of diagnoses, leading to better patient outcomes.

3 Cost-Effectiveness

QC reduces the need for repeat scans, optimizing resource utilization and minimizing healthcare costs.

4 Legal Compliance

QC practices ensure compliance with regulatory standards, protecting healthcare providers from legal liabilities.

Routine Quality Control Checks

1

Daily Quality Control Practices

Check CT Scanner Warm-up, CT Number accuracy, Monitor Image Quality, Check Display Monitors, Review Radiation Dose

2

Weekly Quality Control Practices

Image Uniformity, Slice Thickness Verification, Detector Artifacts, Radiation Output,…

3

Monthly Quality Control Practices

Spatial Resolution Evaluation, Noise Assessment, Image Artifacts, …

4

Annually Quality Control Practices

CT Dose Index (CTDI), Z Sensitivity, geometric efficiency,…

Quality Control in Magnetic Resonance Imaging

Quality control in MRI is crucial for ensuring accurate diagnoses and safe patient care. It involves a comprehensive set of procedures and protocols to monitor and maintain the performance of the MRI system.

Phantom Imaging and Calibration

1 **Phantom Selection**

Choosing an appropriate phantom that mimics human tissues and simulates various scan parameters.

2 **Imaging Procedure**

pulse sequences and parameters to assess the sysScanning the phantom with various tem's performance.

4 **Data Analysis**

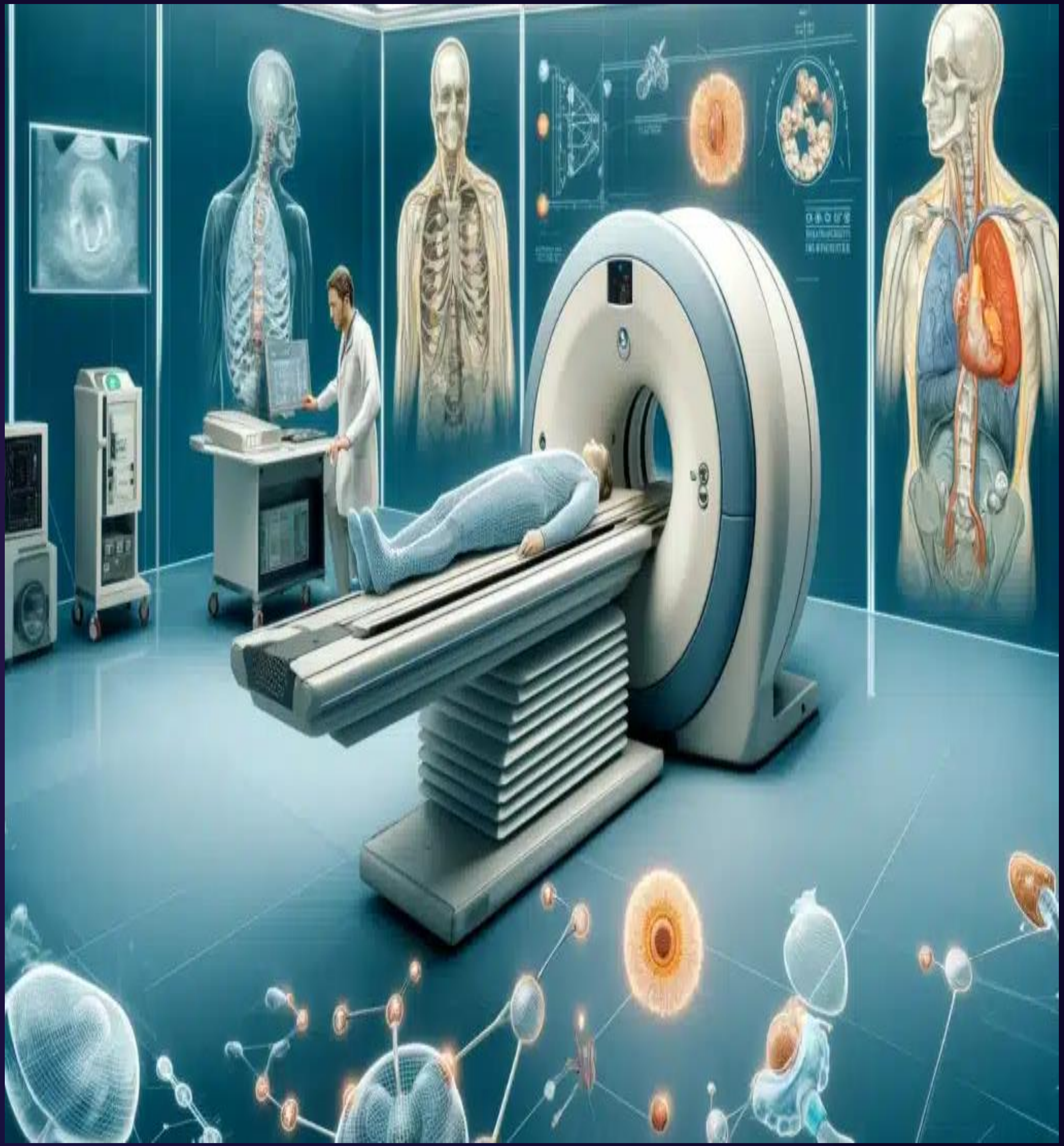
Analyzing the images to evaluate image quality metrics, identify potential issues, and adjust system settings.

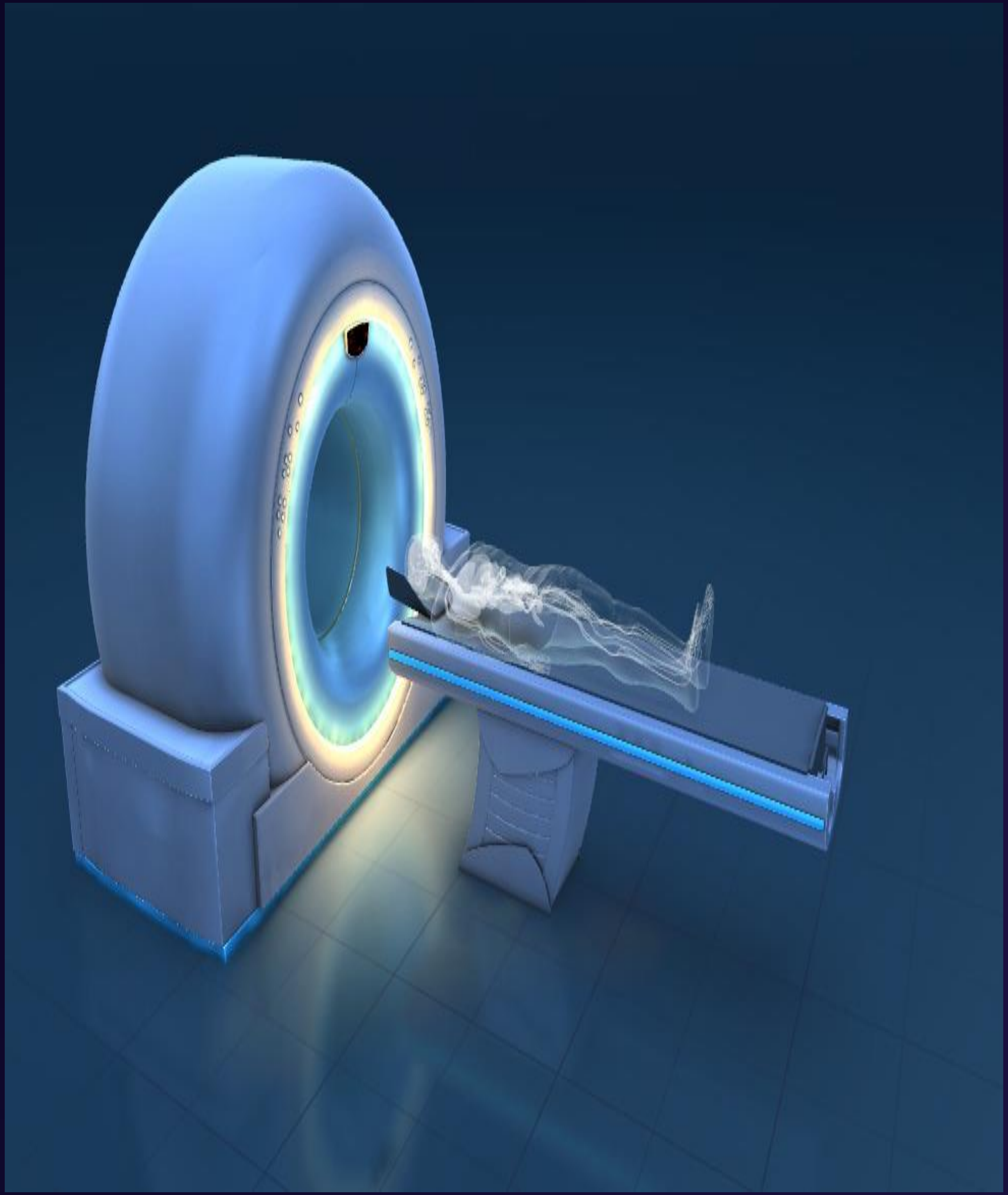
Routine Quality Control Checks

Daily	Visual inspection of all scanner hardware, the function of safety and communication devices, and general assessment of image quality including identification of artifacts
Weekly	Signal-to-noise ratio, Center Frequency, Image Uniformity, transmitter gain or attenuation, geometric distortion, spatial resolution, artifact evaluation, and Setup and Table Position Accuracy
Quarterly/ biannually	Shimming, Slice thickness and position

Quality Control in Nuclear Medicine

Quality control is required to ensure that NM equipment functions properly and constitutes an important part of quality management in an NM department. The described QC tests are designed to detect problems before they affect clinical patient studies.



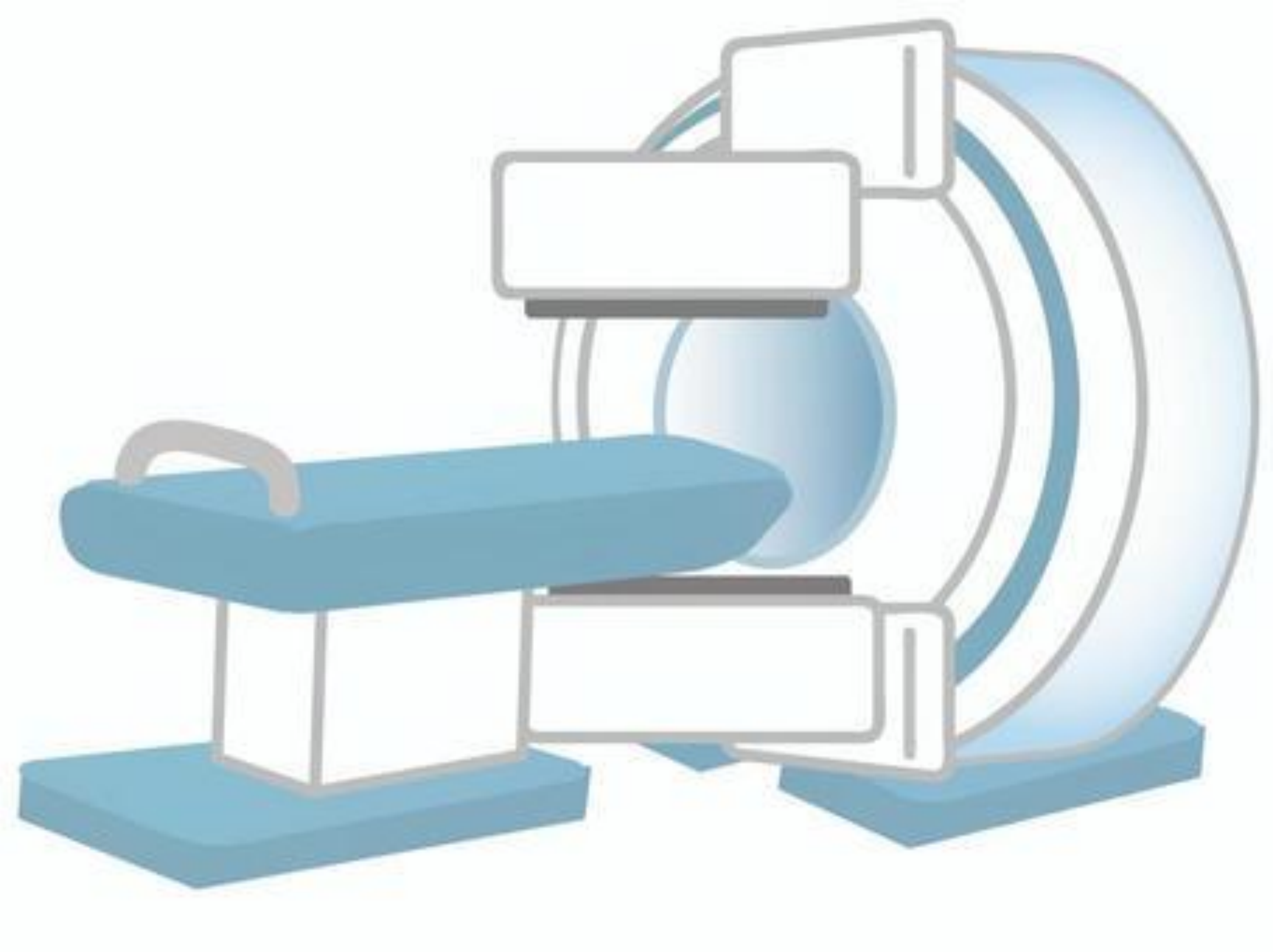


Quality Control in NM

1. QC in Planar Imaging
2. QC in SPECT Imaging
3. QC in PET Imaging

QC in Planar Imaging

1. Uniformity
2. Linearity
3. Resolution



Uniformity

Uniformity is a measure of a gamma camera's response to a uniform source of irradiation.

- Intrinsic uniformity
- Extrinsic uniformity

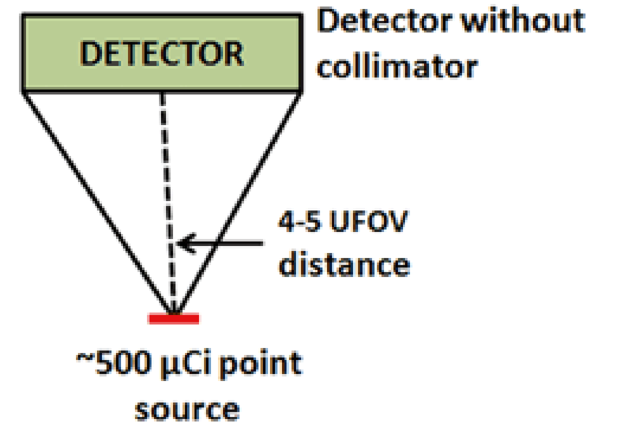
The single most important QC test should be performed daily!

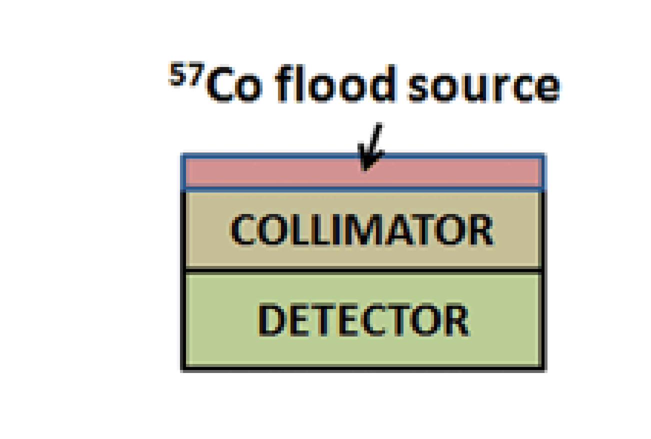
Intrinsic uniformity

- 37 MBq of ^{99m}Tc
- Distance = 5 FOV
- Matrix size = 256 × 256
- Total counts= 5–10 million

Extrinsic uniformity

- ^{57}Co Co sheet source
- Distance = 5 FOV
- Matrix size = 256 × 256
- Total counts= 5–10 million





Uniformity

Intrinsically (without Collimator)	Extrinsically (with Collimator)
Activity: (~ 500 uCi) point source of Tc-99m	**Activity:** A solid disk of Co-57 or a refillable plastic source containing a mixture of Tc-99m and water.
Distance: **Five** times the detector field of view (UFOV)	**Distance:** On the collimator
Advantages: inexpensive, low radiation to technologist, evaluated with the most common isotope	**Advantages:** possible to simultaneously acquire uniformity images on both heads and reducing the QC time
Disadvantages: the damage to collimator is not evaluated (Cold Spots), Time consuming to orientate the detector heads, increased risk of damage to the exposed crystal	**Disadvantages:** For fillable Source: Time taken in preparing the source, Radiation exposure to the technologist, distortion of the sheet source, presence of air bubbles inside the source, poor mixing of the isotope within the source, clumping or adhesion of the isotope to the container walls

Uniformity

Extrinsic flood image is preferred (Daily) and Intrinsic flood image (weekly).

Integral Uniformity (IU) (Global)

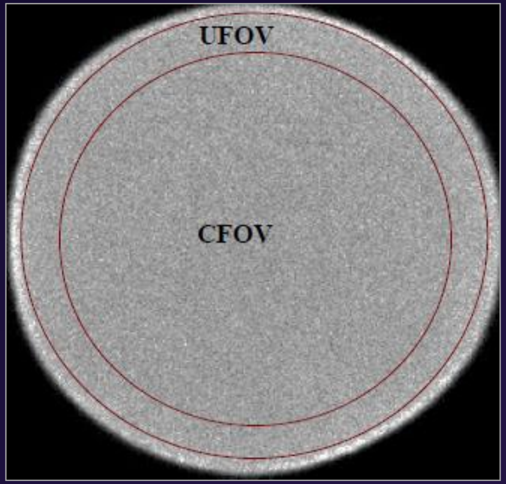
$$\frac{\text{Max. Pixel} - \text{Min. Pixel}}{\text{Max. Pixel} + \text{Min. Pixel}} \times 100\%$$

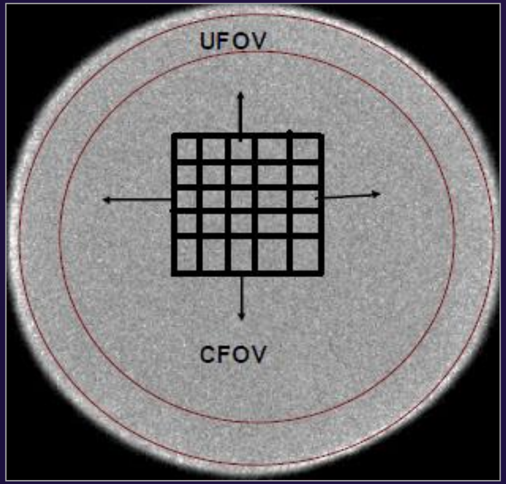
UFOV or CFOV IU of **2-3 %** expected

Differential Uniformity (DU) (local)

Maximum (Worst) rate of change across nearby pixels (~ 5)

UFOV or CFOV DU of **1.5 -2.0%** expected





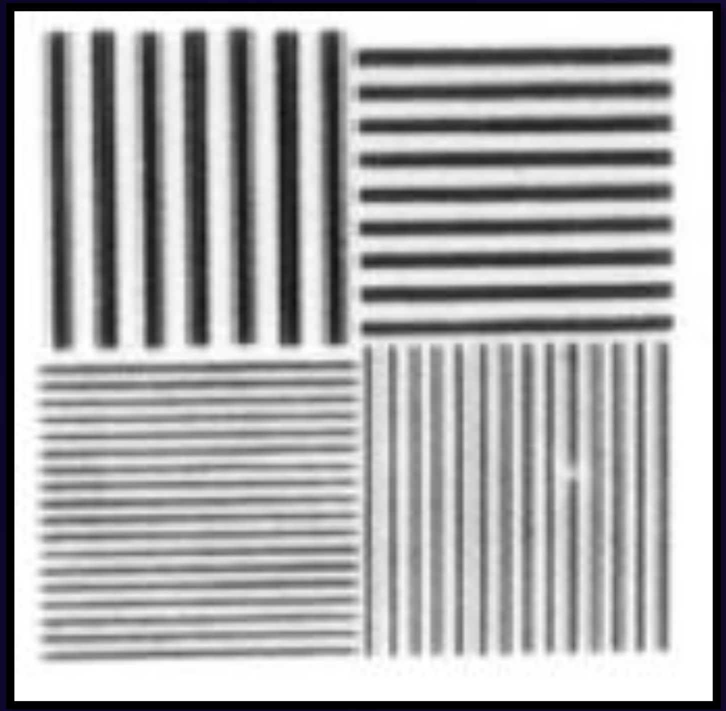
CFOV is 75 Percent of UFOV

Intrinsic Uniformity IU in UFOV	Extrinsic Uniformity IU in UFOV
< 3.5 GOOD	< 5 GOOD
3.5 – 5 Marginal	5 – 6 Marginal
Above 5 Unacceptable	Above 6 Unacceptable

Linearity/Resolution

A qualitative index of resolution (performed either intrinsic or extrinsic)

Test patterns phantoms



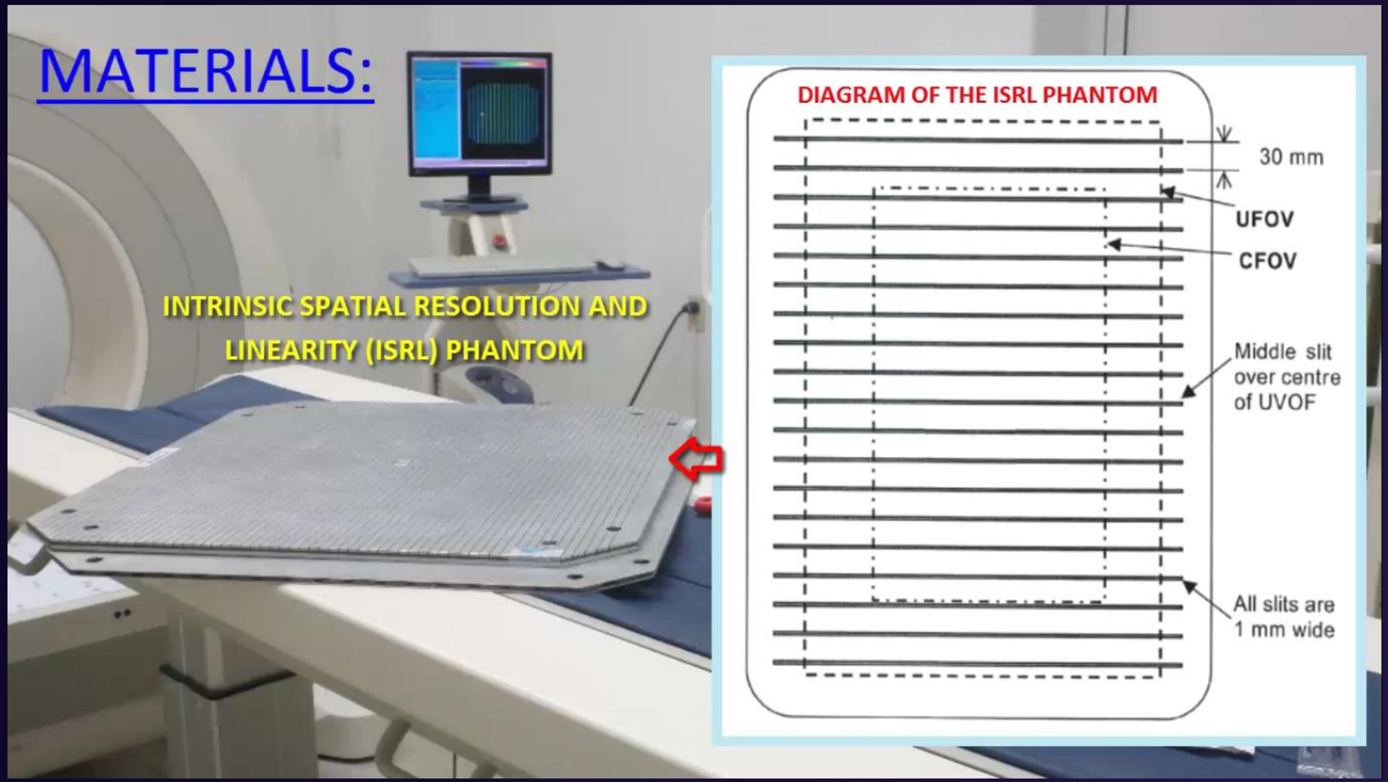
Four-Quadrant Bar Phantom

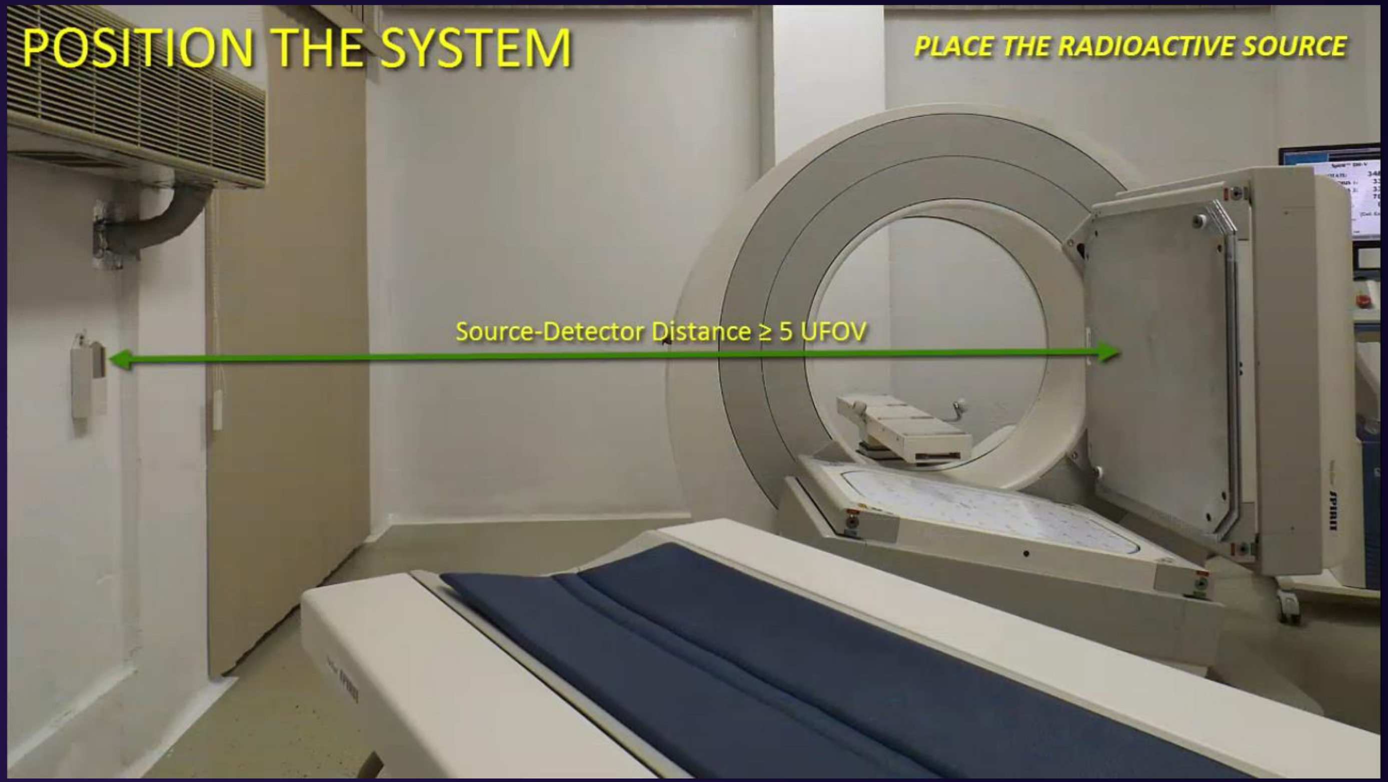
The most common

Orthogonal Hole

Parallel Line Equal Spacing (PLES)

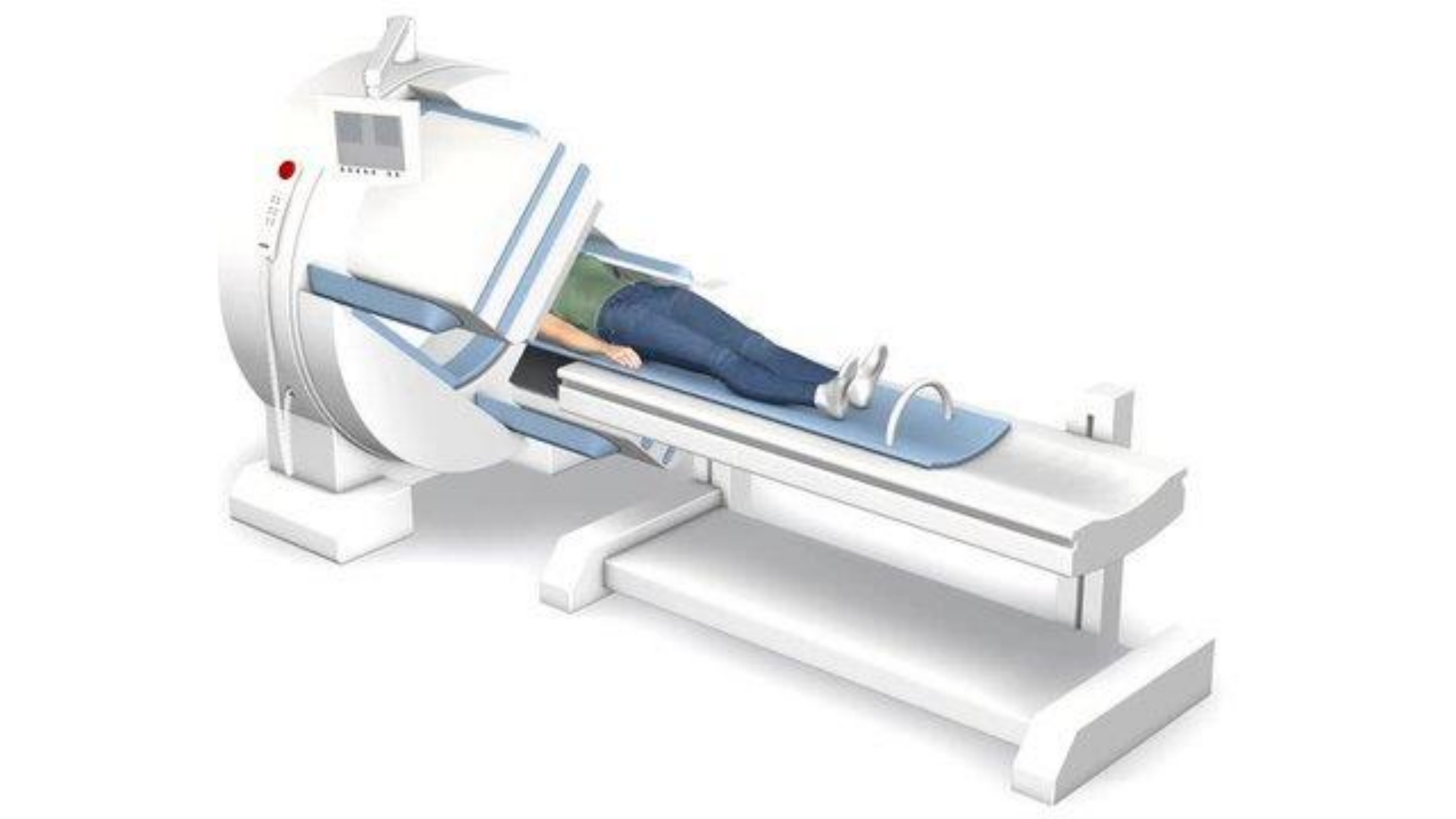
Linearity/Resolution





QC in SPECT

1 — **Center of Rotation**

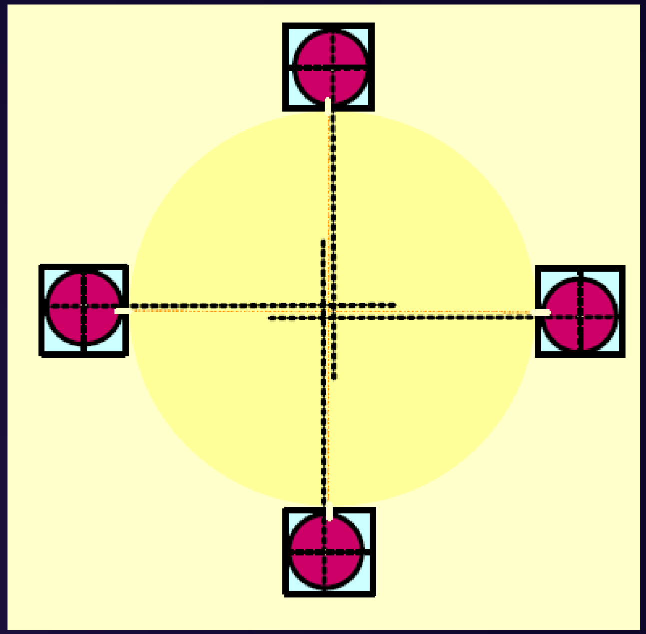


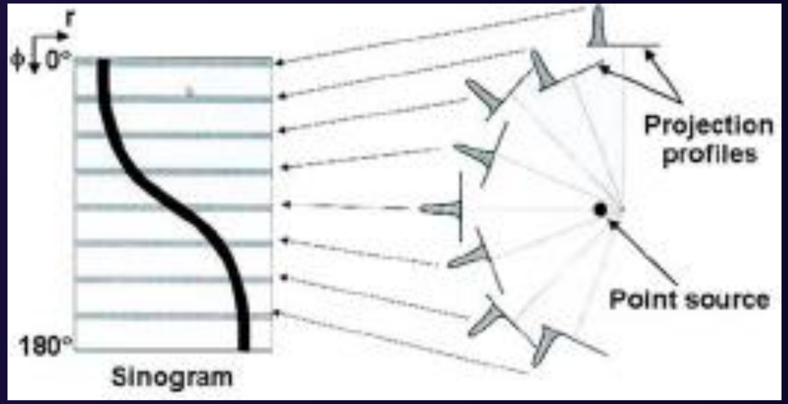
Center of Rotation

- Errors in COR of as little as 0.5 pixel in a 128 x 128 matrix degrade Image Quality

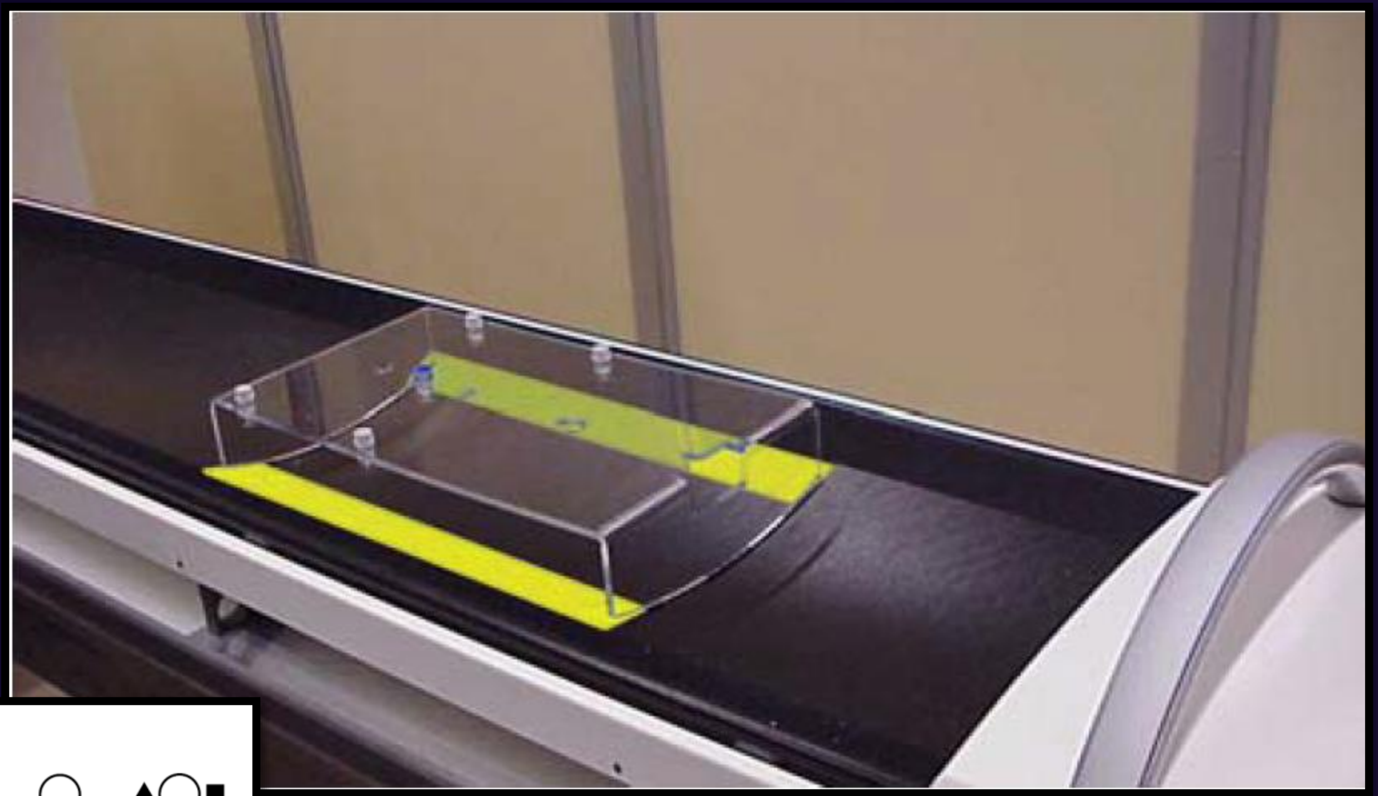
- COR is measured by performing a 360 degree acquisition around 1 mCi point source of Tc-99m placed off center of the axis of rotation (Must follow manufacturer recommendations).

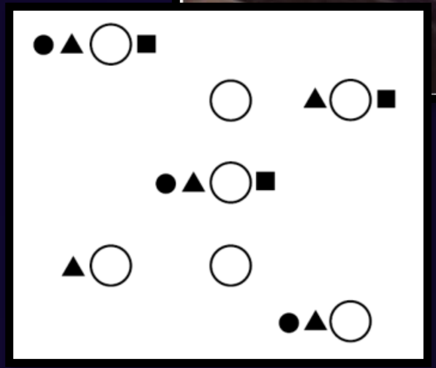
- At a radius of rotation of 20 cm, both the X and Y values for the COR should show less than a 2 mm variation over a 360 degree orbit.



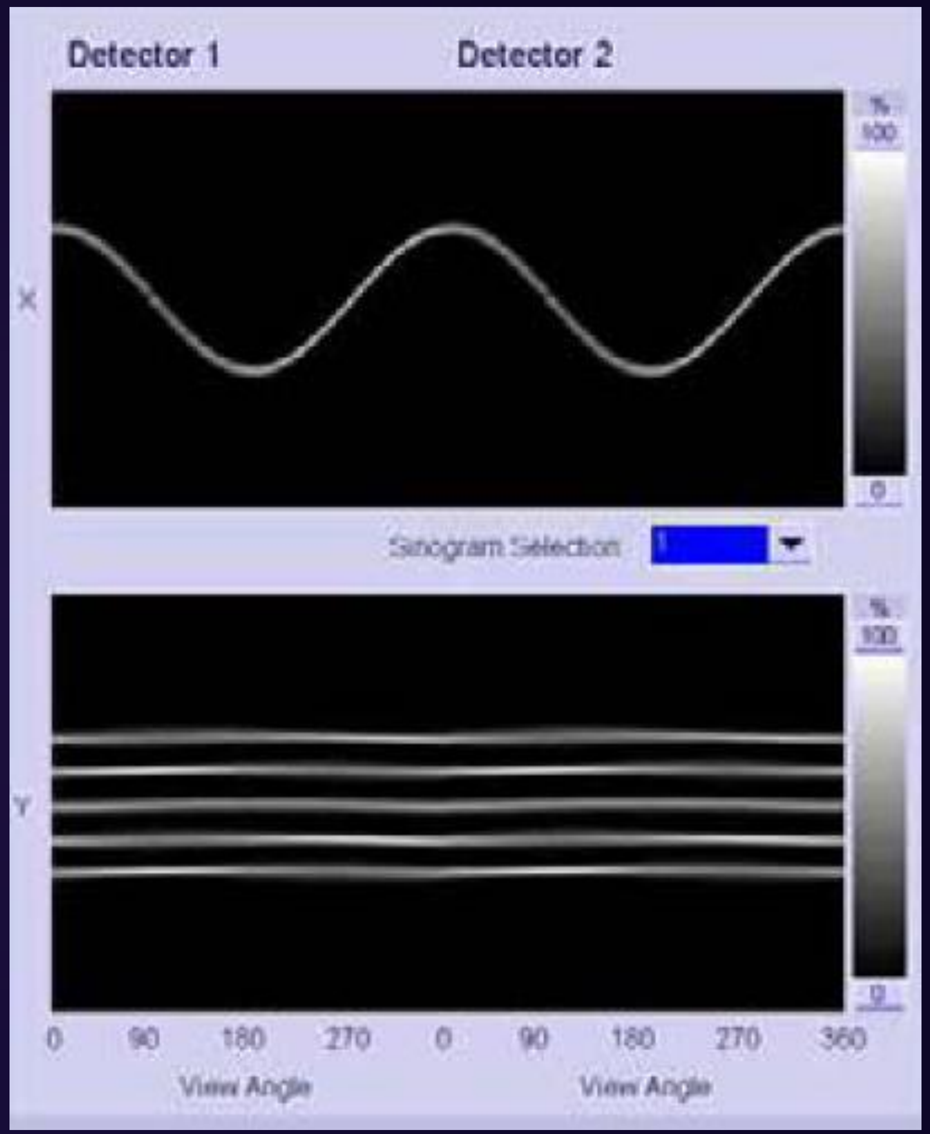


Center of Rotation





- ■ Extra High Energy Collimator
- ▲ UHR, HRES, LEAP & Fanbeam Collimator
- ● All Others



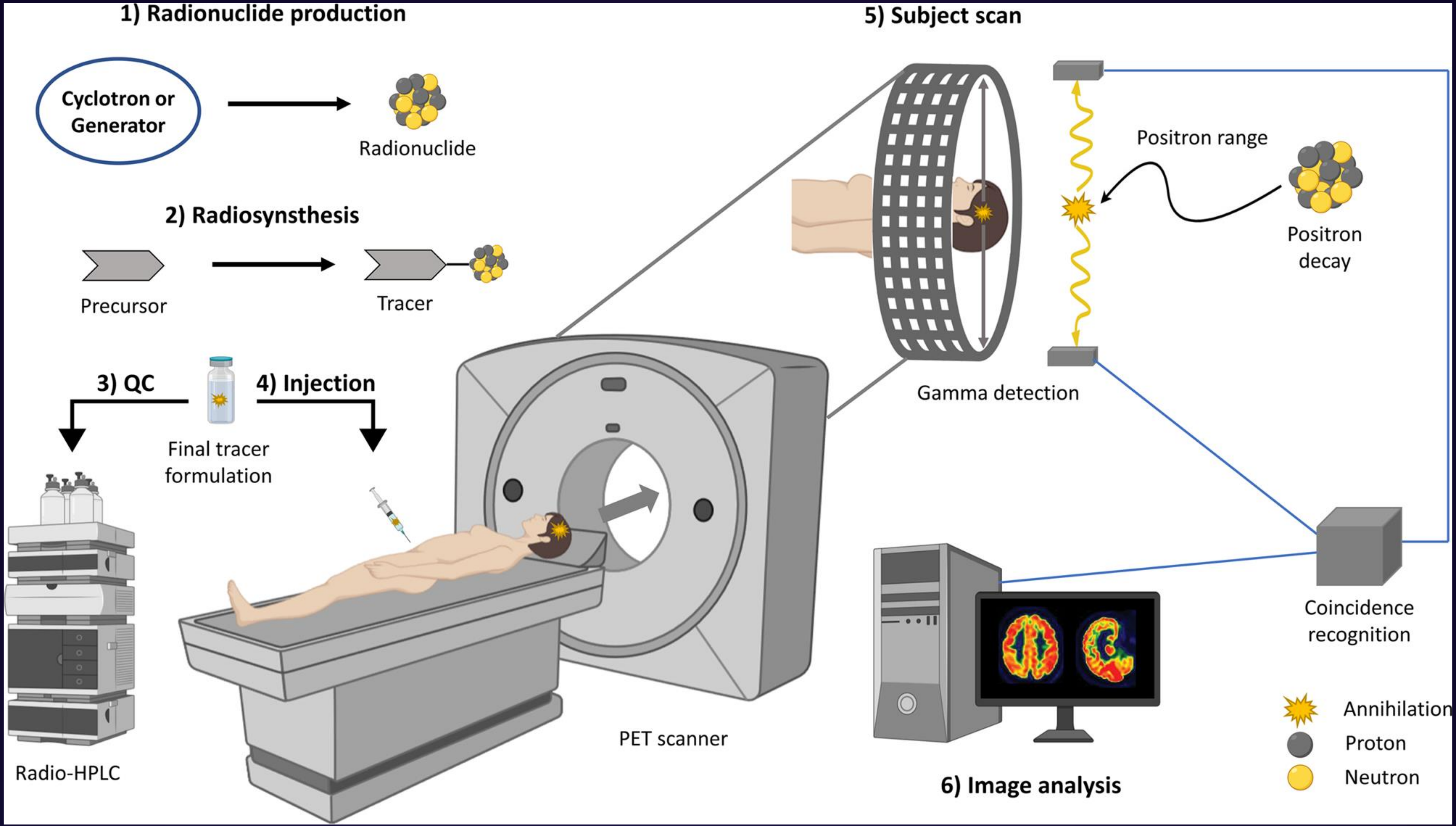
Recommended Frequency Of QC Tests

Test	Purpose	Frequency
Physical inspection	Collimator mounting and damage	Daily
Collimator touch pad and gantry emergency stops	Unexpected collision with the patient or an obstacle during motion	Daily, and after collimator change
Energy window setting	To check and center the energy window on the photopeak	Daily, for any radionuclide
Background count rate	Detect radioactive contamination	Daily
Intrinsic/extrinsic uniformity and sensitivity- visual	Test response to uniform flux of photons, record cps/MBq and monitor sensitivity	Daily (low count)
Intrinsic/extrinsic uniformity and sensitivity- quantitative	To monitor the trend in uniformity with quantitative indices, check the sensitivity	Weekly/monthly (high count)
Spatial resolution and linearity – visual	To detect distortion of spatial resolution and linearity	Six-monthly
Multiple window spatial registration (MWSR)	To test that all images superimpose in an additive or subtractive mode	Six-monthly yearly

Recommended Frequency Of QC Tests

Test	Purpose	Frequency
Rotational field uniformity and sensitivity	To assess magnetic field effects on sensitivity	
Detector head tilt	To adjust the alignment of detector head tilt in the Y-axis	Before use
COR alignment/calibration	To check that the mechanical and electronic CORs are aligned	Weekly/As required
Tomographic spatial resolution in air	To check tomographic spatial resolution of the system in air, with no scatter	Six-monthly
Overall system performance	Tomographic uniformity and contrast resolution	Six-monthly
Whole-body scan spatial resolution in air	To test spatial resolution both parallel and perpendicular to direction of motion	Yearly
Pixel size	To determine absolute pixel size for quantitation, fusion and AC	Six-monthly

QC in PET


1) Radionuclide production
Cyclotron or Generator
Radionuclide
2) Radiosynthesis
Precursor
Tracer
3) QC
4) Injection
Final tracer formulation
Radio-HPLC
5) Subject scan
Positron range
Positron decay
Gamma detection
PET scanner
Coincidence recognition
6) Image analysis
Annihilation
Proton
Neutron

Daily QC and Normalization

- Data normalization in PET is the process for compensating the nonuniformities of LOR's efficiencies by multiplying the counts in each LOR by an appropriate factor.
- Normalization values are typically derived by scanning a geometrically uniform object, such as a cylinder with a uniform activity concentration.
- Normalization of the acquired data is accomplished by exposing uniformly all detector pairs to a 511-keV photon source (e.g., Ge-68 source), without a subject in the field of view.

$$F_i = \frac{A_{\text{mean}}}{A_i},$$

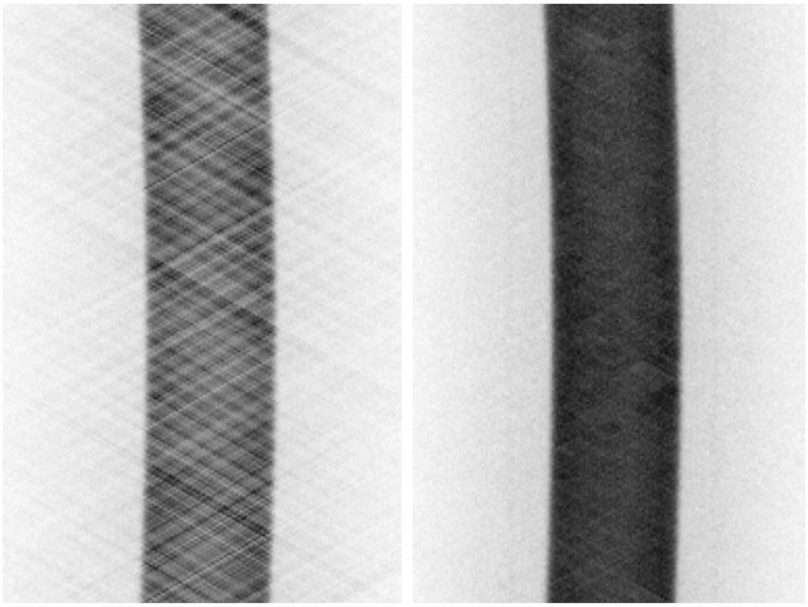
where A_{mean} is the average coincidence counts for all LORs in the plane and A_i is the counts in the ith LOR.

- The normalization factor is then applied to each detector pair data in the acquisition sinogram of the patient as follows:

$$C_{\text{norm},i} = C_i \times F_i,$$

where Ci is the measured counts and Cnorm,i is the normalized counts in the ith LOR in the patient scan.

Solid ^{68}Ge Phantom



Before Normalization After Normalization

Recommended Frequency Of QC Tests

Overview of recommended QC tests and preventive actions, together with the appropriate frequency scheme. Quarterly and yearly actions can be done on a more regular basis based on recommendations by the manufacturer and on initiative of the medical physicist, especially shortly after system installation.

Frequency	Actions	
Daily*	General	• partial or full reboot • synchronized clock settings • visual check of the system including critical system components such as gantry, patient table, and console • visual and functional check of peripheral injection, patient monitoring and triggering devices
	PET	• Qualitative, visual inspection of sinogram data • Quantitative inspection to determine whether signal gain, energy settings, coincidence timing as well as singles and coincidence rates of the individual detector elements and modules are within user-defined and acceptable limits • **uniformity and SUV of PET data acquired with a uniform cylindrical source using a long-lived PET isotope
	PET-CT	• tube warm up • air calibration • "x-ray on" entry warning lights
	PET-MR	• check of the cooling system's water temperature • check of the level of the liquid helium • visual check of coil connectors and sockets • check gantry, bed and space below removable coils for small metal parts
Quarterly	PET	• full detector setup which includes compensation for detector gain changes and changes in crystal energy profiles as well as generation of new crystal region maps and renewed time alignment of detector electronics • check of the calibration factor of the PET system including uniformity and SUV of PET data acquired with a uniform, cylindrical phantom using ^{18}F • update of the normalization correction map • **cross-calibration between PET system and radionuclide calibrators, well-counters and blood sampling systems
Yearly	General	• ***spatial alignment between the PET- and CT- or MR-component
	PET	• Uniformity and SUV of PET data for all clinically relevant PET isotopes, including PET isotopes other than ^{18}F • PET image quality using the NEMA IEC Body Phantom filled with 18F

* or day of clinical use.
** not standard practice yet but recommended.
*** or after maintenance with corrective interventions involving a recalibration of table position or table motion.


Thank you for
your attention