Quality Assurance in Gamma Camera & SPECT Systems

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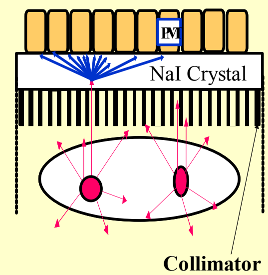
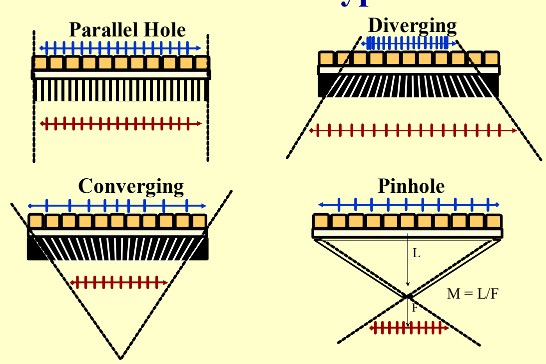
Gamma Camera Imaging of Radioactive Sources in Patients

Three major Components:

1. **Collimator** – localizes γ-ray source in patient
2. **NaI(*Tl*) Crystal** (single or multi-crystal) over width of patient stops the γ-rays.
3. **Array of PMT's** – localizes γ-ray interaction in crystal



Collimator Types



Energy Rating of Available Collimators

Collimator Type	Max. Energy Rating (keV)	Septal Thickness (mm)	Isotopes
Low Energy	140 - 200	0.2 - 0.3	^{99m}Tc, ^{201}Tl, ^{133}Xe, ^{123}I
Medium Energy	300	1.1 - 1.4	^{67}Ga, ^{111}In
High Energy	360 - 500	1.3 - 3.0	^{131}I
Ultra-High Energy	511	3.0 - 4.0	Positron Emitters

Septal Penetration Artifact

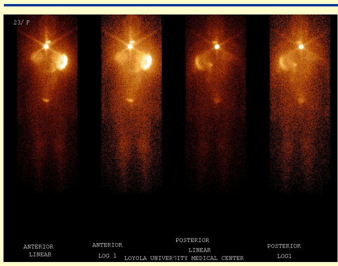
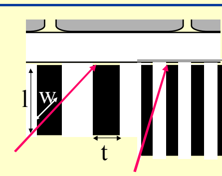


Image of I-131 in thyroid with Septal Penetration

- Streak artifacts appear along directions of septa that is thinnest. Streaks extend over distances of many cm indicating penetration of many holes.
- Image resulted from using a hig energy collimator that has hexagonal holes.

Septal Thickness Requirements



w is the minimum path length for a γ-ray to be stopped for hole length l, hole diameter d, and septal thickness t. The longer the hole length l, the thinner (t) the septum required.

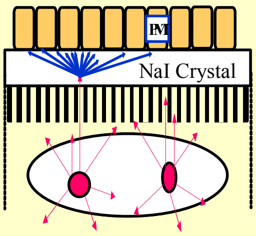
The thickness required is designed for less than 5% transmission:

$$t \geq \frac{6d/\mu}{l-(3/\mu)}$$

where μ is the linear attenuation coefficient of the absorber, usually lead.

Could use higher Z and density tungsten, tantalum, or gold that have higher μ and hence thinner septal thickness offering improved resolution and sensitivity.

Spatial Resolution



- **Collimator** – **Ability of the collimator to localize the γ-ray source in the patient (~6-12 mm)**
- **Intrinsic** – **Ability of the NaI(*Tl*) crystal and PMT to localize the γ-ray interactions in the crystal (~3-4 mm)**
- **Extrinsic** – **Overall system resolution combining collimator and intrinsic factors. Quadratic sum of FWHM of intrinsic and collimator resolution.**

Resolution vs. Crystal Thickness

- **The thinner crystal has better the intrinsic resolution** (e.g. 3/8" has 3.5 mm FWHM vs. 3.9 mm FWHM for 5/8" crystal)

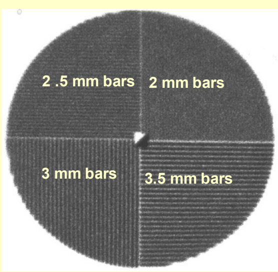
Resolution vs. Number of PMT's

- **The larger number of tubes the better the intrinsic resolution** (e.g. 3.9 mm FWHM for 37 tubes vs. 3.6 mm FWHM for 75 tubes)

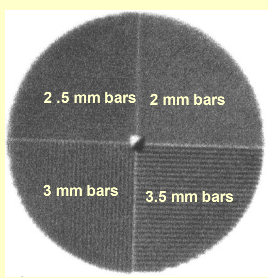
Resolution vs. Photon Energy

- **Intrinsic resolution is better for high energy photons.**

Intrinsic Resolution of ^{99m}Tc & ^{201}Tl

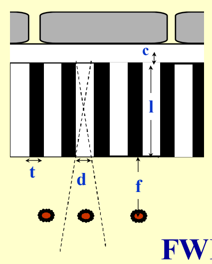


^{99m}Tc (140 keV)
3.5 mm FWHM



^{201}Tl (70 keV)
4.0 mm FWHM

Resolution of a Collimator



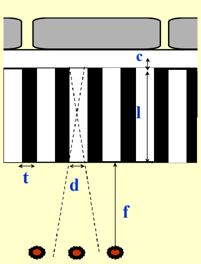
d – hole diameter
l – hole length
t – septal thickness of lead
f – collimator to source distance
c – collimator to crystal center distance

$$FWHM_C \sim \left[\frac{d}{l}\right](l+f+c)$$

Collimator Ratio – Resolving power of collimator

Source to Crystal Distance

Geometric Efficiency of a Collimator



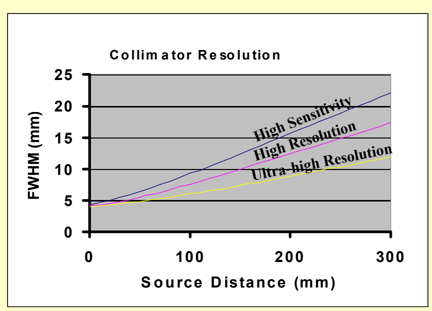
$$Efficiency_C \sim K\left[\frac{d}{l}\right]^2\left[\frac{d}{d+t}\right]^2$$

Collimator Ratio **Open Hole Fraction**

(Note: for high energy collimators, d+t is large, and hence Efficiency$_C$ becomes too low)

K = 0.24 round hole in hex array
K = 0.26 hex hole in hex array
K = 0.28 square hole in square array

System Resolution Vs. Distance



Performance of Available Collimators

Collimator Type	Hole Diameter (mm)	Hole Length (mm)	FWHM at 0 cm (mm)**	FWHM at 10 cm (mm)**	FWHM at 20 cm (mm)**	Sensitivity (CPM/μCi)
Low Energy All Purpose (LEAP or GAP)	1.43	23.6	4.4	9.1	15.3	360 (^{99m}Tc)
Low Energy High Resolution	1.11	23.6	4.2	7.5	12.3	230 (^{99m}Tc)
Low Energy Ultra-High Resolution	1.08	35.6	4.2	5.9	8.6	100 (^{99m}Tc)
Medium Energy	3.02	40.6	5.6	12.1	19.7	288 (^{67}Ga)
High Energy	4.32	62.8	6.6	13.8	22.0	176 (^{131}I)
Ultra-High Energy	3.4	75.0	6.0	10.4	~20.0	60 (^{18}F)

** Siemens Orbiter Gamma Camera System with intrinsic resolution of 3.9 mm FWHM

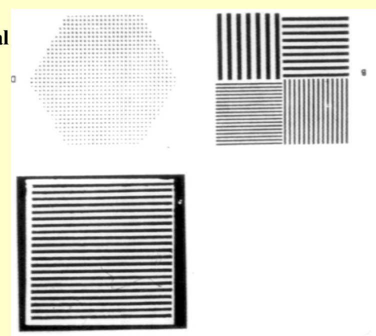
Gamma Camera Performance & Quality Control

- **Resolution**
- **Uniformity**
- **Linearity**
- **Evaluated:**
  - **Intrinsically - Specific to Crystal and PMT's**
  - **Extrinsically - Includes the Collimator**

Spatial Resolution Phantoms

Orthogonal Hole

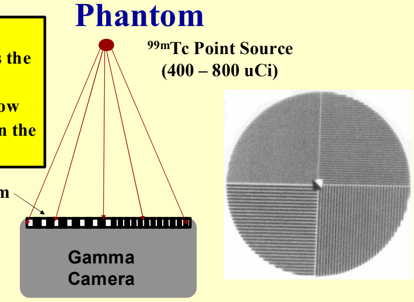
Four-Quadrant Bar Phantom



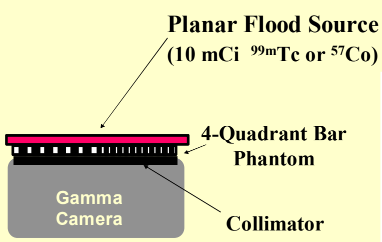
Parallel Line Equal Spacing (PLES)

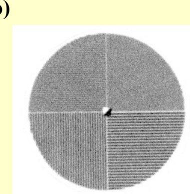
Intrinsic Spatial Resolution Measurement with 4-Quad. Bar Phantom

4-Quadrant bar phantom replaces the collimator – The image is the shadow of the lead bars on the crystal.

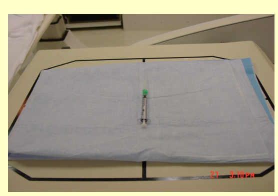


Extrinsic Spatial Resolution Measurement with 4-Quad Bar Pattern

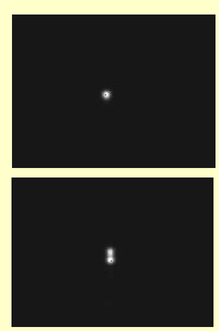




Point Sources



- **Isotope in 0.1 - 0.2 ml in hub of syringe or in end of the needle cap.**
- **Requires exchange of needle.**
- **Do not mishandle and fracture source.**

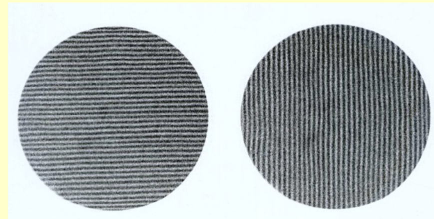


Planar Flood Sources

^{57}Co Flood Source – $T_{1/2}$ 270 days; 122 keV γ; 10-15 mCi at time of purchase.

^{99m}Tc Flood Source (water filled) – $T_{1/2}$ 6 hrs.; 140 keV γ; 10-15 mCi at time of filling.

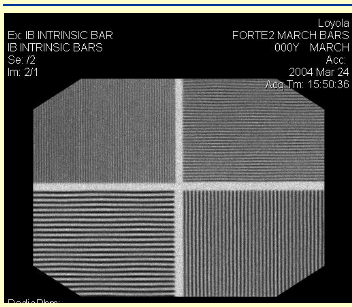
Measure Spatial Linearity with PLES Phantom



Deviation from straight line of less than 1.0 mm for UFOV.

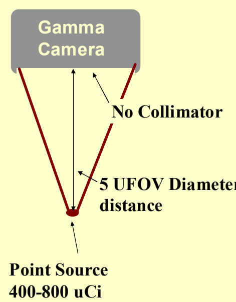
Images of PLES (parallel line equal spacing) phantom with ^{99m}Tc source

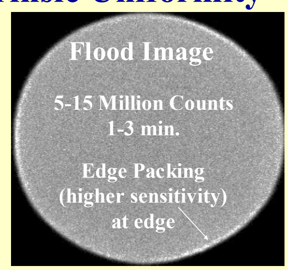
Measure Linearity with 4-Quadrant Bar Phantom



Note wavey/curve-linear appearance of lead bars throughout the image.

Measuring Intrinsic Uniformity



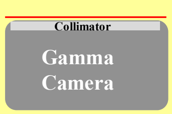


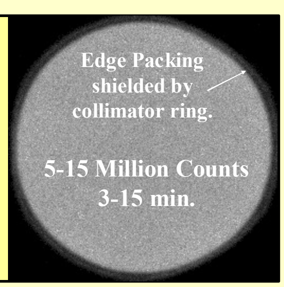
Statistical Variation:

- 3 Mcts. ~ 1600 ct/cm² ($\pm$ 2.5%)
- 15 Mcts. ~ 4800 ct/cm² ($\pm$ 1.4%)

Measuring Extrinsic Uniformity

Planar Source
10-15 mCi of
^{57}Co or ^{99m}Tc



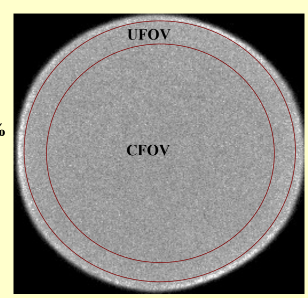


Integral Uniformity (IU) Index

Integral Uniformity (IU)
(4000 cts/cm² with 9-pt. smoothing in 6 mm pixels)

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

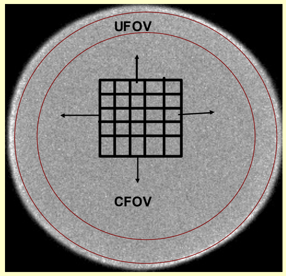
- Range of sensitivity variations over the UFOV or CFOV
- IU of 2-3 % expected



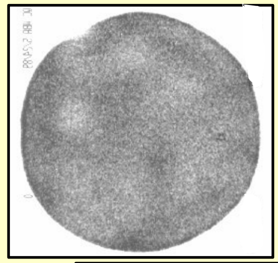
Differential Uniformity Index

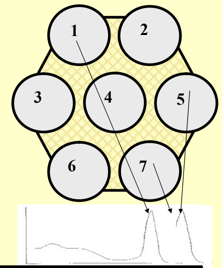
Differential Uniformity (DU)

- Maximum rate of change in sensitivity across the UFOV or CFOV
- DU of 1.5 – 2.0% expected.



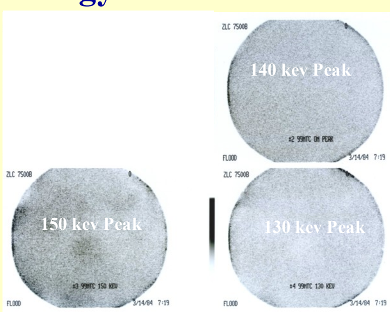
Non-Uniformity from PMT Drift





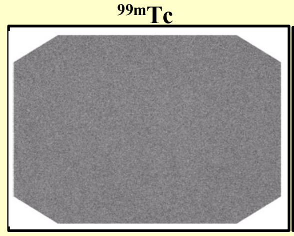
PMT voltage drift causes peak shift and difference in sensitivity.

Uniformity Dependent on Energy Window Centering

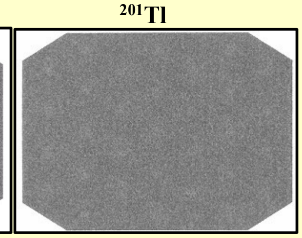


Energy Dependence of Uniformity

^{99m}Tc

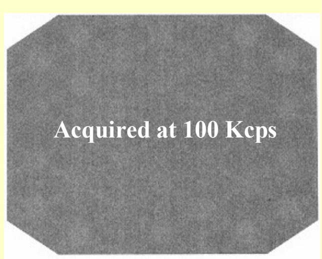


^{201}Tl



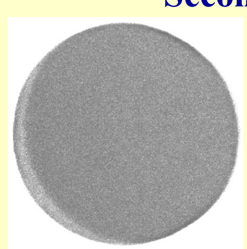
Uniformity is best for single energy isotopes, like ^{99m}Tc, ^{123}I, ^{57}Co, or ^{131}I. Varies by vendor.

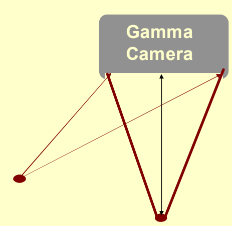
Non-Uniformity at High Count Rates



High count rates also leads to loss of resolution and linearity

Non-Uniformity From a Second Source

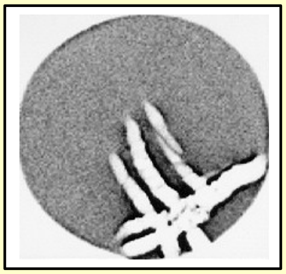




A second ^{99m}Tc source in the room or in the hot lab next door. Susceptible artifact when acquiring intrinsic floods.

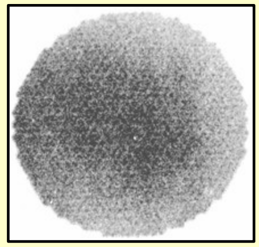
Non-Uniformity from Cracked/Broken Crystal

Crystal may cracked:
- from mechanical shock during collimator exchange.
- by thermal shock where the crystal temperature changes by more than 10 deg./hour.

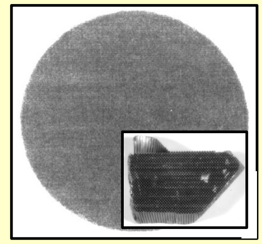


Non-Uniformity from Collimator Structure Artifacts

Large Diameter Holes

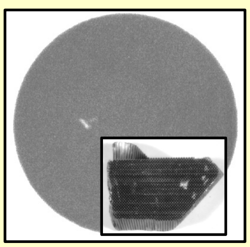


Irregular Lead Foil Construction

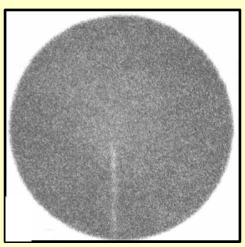


Non-Uniformity from Collimator Damage

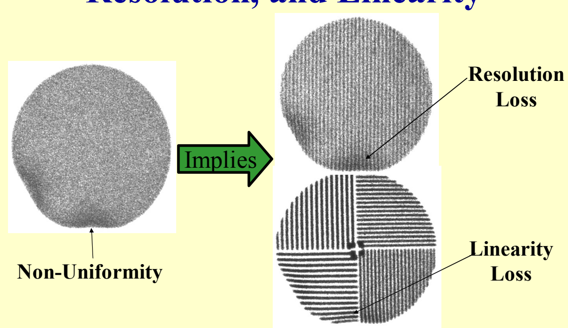
Crushed Lead Septa



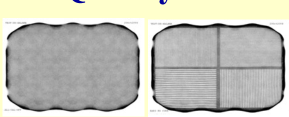
Lead Foil Separation



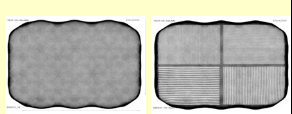
Inter-Relationship of Uniformity, Resolution, and Linearity



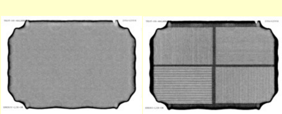
Sequential Improvement in Image Quality with added Corrections



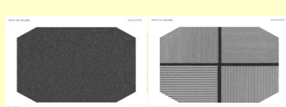
No corrections



First - Energy Correction

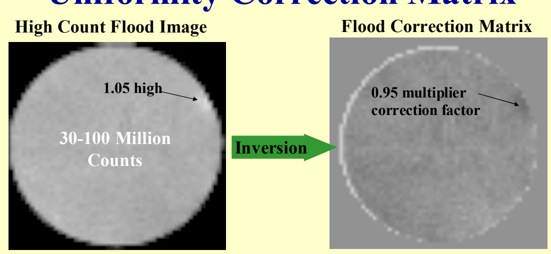


Second - Linearity Correction



Third - Uniformity Correction

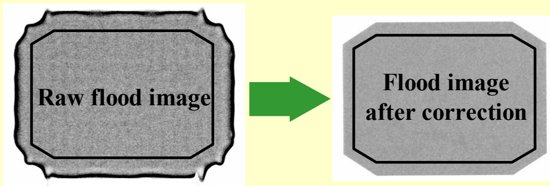
Uniformity Correction Matrix



- Applied during or following image acquisition
- Needs ten (10) times the counts of a routine flood image to reduce counting statistic variations to < $\pm$ 1%.
- May be acquired intrinsically or extrinsically.

Uniformity Correction Improvements

IU = 4.2% IU = 2.5%

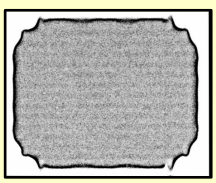


- Uniformity correction routinely applied to all gamma camera images. Correction improves IU and truncates edge packing artifact.
- Requires 10 times counts used for daily floods.

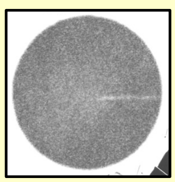
Uniformity Correction is a Calibration

- Intrinsic calibration requires
  - Precise point source background and scatter free
  - Correct count rate
- Extrinsic calibration
  - Planar flood source
  - Required for each collimator
  - Includes intrinsic calibration

Uniformity Correction – May Mask Underlying Problems!

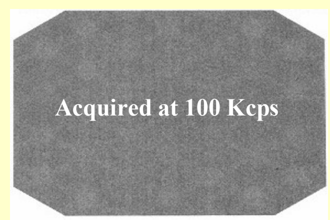


Detector with intrinsic linearity problems

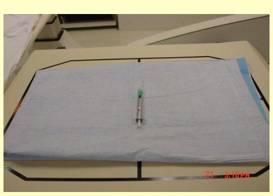


Damaged collimator with crushed lead septa

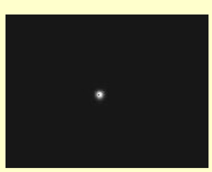
Can this be used?

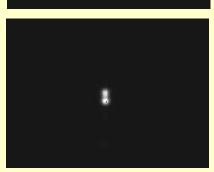


Fractured Point Source?



- Isotope in 0.1 - 0.2 ml in hub of syringe or in end of the needle cap.
- Requires exchange of needle.
- Do not mishandle and fracture source.

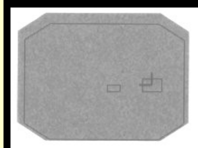




Quality Control Practices

1. Peak daily for ^{57}Co, ^{99m}Tc, & other isotopes to be used that day.
2. Uniformity - Flood images of 5-15 million counts each day of use, before imaging begins.
   a) Extrinsic flood image is preferred and tests heavily used collimators.
   b) Intrinsic flood image to test detector only, especially at the periphery of the FOV. Acquired at least one per week.
3. Resolution - Intrinsic (preferred) or extrinsic images of 5-10 million counts of four-quadrant bar phantom once per week.
4. Linearity - Intrinsic (preferred) or extrinsic images of 5-10 million counts with PLES or four-quadrant bar phantom once per week.
5. Uniformity Correction Matrix – Flood images of 100 Mcts or more once per month for each isotope used (vendor dependent).

Quantitate Daily Floods



```
Full Report of Uniformity Analysis
NAME:                    3-04-97 ID:     INTR FLD DATE:
UFOV

  Integral Uniformity =  2.87%
           Counts      Location
  Minimum  7132        ( 34, 33 )
  Maximum  7554        ( 46, 32 )

  Row Differential Uniformity =  1.69%
  Column Differential Uniformity =  1.55%

           Diff.       Location
  Max Row   251        ( 42, 32 )
  Max Col   230        ( 46, 28 )

CFOV

  Integral Uniformity =  2.87%
           Counts      Location
  Minimum  7132        ( 34, 33 )
  Maximum  7554        ( 46, 32 )

  Row Differential Uniformity =  1.69%
  Column Differential Uniformity =  1.55%

           Diff.       Location
  Max Row   251        ( 42, 32 )
  Max Col   230        ( 46, 28 )
```

- **High Counts > 10-15 million counts for large area detectors**
- **Consistent source strength with count rate < 40,000 cps.**
- **Consistent source positioning.**

Pre-Assigned Action Levels

I. **Good** – no further evaluation needed
II. **Marginal** – repeat flood once; if still marginal next day/week contact Physicist or supervisor to determine status; a re-calibration may be necessary.
III. **Unacceptable** – repeat flood once; if still unacceptable contact Physicist or supervisor to determine status; a re-calibration may be necessary

Gamma Camera	Intrinsic Uniformity – IU in UFOV	Extrinsic Uniformity – IU in UFOV
Vertex	I – below 3.5 II – 3.5 – 5.0 III – above 5.0	I – below 5.0 II – 5.0 – 6.0 III – above 6.0
Forte I	I – below 3.5 II – 3.5 – 5.0 III – above 5.0	I – below 5.0 II – 5.0 – 6.0 III – above 6.0
Forte II	I – below 3.5 II – 3.5 – 5.0 III – above 5.0	I – below 5.0 II – 5.0 – 6.0 III – above 6.0

Irregradless of IU, if a single tube is visible in the flood image, contact Physicist or supervisor to determine status.

NM Accreditation Programs

- **ICANL - The Intersocietal Commission for the Accreditation of Nuclear Medicine Laboratories**
  - Society of Nuclear Medicine
  - American Society of Nuclear Cardiology
  - American College of Nuclear Physicians
  - Academy of Molecular Imaging
  - American College of Cardiology
- **ACR – American College of Radiology**

Program Comparison

ICANL	ACR
Intersocietal sponsorship	Solely Radiology based
Accreditation by facility for up to 13 organ systems, PET, & therapy	Accreditation by unit per site for planar, SPECT, cardiac, & PET
Emphasis on case review Up to 24 cases reviewed	Emphasis on equipment Up to 6 cases per unit
Extensive protocol and QA protocol review	Planar and SPECT Phantoms and images required
Mandatory site visit	Random site visit
$200 application fee plus $3800 fee for comprehensive nuclear medicine & PET (includes site visit)	$1200 facility fee each for NM & PET plus $600/module - additional fees for repeat after deficiency

ICANL Quality Control Protocols

ESSENTIALS AND STANDARDS FOR NUCLEAR MEDICINE ACCREDITATION

SECTION 3
Equipment Quality Control Protocols

3.1 **Equipment Quality Control**
The facility must have site-specific written protocols for and maintain records of all routine quality control of imaging and non-imaging equipment. There must also be records of service and maintenance.

3.2 **Imaging Equipment Quality Control**
Imaging equipment must be in good working condition. Routine assessment of basic parameters and calibration of imaging equipment must be performed according to approved written standards, and records must be retained for comparison. The results must be reviewed by appropriate staff in a timely manner and action taken (and documented) if not within standards. These include:

Test (Scintillation cameras)	Frequency
Energy peaking	Daily (prior to use; documentation not required)
Intrinsic or extrinsic uniformity (approximately 2-5 million counts)	Daily (prior to use)
Resolution and linearity	Weekly
High count calibration floods (>30 million count)	Monthly, or per manufacturer's recommendations
Center of rotation (SPECT)	Monthly
Collimator integrity	Annually
Uniformity calibration	Per manufacturer's recommendations
Preventive maintenance	Every 6 months, or per manufacturer's recommendations

ACR Routine Quality Control Tests

Nuclear Medicine Technologist's Quality Control Tests

1. **Intrinsic or System Uniformity** (each day of use) - Performed to verify that components are properly functioning and provide a uniform image in response to a uniform flux of radiation.
2. **Intrinsic or System Spatial Resolution** (weekly) - Performed to quantitatively verify that detector spatial resolution is satisfactory for clinical imaging.
3. **Center-of-Rotation or Multiple Detector Registration Calibration/Test for SPECT Systems** (monthly) - Performed to maintain ability to resolve details in clinical SPECT studies.
4. **High-Count Floods For Uniformity Correction for SPECT Systems** (frequency as recommended by a qualified medical physicist) - Performed to correct for residual detector and collimator non-uniformity and to minimize the production of artifacts in clinical studies.
5. **Overall System Performance for SPECT Systems** (quarterly) - Performed to qualitatively verify that the system has maintained its capabilities with respect to tomographic uniformity, contrast, and spatial resolution that maximize the benefit in clinical studies. Technetium must be done at least semiannually; other radionuclides may be tested on alternate quarters.

ACR – Acceptance Tests and Annual Survey

Acceptance tests must be performed on systems when they are installed. At least annually thereafter, the performance tests listed below must be performed on all units. These tests do not need to be as rigorous as acceptance tests but must be a comprehensive suite of individual measurements that ensure adequate sensitivity for detecting detrimental changes in performance.

ACR – Physics Survey

Nuclear Medicine Performance Tests – At Least Annually

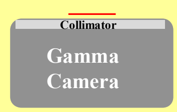
1. **Intrinsic Uniformity** - Performed to ensure that the intrinsic detector integral and differential uniformity are sufficient to minimize the production of artifacts and ensure that patient abnormalities can be visualized without interference from the imaging system. These tests also monitor a scintillation unit for electronic problems and crystal deterioration (hydration).
2. **System Uniformity** - Performed to check all commonly used collimators for defects that might produce artifacts in planar and tomographic studies.
3. **Intrinsic or System Spatial Resolution** - Performed to ensure that the detector resolution is sufficient to provide satisfactory detection of lesions and delineate detail in clinical images.
4. **Sensitivity** - Performed to verify that count rate per unit activity is satisfactory to maintain image quality and preserve the integrity of quantitative studies.
5. **Energy Resolution** - Performed to verify that scatter rejection is sufficient to provide optimal contrast in clinical studies. *Note: On some systems, energy resolution is very difficult to measure precisely.*
6. **Count Rate Parameters** - Performed to ensure that the time to process an event is sufficient to maintain spatial resolution and uniformity in clinical images acquired at high count rates.
7. **Multiple Window Spatial Registration** - Performed to verify that contrast is satisfactory for imaging radionuclides, which emit photons of more than one energy (e.g., Tl-201, Ga-67, In-111). Multiple window spatial registration is also important for dual radionuclide studies (e.g., Tc-99m/Tl-201).
8. **Formatter/Video Display** - Performed to ensure that systems used to produce hard copy and monitors that are used for interpretation of clinical studies provide satisfactory image quality in terms of uniformity and spatial resolution.
9. **Overall System Performance for SPECT Systems** - Performed to quantitatively verify that SPECT systems provide satisfactory tomographic uniformity, contrast, and spatial resolution.
10. **System Interlocks** - Performed to verify that all system interlocks are operating as designed and that the system is safe and reliable for the nuclear medicine technologist to operate and for imaging patients.

NEMA and Gamma Camera Acceptance Test Guides

- **NEMA: NEMA Standards Publication NU 1-2001 Performance Measurements of Scintillation Cameras**
- **AAPM Report No. 9: Computer Aided Scintillation Camera Acceptance Testing**
- **AAPM Report No. 22: Rotating Scintillation Camera SPECT Acceptance Testing and Quality Control**

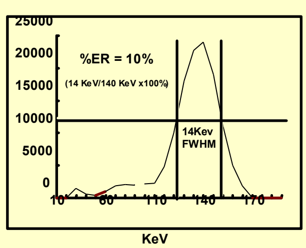
Sensitivity Measurement

~1000 µCi ^{99m}Tc source in dish to measure and compare sensitivity (cpm/µCi) of each detector and collimator combination



- **Expect range of sensitivity of each head and collimator combination < 5%**
- **For LEHR sensitivity ~ 200 cpm/µCi**

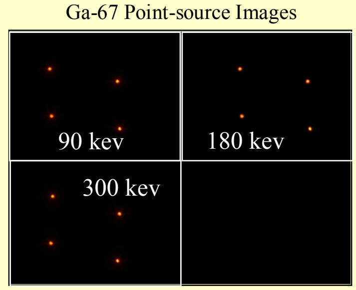
Energy Resolution Measurement



- **Energy resolution for ^{99m}Tc is 10% of the 140 keV photopeak. Acquisition window 20%.**

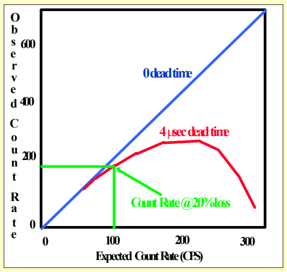
Multiple Window Spatial Registration Measurement

Ga-67 Point-source Images



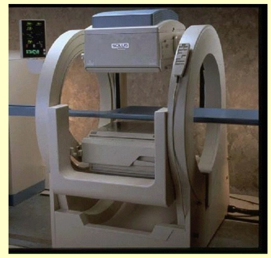
- **Image point sources of Ga-67 or Tl-201 with a single energy window at energy peak.**
- **Measure the position of each image.**
- **Registration of the point sources vs. energy should be less than ~1 mm over the UFOV**

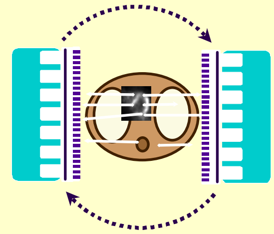
High Count Rate Measurement



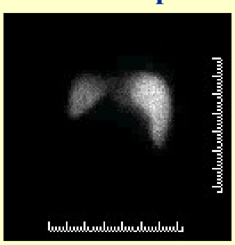
- Dead time of ~4 μsec - measurement no longer specified.
- Maximum achievable count rate in air of ~ 250 kcps.
- Use decay method to generate count rate response curve.
- Observed count rate in air at 20% loss is ~ 100 kcps.
- Note - patient count rates from 1-15 Kcps.

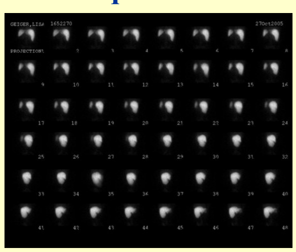
Rotating Gamma Camera SPECT





Liver/Spleen SPECT Acquisition

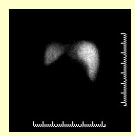




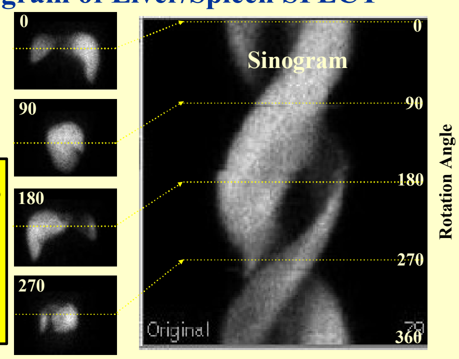
- 120 128x128 images
- 3° step & shoot rotation over 360°

- 15 sec/image/head
- 16 min. total acq.
- 85,000 cts/image
- 10.88 million cts

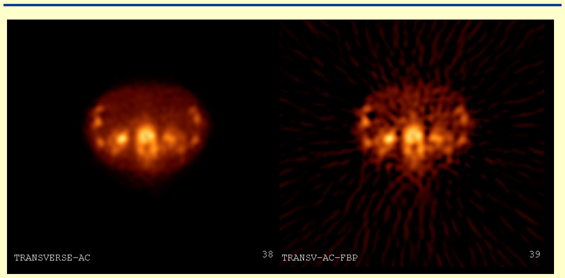
Sinogram of Liver/Spleen SPECT



- Sinogram has all count data to reconstruct a single slice
- One sinogram per slice
- Can be used for motion correction

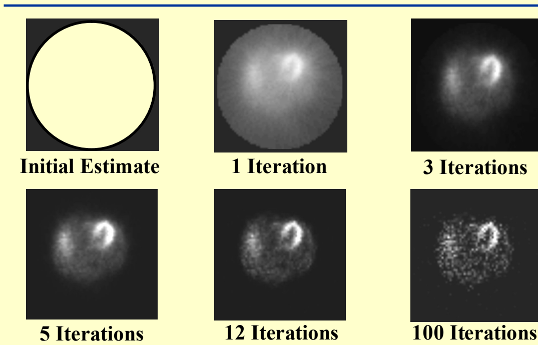


FPB vs. Iterative Reconstructions

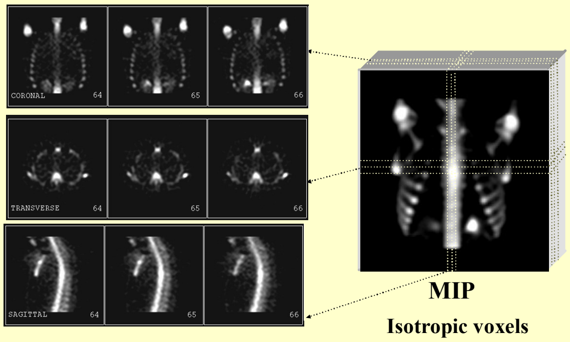


Iterative - OSEM FBP

Iterative Reconstruction



3-D Reconstruction



MIP

Isotropic voxels

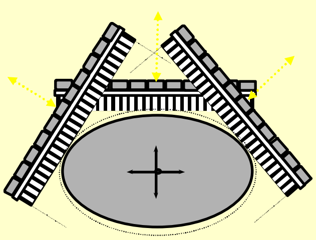
SPECT Resolution Based on Collimator (at 20 cm radius of rotation)

Collimator Type	Hole Diameter (mm)	Hole Length (mm)	FWHM at 0 cm (mm)**	FWHM at 10 cm (mm)**	FWHM at 20 cm (mm)**	Sensitivity (CPM/μCi)
Low Energy All Purpose	1.43	23.6	4.4	9.1	15.3	360 (^{99m}Tc)
Low Energy High Resolution	1.11	23.6	4.2	7.5	12.3	230 (^{99m}Tc)
Low Energy Ultra-High Resolution	1.08	35.6	4.2	5.9	8.6	100 (^{99m}Tc)
Medium Energy	3.02	40.6	5.6	12.1	19.7	288 (^{67}Ga)
High Energy	4.32	62.8	6.6	13.8	22.0	176 (^{131}I)
Ultra-High Energy	3.4	75.0	6.0	10.4	~20.0	60 (^{18}F)

** Siemens Orbiter Gamma Camera System with intrinsic resolution of 3.9 mm FWHM

Non-Circular Motion SPECT

- Circular Camera Rotation with translation of the camera and/or patient.
- Improves spatial resolution by moving collimator/patient closer.

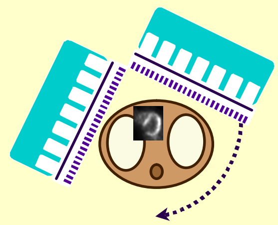


180 Degree Acquisition Arc for Heart

Heart sits anterior in the chest.

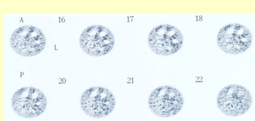
Heart not visible in posterior projections.

Dual detectors set at 90 degree angle most efficient.

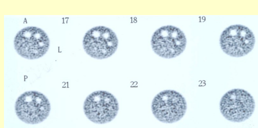


180 or 360 Degree Acquisition Arc?

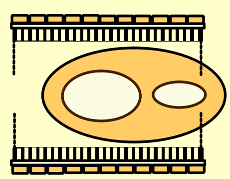
180 Degree Acquisition Arc

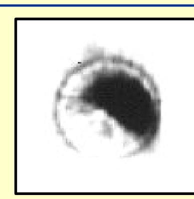


360 Degree Acquisition Arc



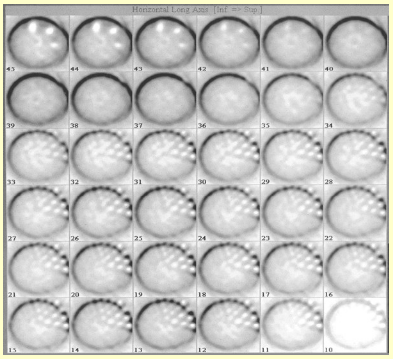
Truncation





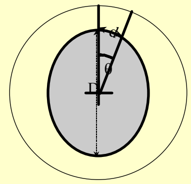
Portion of the imaging volume falls outside the gamma camera field-of-view during a portion of the acquisition arc.

High density ring at the edge of the reconstruction of arc length proportional to the number of views with truncation.



Small FOV Camera & 180^o Acq.

How Many Images to Acquire?

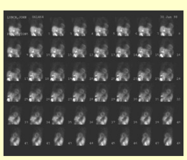


- Typically camera detectors rotate through 360 degrees.
- Stepping angle (θ) = 360 deg. / # stops
- Sampling distance (d) at the organ edge = θD/2
- For good resolution d must be small which implies small q and a large number of stops.

Low Resolution SPECT - 60 images at 6 degree steps

High Resolution SPECT - 120 images at 3 degree steps

How Many Counts in a SPECT Study?

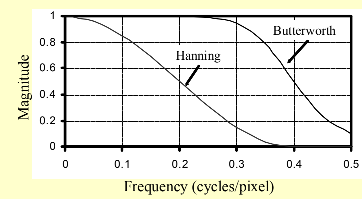


Total Counts/Study = [Counts/Image] * [Number of Images]

Total Counts/Slice = [Counts/Slice] * [Number of Images]

The total counts in a SPECT study range from 2-8 million counts.

SPECT Low Pass Frequency Filters



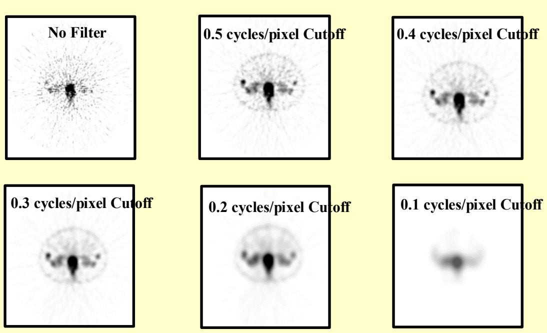
Butterworth Filter

$$B(f) = \frac{1}{1 + (f/f_{cutoff})^{order}}$$

Hanning Filter

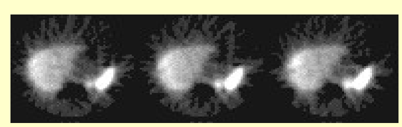
$$H(f) = \tfrac{1}{2}[1 + \cos(\pi f/f_{cutoff})]$$

Low Pass Filters -Butterworth Filter

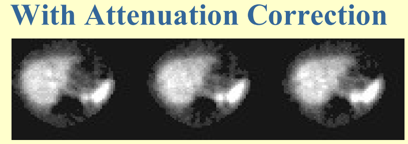


Attenuation in the abdomen

No Attenuation Correction



With Attenuation Correction



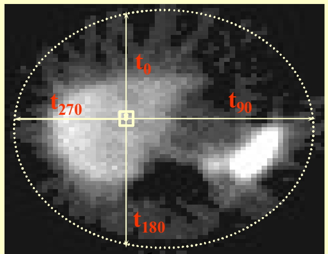
Chang Attenuation Correction Method

$C = C_0 e^{-\mu t}$

μ - linear attenuation coefficient in tissue. Assume uniform tissue density *(for 140 keV, μ=0.15/cm)*

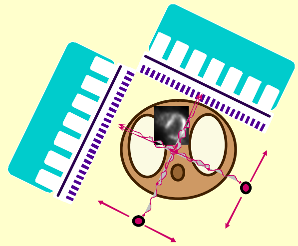
t - depth in mm

Body Contour change must be consistent from slice-to-slice.



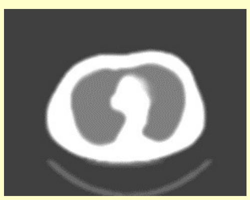
Body Contour

Measured Attenuation in Chest



- Perform transmission imaging just like X-ray CT
- Line source of ^{153}Gd *($T_{1/2}$ 242 days, photon energies of 97 & 104 keV)* scans across the camera FOV at every camera stop, or multiple parallel line sources across field-of-view.
- Dual Isotope windows allows for simultaneous emission and transmission data.

CT μ-Map

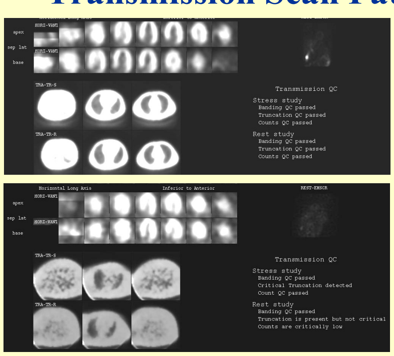


- Measured linear attenuation coefficients used instead of uniform coefficients in Chang attenuation correction method.
- Attenuation map is segmented to fixed attenuation coefficients for soft tissue to reduce noise.

Blank Scan - Transmission Scanning QC

- Blank scan acquired daily.
- Compared to "mother" original blank scan and analyzed for changes by calculating IU.
- Source strength is evaluated by total counts in the blank scan acquisition.

Transmission Scan Patient QC

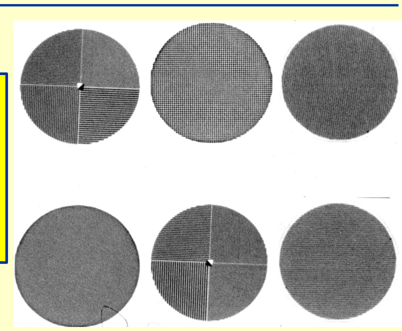


Look for:

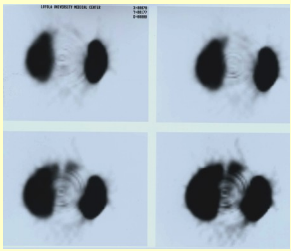
- Insufficient number of counts
- Banding at edge from truncation
- Banding from line source translation problems

SPECT Quality Control

- Gamma camera must operate at optimum performance.
- Uniformity is critical

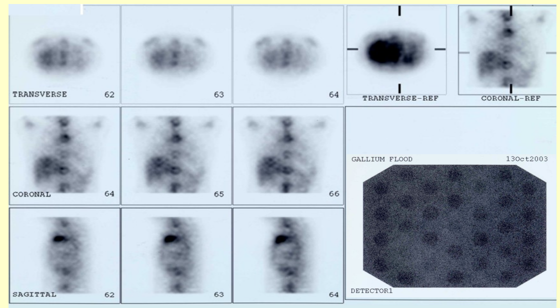


Bullseye Ring Artifact



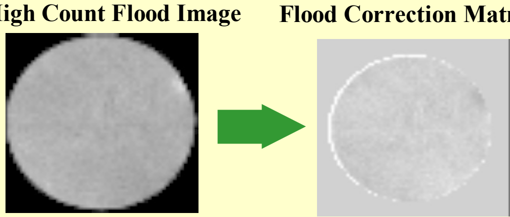
Concentric rings of alternating high and low count densities appear in the transaxial images due to insufficient gamma camera uniformity.

Serial Ring Artifacts



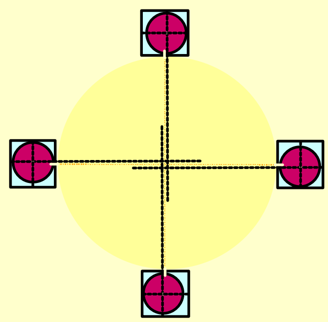
Uniformity Correction By Computer

High Count Flood Image — Flood Correction Matrix



- 30-100 million count flood images, 10 times daily flood requirements
- Must follow manufacturer recommendations

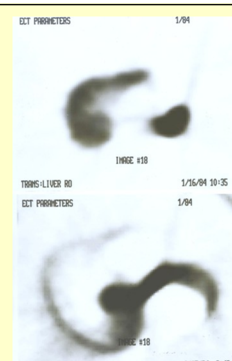
Center-of-Rotation Error



- COR error is propagated as offset during backprojection
- COR study acquired monthly

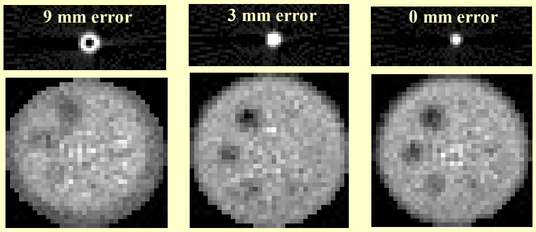
COR Acquisition is a Calibration

- Used to correct patient images
- Extrinsic calibration for both 180 and 90 degree detector separations
- Must follow manufacturer recommendations regarding number and placement of sources
- Sources must have sufficient activity
- Completed monthly



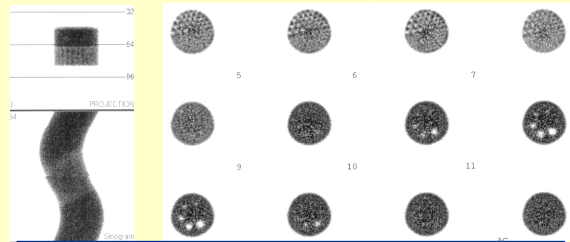
Center-of-Rotation Artifact

Center-of-Rotation Offset Error



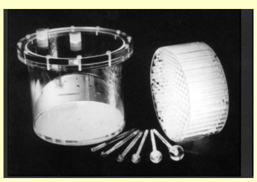
Center-of-rotation errors cause loss in transaxial image resolution.

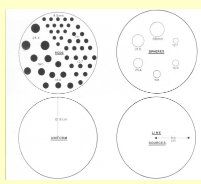
Mis-alignment in Dual Detector SPECT



Top detector mis-aligned with bottom detector, leading to distortion in reconstructed images. Misa-alignment due to either error in COR or detector configuration.

Jaszczak SPECT Phantom





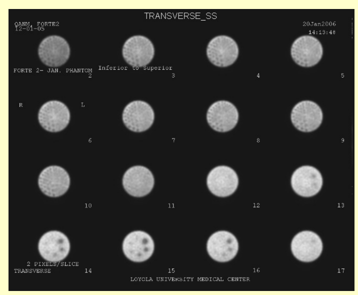
Standard:

- Cold Rods – 16.0, 12.7, 11.1, 9.5, 7.9, 6.4 mm
- Cold Spheres – 38.0, 31.8, 25.4, 19.1, 15.9, 12.7 mm

Deluxe:

- Cold Rods – 12.7, 11.1, 9.5, 7.9, 6.4, 4.8 mm
- Cold Spheres – 31.8, 25.4, 19.1, 15.9, 12.7, 9.5 mm

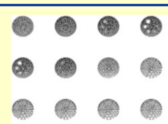
SPECT Phantom Study



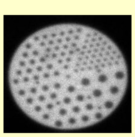
- Quarterly acquire SPECT phantom studies with 2-3 time counts obtained clinically.
- Reconstruct at highest resolution filter.
- Look for bullseye artifacts. If present, new intrinsic correction flood needed.
- Look for consist transaxial resolution. If resolution loss, acquire new COR.

ACR SPECT Phantom Submission

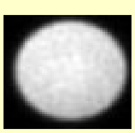
- Phantom images scored by Nuclear Medicine physicists for planar & SPECT uniformity, resolution, and contrast.



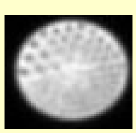
Transaxial SPECT Images



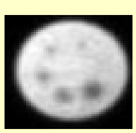
Planar Image



Uniformity (3 slices)



Resolution (12 slices)



Contrast (2 slices)

Conclusions

- Standard QC procedures for gamma cameras required in accreditation programs.
- SPECT uniformity corrections and COR are camera calibrations
- SPECT demands strict QC program