NHS
Hull University Teaching Hospitals
NHS Trust

FRCR Nuclear Medicine

Lecture 3: Patient Pathway, QC and Artefacts

Today

- Bone Scan Pathway – a closer look
- QC testing in NM
- Artefacts
- Future parts in NM
  - MIRC
  - StarGuide
  - Omni
- Quiz

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Nuclear Medicine Bone Scan – A closer look

- Possibly most common scan

- Administration
  - How?
  - What radiopharmaceutical?
  - How much?

- Patient
  - Preparation before scan
  - Uptake time following administration

- Imaging
  - Collimators, pixel size
  - Types of imaging performed
  - Example images

- After Imaging
  - Patient restrictions
  - Waste management?

Bone Scan - Administration

- Indication:
  - Trauma, bone pain, bone mets, possible loose/infected prostheses
- Patient Questionnaire
- Tc99m HDP or MDP (diphosphonates)
- Intravenous injection

Sites of pain?
Recent injuries/surgery?

Uptake dependant on blood flow and new bone formation (osteoblastic activity)
Functional display of skeletal metabolic activity – any area of fracture, infection, tumour or healing bone will show as an area of increased radiopharmaceutical accumulation.

Bone Scan - Administration

- Contraindications:
  - Pregnancy

- Local DRL = 600MBq (800MBq for SPECT)

- Why not x-ray?
  - Functional change in bone occurs before structural change, image blood flow for infection query

Why SPECT and why more activity for SPECT?
Better contrast with SPECT – less overlying structures Less counts per projection in SPECT so require more activity. Balance between activity and scan time.

Bone Scan - Administration



Before patient arrives

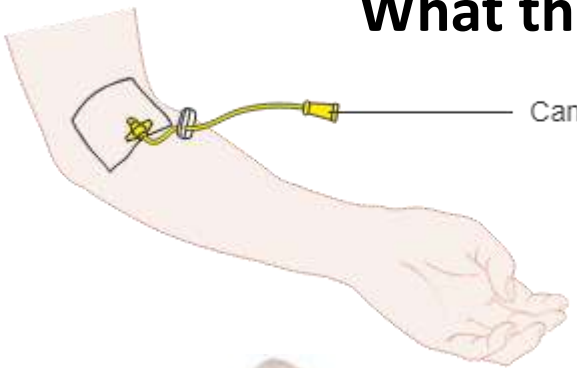


Measure activity in radionuclide calibrator



L-Shield

What the patient sees





Syringe Shield

PPE



Bone Scan – Patient Preparation before scan

- Stay hydrated between injection and imaging
- Empty bladder

Why?
Some will be filtered out into urine and so the bladder will appear ‘hot’ in the images. We want to try minimise this.

- Remove metal items

Why?
Can lead to artefacts in the NM images – block counts. If having SPECT-CT then will lead to metal artefacts

Bone Scan – Image Acquisitions

- Imaging dependent on indication. Options include:

- Dynamic
- Static
- SPECT-CT
- Whole Body



Administration of Radioactive Substances Advisory Committee

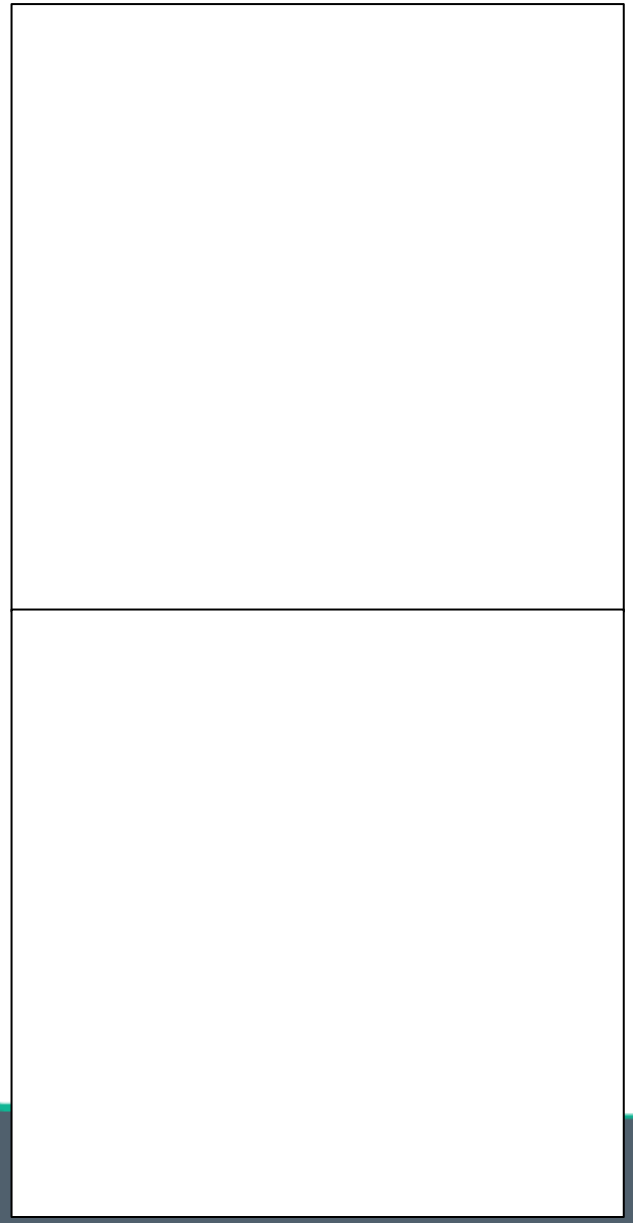
- Decision of IRMER Practitioner (ARSAC license holder) what imaging is required

Bone Scan - Dynamic

- Characterise blood flow – infection query

- Imaging started with injection
- Ant/post of area of interest
- 140.5keV ± 10%
- LEGP (or LEHRS) collimators
- 128x128 matrix size
- 60x2s frames (2 minutes total)

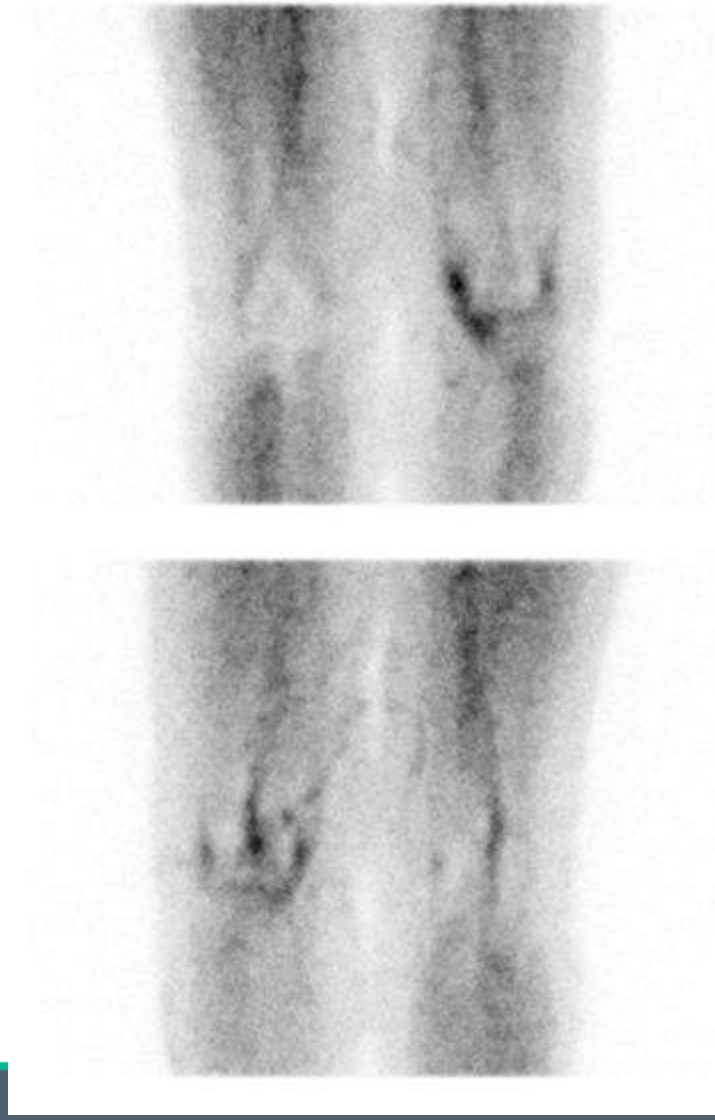
Quick process, we want resolution but we won't have many counts so need bigger pixel size, short frames as otherwise would lose temporal resolution



Bone Scan – Static (Blood Pool)

- See areas of inflammation where blood is pooling – infection query

- Immediately after dynamic
- Ant/post of area of interest
- 140.5keV ± 10%
- LEHRS
- 256x256
- 180s



Ant

Post

Bone Scan – SPECT-CT

- 2-5 hours post injection



- Area dependant on area of clinical interest
- 140.5keV ± 10% (and scatter window 120keV ± 5%)
- LEHRS
- 128x128
- 120 x 12s projections over 360 degrees (24 minute scan)
- CT protocol used dependent on area imaged
  - Skull



Intense tracer activity along the medial tibial cut surface of the left knee prosthesis with activity in this region on early phase imaging. Appearances are in keeping with loosening, given the early phase findings, this is likely to be secondary to infection.

Bone Scan – SPECT-CT

- 2-5 hours post injection



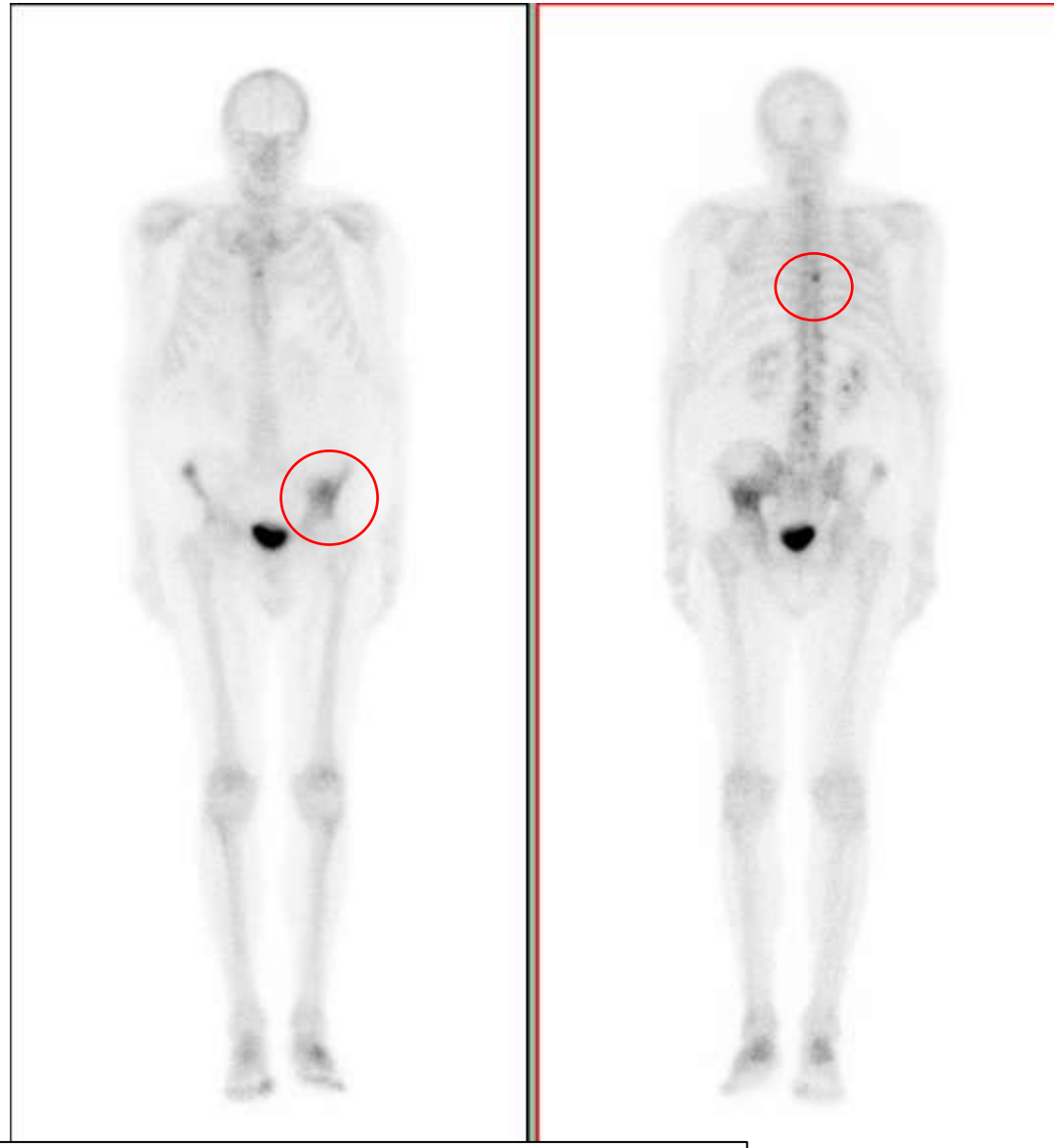
- Area dependant on area of clinical interest
- 140.5keV ± 10% (and scatter window 120keV ± 5%)
- LEHRS
- 128x128

But I thought we needed resolution and smaller pixel size?
Yes, but with SPECT we get less counts in each projection so if we use a pixel size that is too small we will have noisey projections and therefore noisey reconstructed images.

Bone Scan – Whole Body

- 3-5 hours after administration when radiotracer cleared from soft tissue

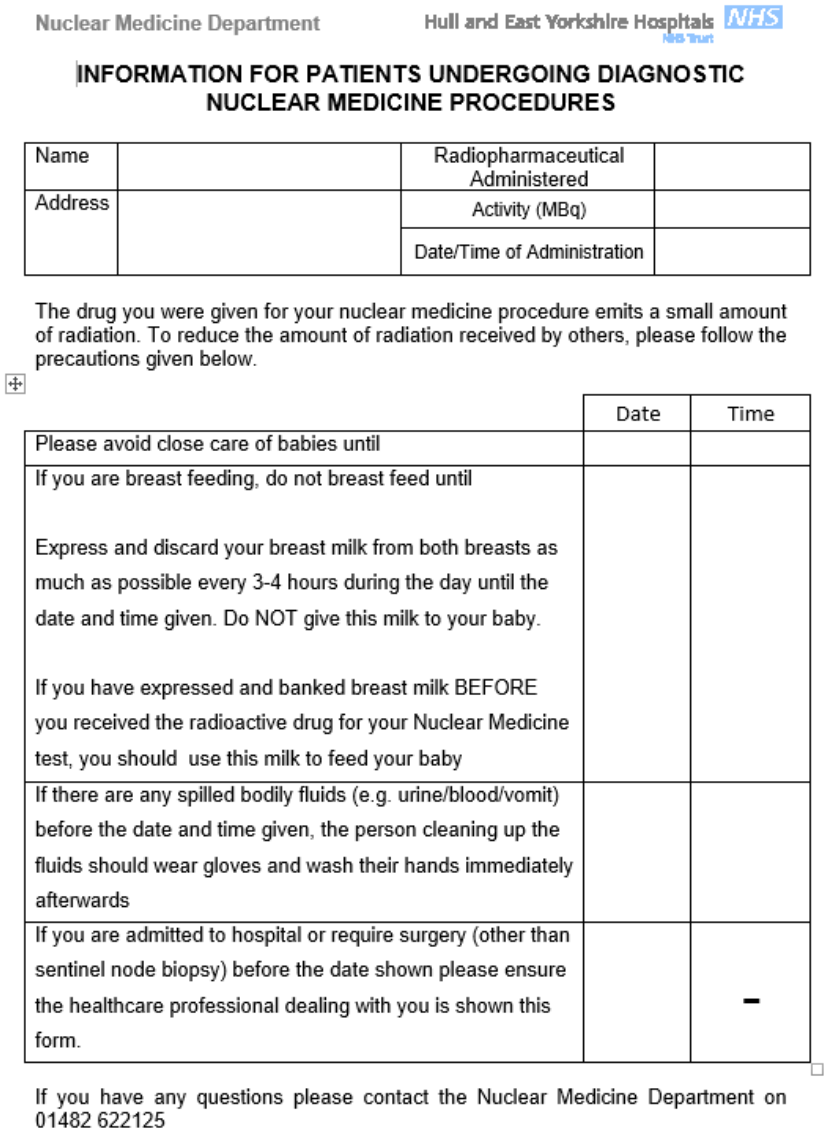
- Straps, feet tied, body contouring on
- Ant/post of area of interest
- 140.5keV ± 10%
- LEHRS
- 1024x256
- 16.6cm/min (approx. 14 mins total)



Persistent metastatic disease within the body of T7 and the pelvis, unchanged from the last study. No appreciable new disease.

Bone Scan – After Imaging

- Restrictions (radiation protection):
  - Close care of babies – not applicable for bone scan – other radionuclides and cardiacs
  - Breastfeeding – not applicable, again other radionuclides that stay present for longer
  - Spilled bodily fluids – wear gloves and wash hands when dealing with this
  - Hospital admission/surgery – delay surgery if possible, waste management, contact department



Nuclear Medicine Department — Hull and East Yorkshire Hospitals NHS Trust

INFORMATION FOR PATIENTS UNDERGOING DIAGNOSTIC NUCLEAR MEDICINE PROCEDURES

Name		Radiopharmaceutical Administered	
Address		Activity (MBq)	
		Date/Time of Administration	

The drug you were given for your nuclear medicine procedure emits a small amount of radiation. To reduce the amount of radiation received by others, please follow the precautions given below.

	Date	Time
Please avoid close care of babies until		
If you are breast feeding, do not breast feed until Express and discard your breast milk from both breasts as much as possible every 3-4 hours during the day until the date and time given. Do NOT give this milk to your baby. If you have expressed and banked breast milk BEFORE you received the radioactive drug for your Nuclear Medicine test, you should use this milk to feed your baby		
If there are any spilled bodily fluids (e.g. urine/blood/vomit) before the date and time given, the person cleaning up the fluids should wear gloves and wash their hands immediately afterwards		
If you are admitted to hospital or require surgery (other than sentinel node biopsy) before the date shown please ensure the healthcare professional dealing with you is shown this form.		-

If you have any questions please contact the Nuclear Medicine Department on 01482 622125

Author: Graham Wright | Signature: | Review Date: 23/06/2020 | Version: 2
Authorised By: Graham Wright | Signature: | Approved Date: 23/06/2017 | SOP code:AF072
Y:\NM Documentation\AF - Admin and Forms\AF072 - Written instructions to diagnostic patients.doc

Great Staff – Great Care – Great Future

Remarkable people.
Extraordinary place.

Bone Scan – Extra: Contamination Monitoring



- Of staff members who have drawn up and performed the injection
- Of the chair/area of injection
- Of the whole department at the end of the day

- How?
  - Contamination monitors
  - Scintillation process
  - Gas filled
    - Ionisation chamber





Bone Scan - Extra

- Radioactive waste?
  - Environmental Permitting Regulations (EPR)
  - Specific requirements for storage, security, amount held, time held for
- Risk assessments
  - Before starting any work with ionising radiation
- Staff dosimetry
  - Are staff safe?
  - Legal dose limits (IRR), badges and finger stalls
- Local rules
  - For radiation controlled areas – likely contamination or high dose rate
- Protocol writing
  - National guidance, local preference, optimisation







Many Other Scans

- Bone scan
- RNVG
- Cardiac MPS stress/rest
- Cardiac Amyloidosis
- Lung VQ
- MAG3 Diuretic Renogram
- MAG3 Micturition Renogram
- DMSA Kidney Imaging
- Gastric Emptying
- Gastro-Intestinal Bleeding
- Small Bowel Transit
- Protein Loss Estimation
- Pulmonary Aspiration Scan
- Hepatobiliary (HIDA) scan
- Liver/Spleen Imaging
- Gallium Imaging
- Leucocyte Imaging
- Parathyroid Imaging (subtraction and washout)
- Thyroid imaging (Tc99m and I-123)
- MIBI Thyroid imaging
- In111 Octreotide
- Thyroid Metastases Imaging
- Post I131 ablation imaging
- Tektrotyd Somatostatin receptor imaging
- Sentinel Node (breast and melanoma)
- Lymphoscintigraphy
- DatScan
- SeHCAT
- GFR

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- **GFR**

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Quality Control testing in Nuclear Medicine

- Gamma Camera:
  - Daily QC – extrinsic uniformity
  - Weekly QC – intrinsic uniformity
  - Centre of Rotation (COR)
  - CT QC

- PET:
  - Daily test
  - Monthly SUV QC
  - Cross calibration

- Other:
  - Radiation Monitors:
  - Calibrators etc

Daily Extrinsic Uniformity QC

- If we expose the detectors to a uniform source of radiation we expect a uniform response
  - Non-uniform area indicates a problem with detection or corrections applied to image

- Uniform source = Co57 flood source (sheet with encased Co-57 resin)
  - half life = 270 days

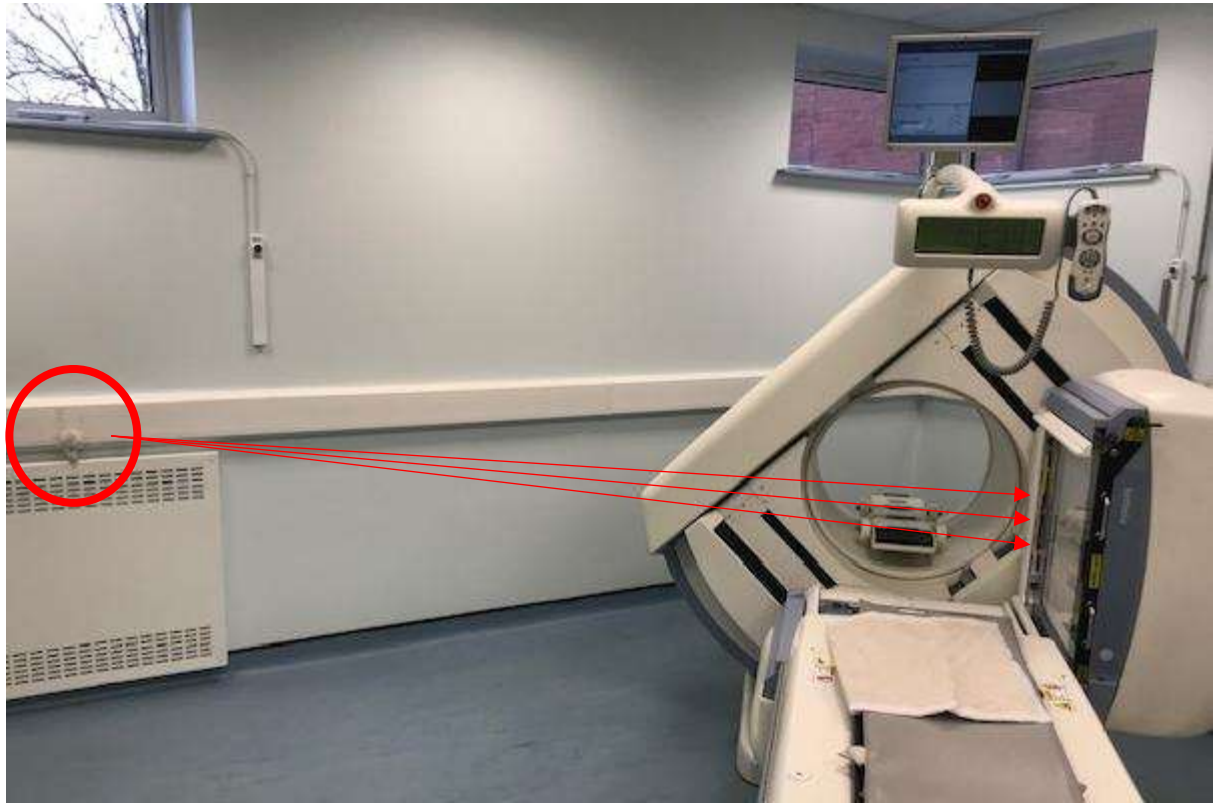






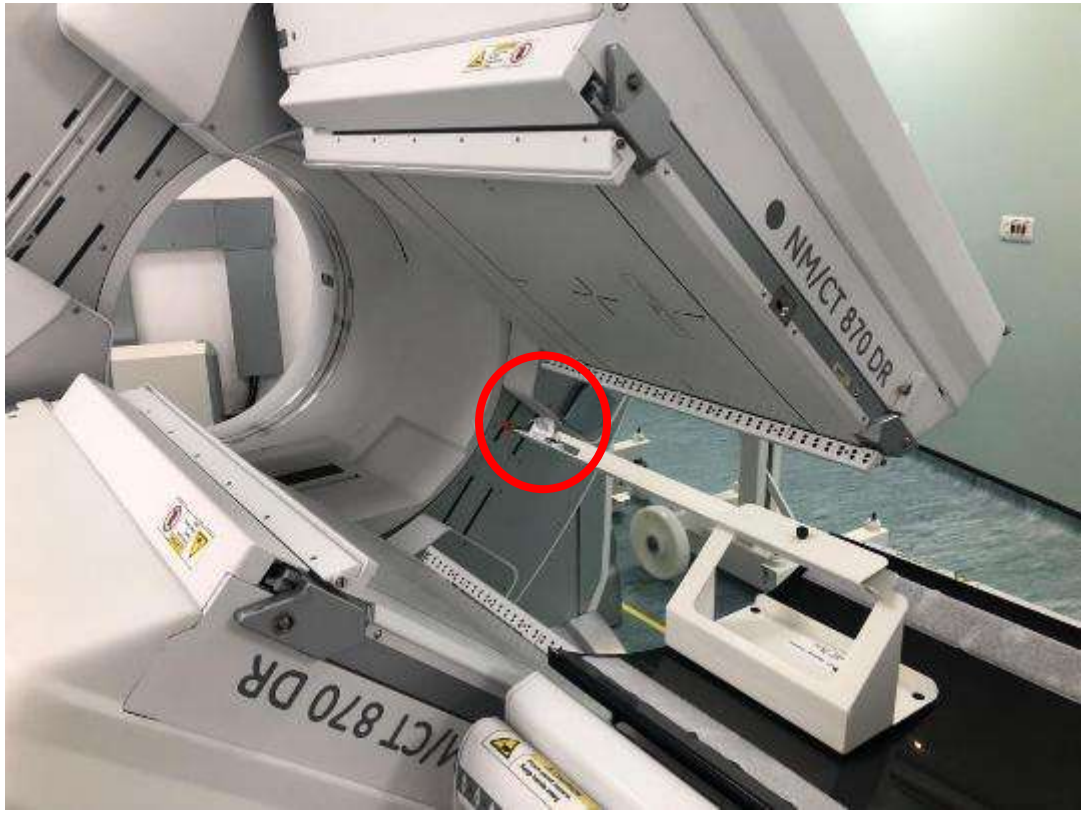
Weekly Intrinsic Uniformity QC

- Extrinsic = collimators on and Co-57
- Intrinsic = no collimator
  - ‘dummy’/ ’decoy’ collimator – Perspex to protect crystal
  - Better to probe issues with crystal/PMTs
  - Nothing obscured by collimators
- Tc-99m point source at distance
  - Aim for gammas to be parallel
- One detector at a time in L-mode
- More counts – better to see defects

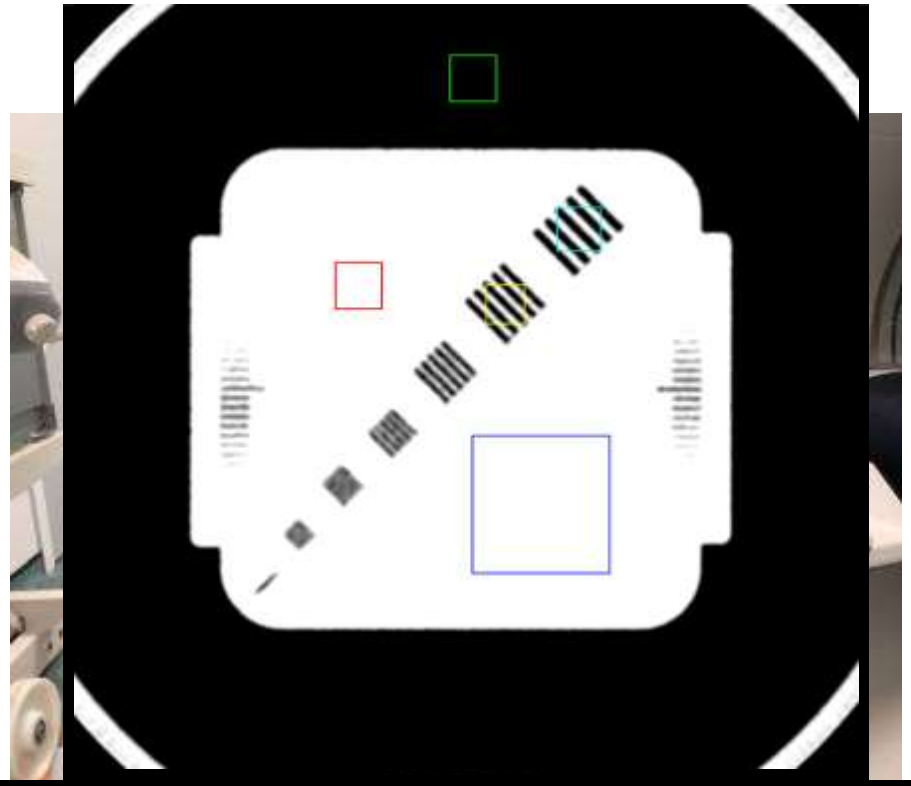


Centre of Rotation

- SPECT systems – two detector heads rotate around a **mechanical centre** and acquire projections which are then reconstructed around an **electrical centre**
- Test that mechanical and electrical centres match
- Tc99m point source positioned in centre
- SPECT acquisition to ensure match



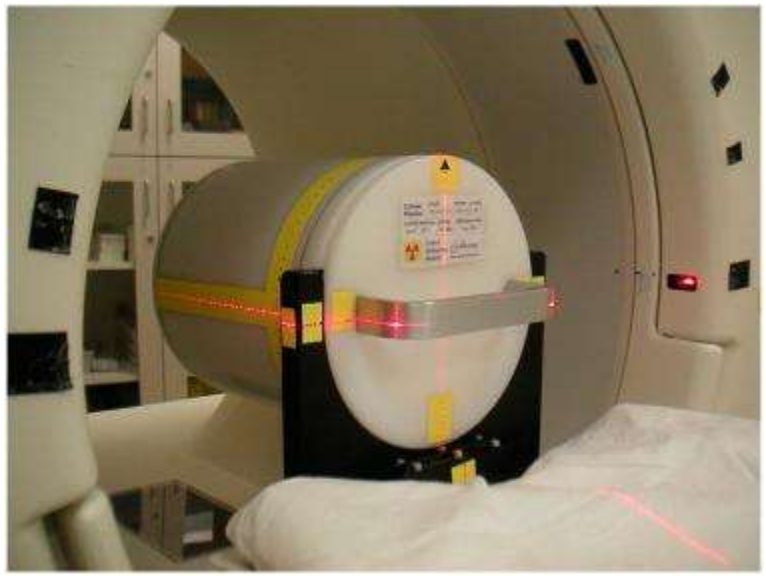
CT QC in Nuclear Medicine



High Contrast Resolution QC		
	1.6mm Bars	1.3mm Bars
St Dev CT #	37.49	30.32
Tolerance	37 +/- 4	31 +/- 3

- Scan a water phantom with inserts
- Check CT Number/HU
- Check uniformity
- Quick check of resolution

Daily PET QC

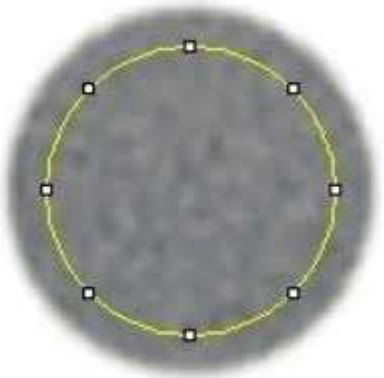


- Ge-68 sealed source
- Half-life = 271 days
- Check detector blocks have same response
- Check uniform cylinder appears uniform

Monthly PET SUV QC

- Fill cylindrical phantom with F-18 FDG
- Ensure uniformly distributed
- Input into scanner the activity in the phantom (residuals accounted for!)
- PET-CT of phantom
- Draw volume of interest (VOI)
- SUV should be 1 (10% tolerance)





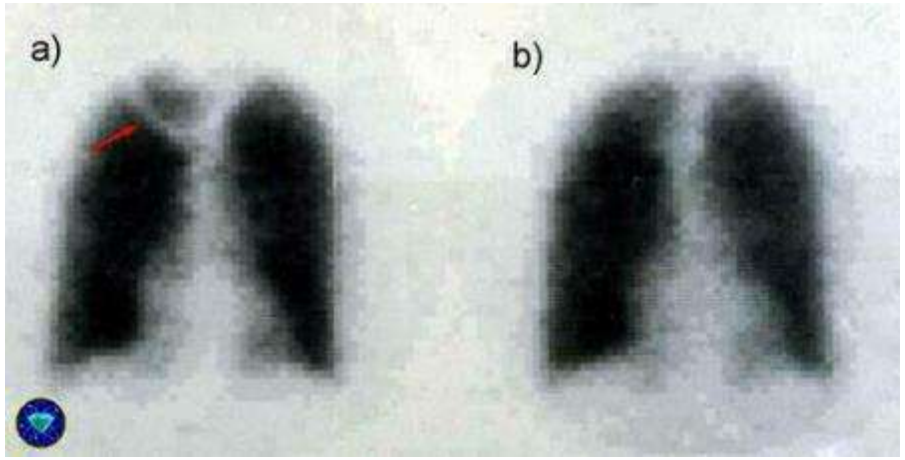
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Artefacts

- A structure in the image that is not naturally present
- A result of an issue with the camera, radiopharmaceutical or due to a patient factor
- Operators and reporters must be aware of these

Artefact 1







Patient wearing chain necklace

Artefact 2

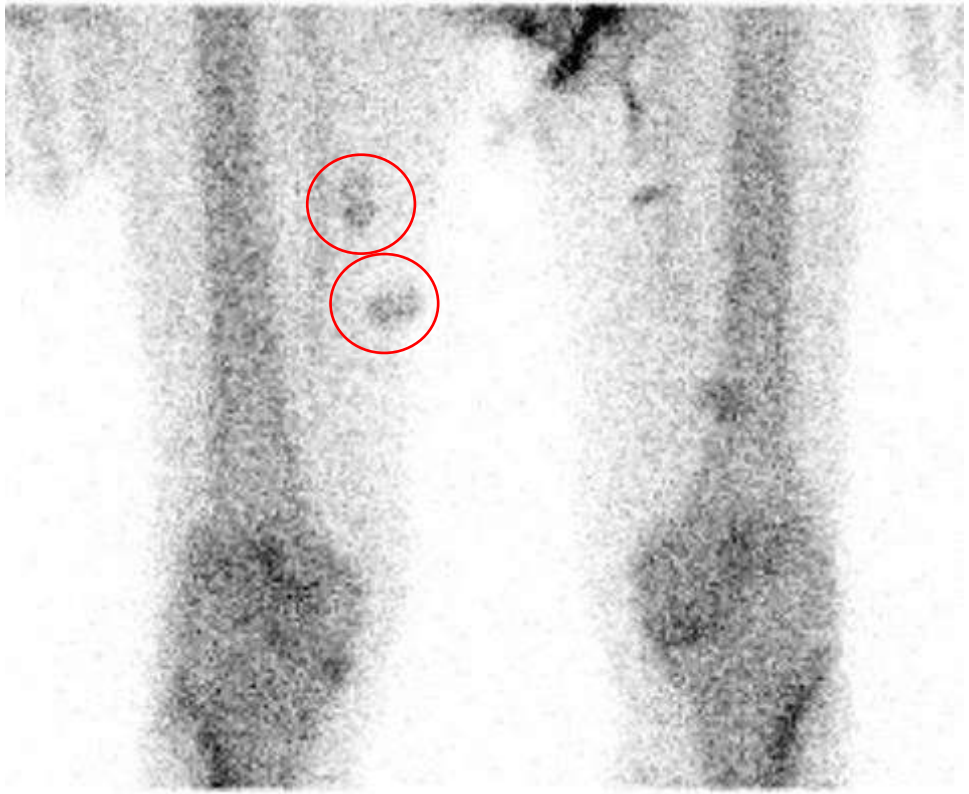






Belt buckle

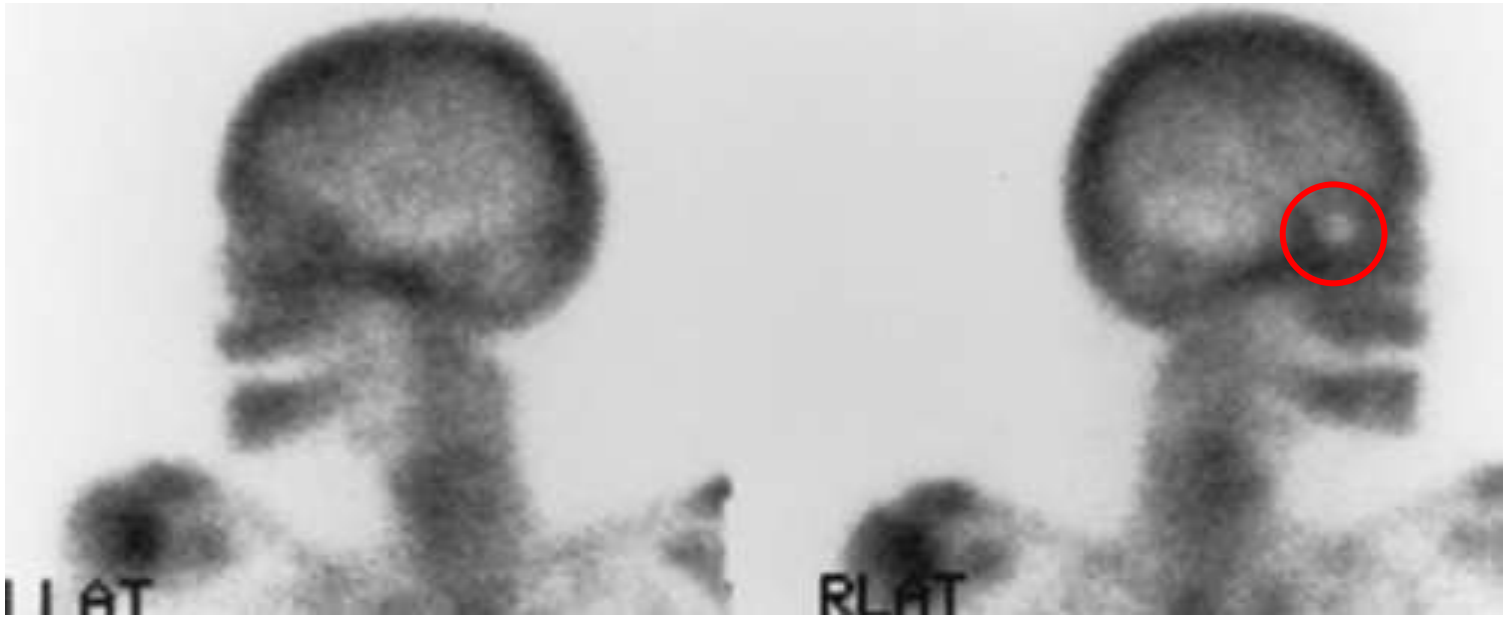
Artefact 3





Urinary contamination

Artefact 4





Apparent ‘cold’ appearing right eye

Artificial eye

Artefact 5

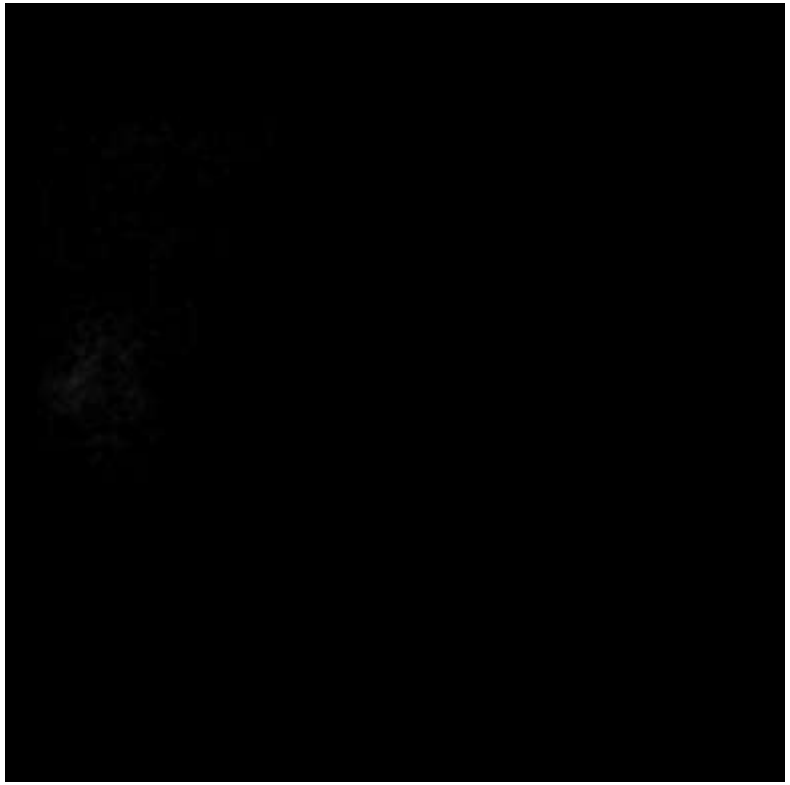






Photomultiplier tube drifting/out

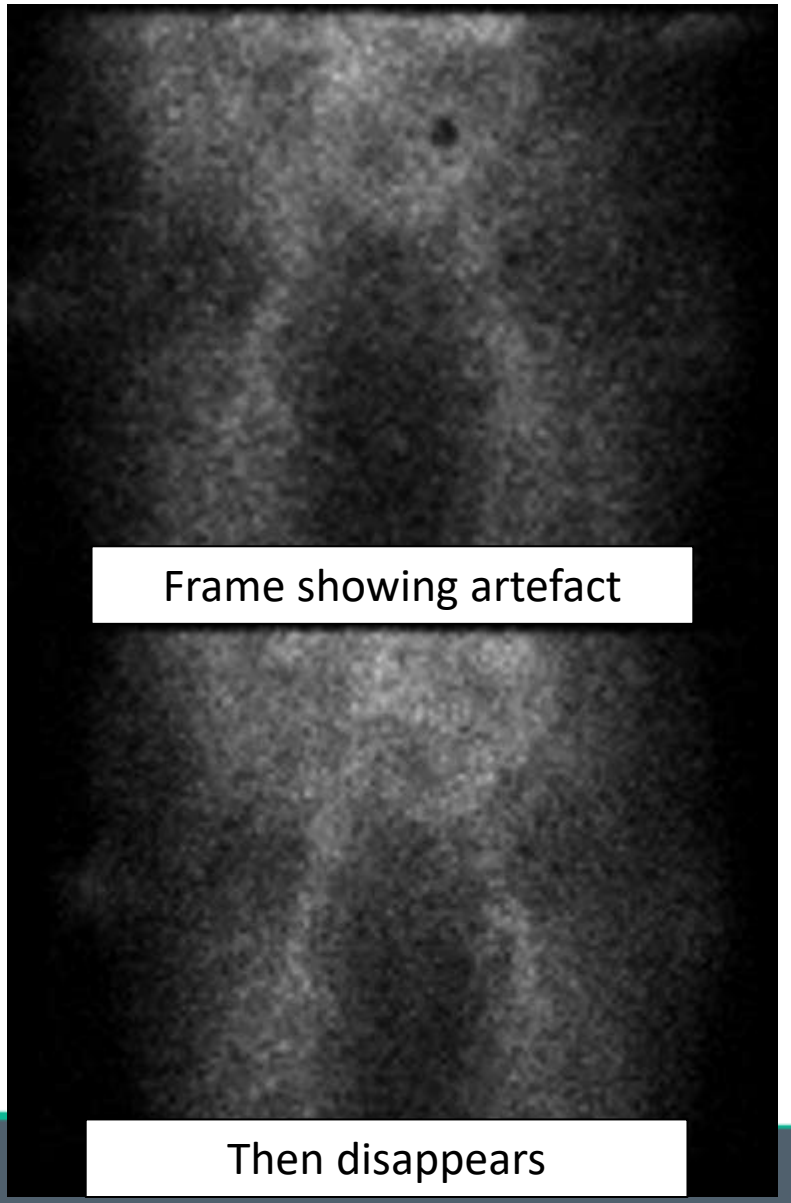
Artefact 6



Dynamic part of bone imaging looking at perfusion



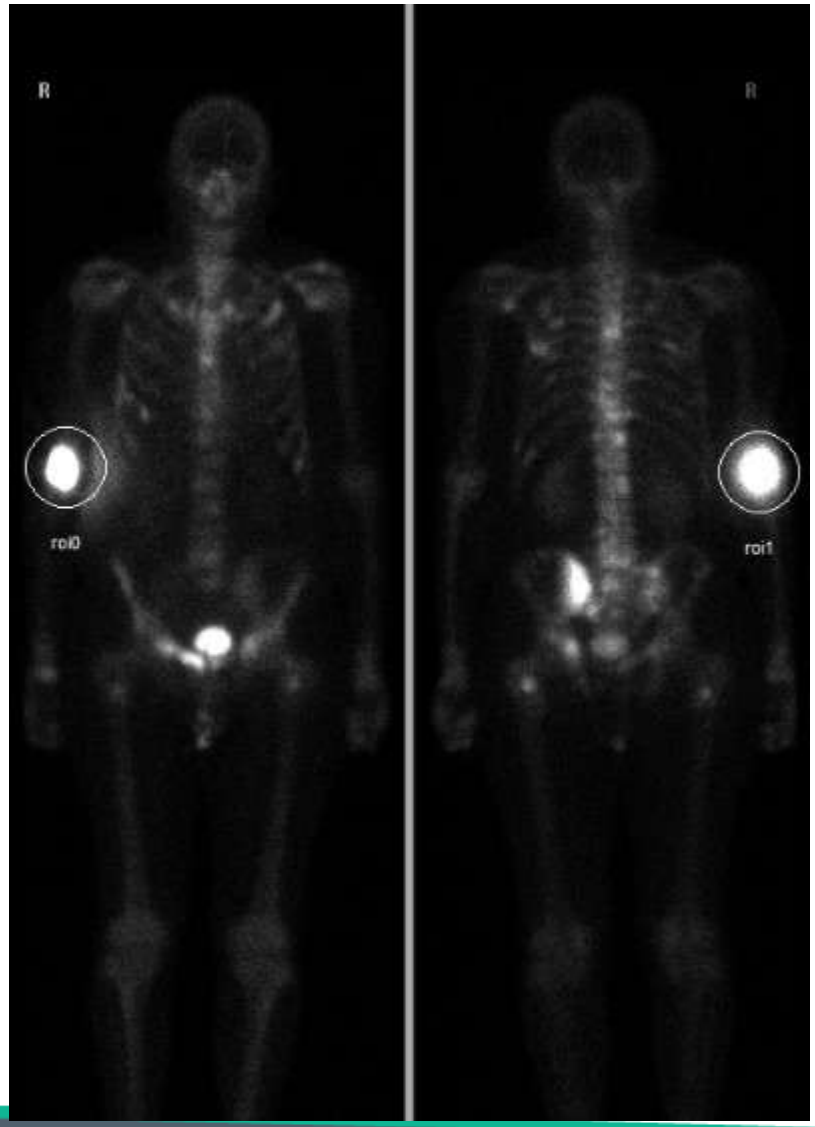
A ring!



Frame showing artefact

Then disappears

Artefact 7



High uptake area on inner arm



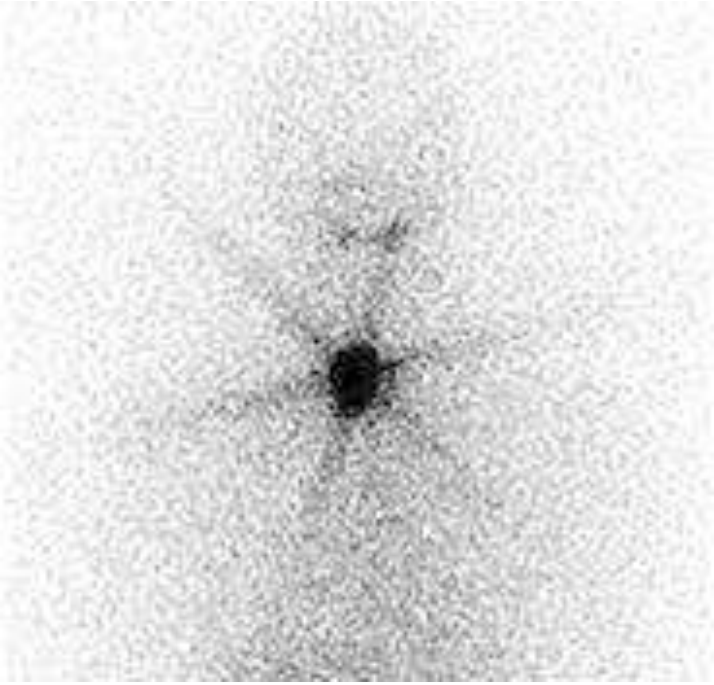
Extravasation



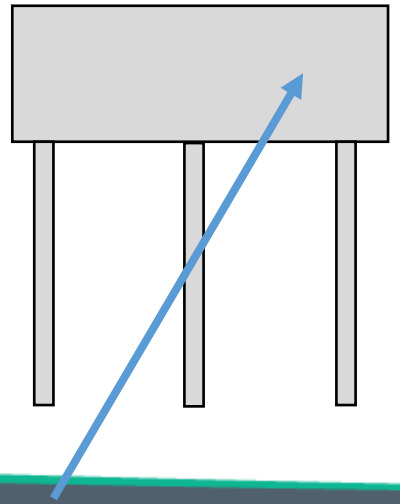
Artefact 8

Star artefact that we saw previously…





Caused by septal penetration through collimator

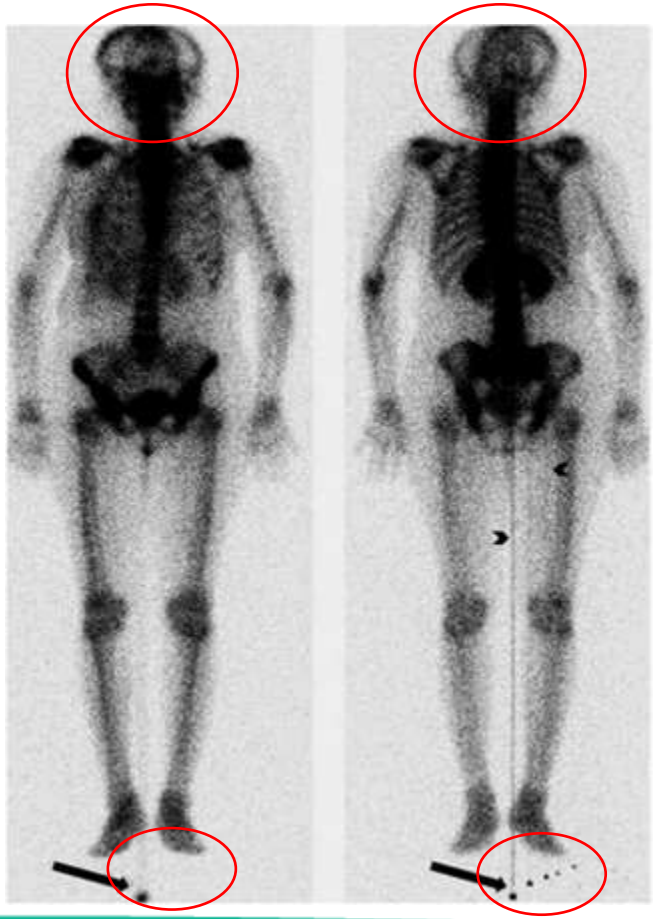


Collimator septa must be thick enough to stop highest energy gamma emitted by source

Artefact 9 & 10

Blurring of the head

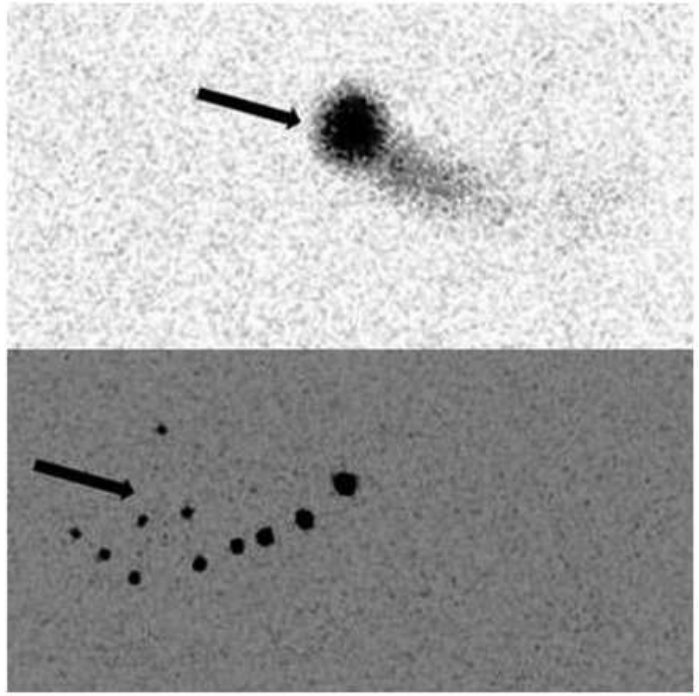
Patient movement





Line down whole body scan and apparent dots in a line at patient's feet

Then seen on static of head and on image without patient



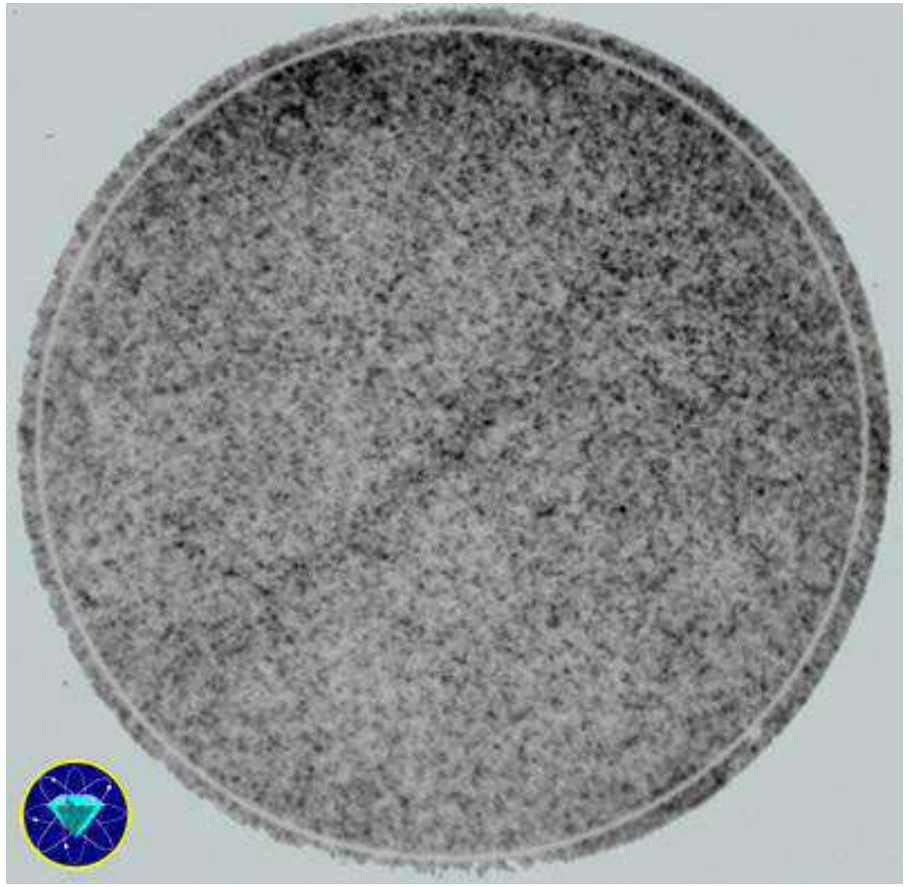
Detector head contaminated

Artefact 11

Patient with urinary catheter



Artefact 12



Crack in crystal
Sudden temperature change

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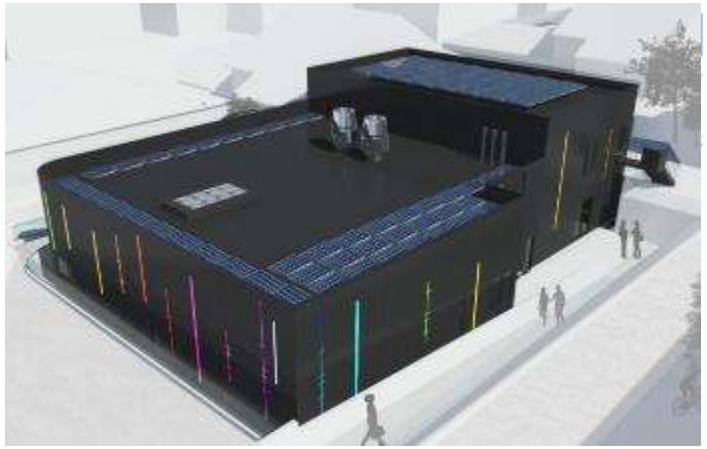
The Future in NM at HUTH…

- MIRC – Molecular Imaging Research Centre
- Starguide Gamma Camera (SPECT)
- Omni Legend (PET)

The Future in NM at HUTH…

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MIRC – Molecular Imaging Research Centre



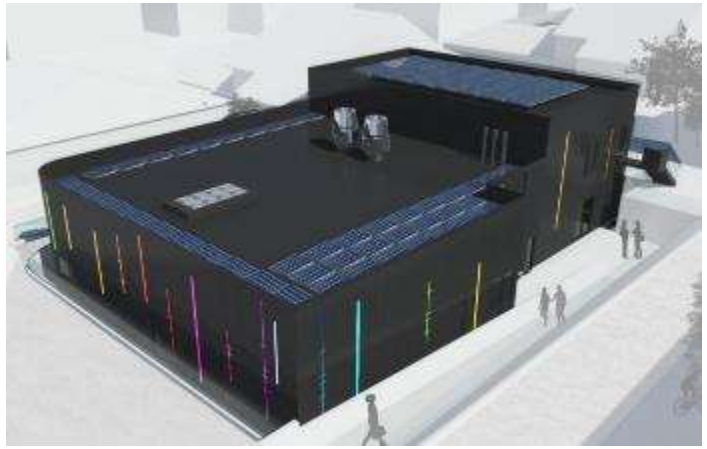
- Cylclotron – production of PET isotopes
- Linked to PETRC – University of Hull PET Research Centre
  - Pre-clinical
  - Cyclotron on site
- Linked to Jack Brignall PET-CT at CHH





MIRC – Molecular Imaging Research Centre

- What does this mean for Hull?
  - State of the art SPECT Radiopharmacy
  - Production of F-18 locally (maybe supply others)
  - Future research and generation of PET radioisotopes

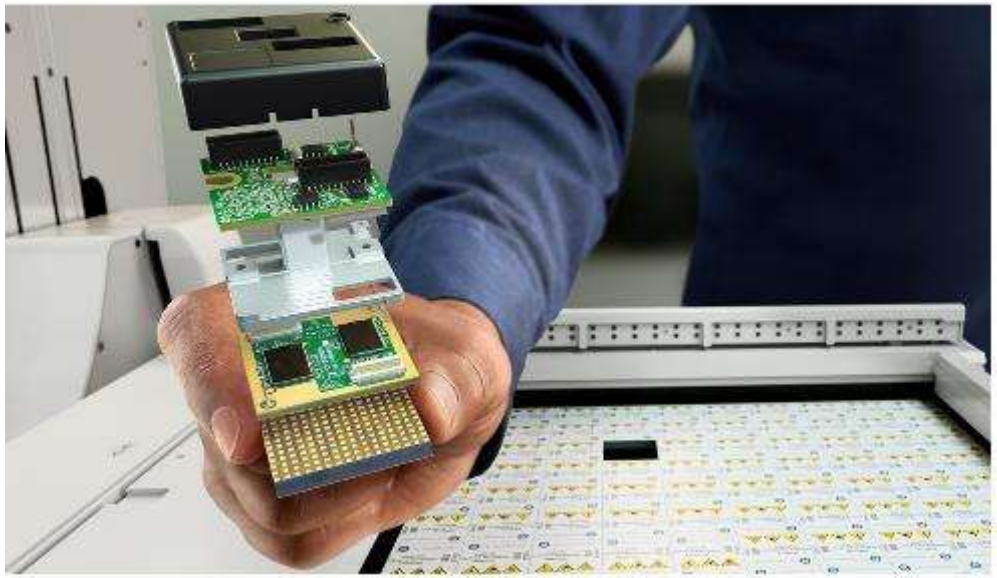


The Future in NM at HUTH…

- MIRC – Molecular Imaging Research Centre
- Starguide Gamma Camera (SPECT)
- Omni (PET)

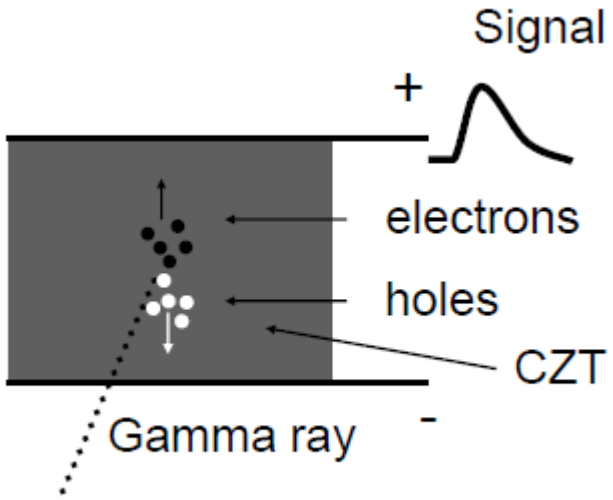
Digital Gamma Camera

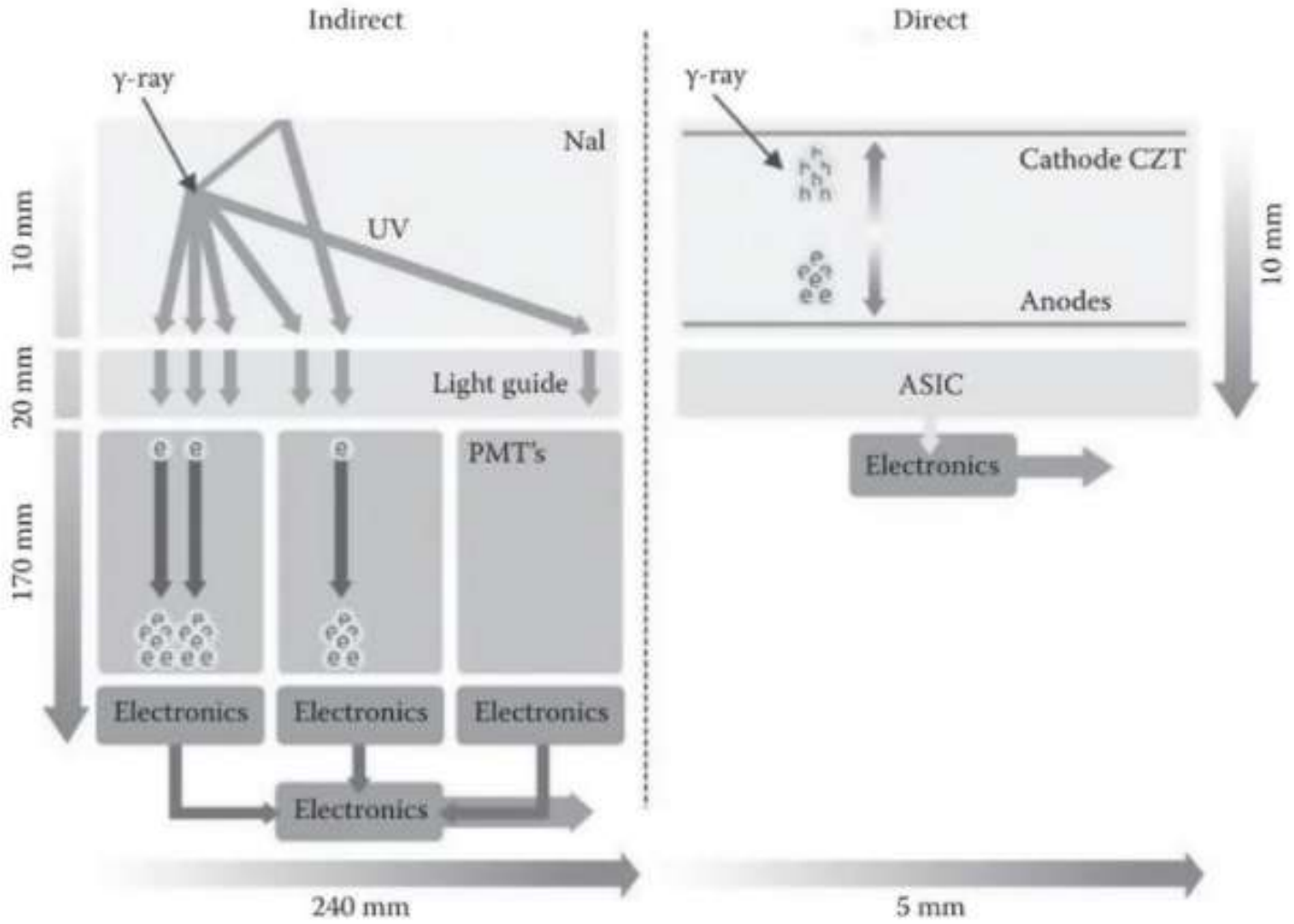
- No Photomultiplier Tubes
- Solid state detector – semiconductor materials
  - E.g. CZT array
- NaI(Tl) Gamma Camera
  - Conversion to light photons and then to electrons = indirect
- CZT (Cadmium Zinc Telluride) Gamma Camera
  - Direct conversion to electron hole pair, no light



CZT Detector

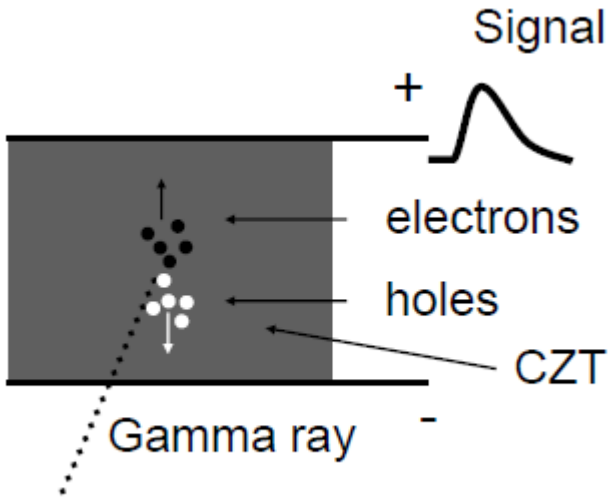
- Gamma ray absorbed in CZT
- Electron-hole pair created
- Electric signal





CZT Detector

- Gamma ray absorbed in CZT
- Electron-hole pair created
- Electric signal



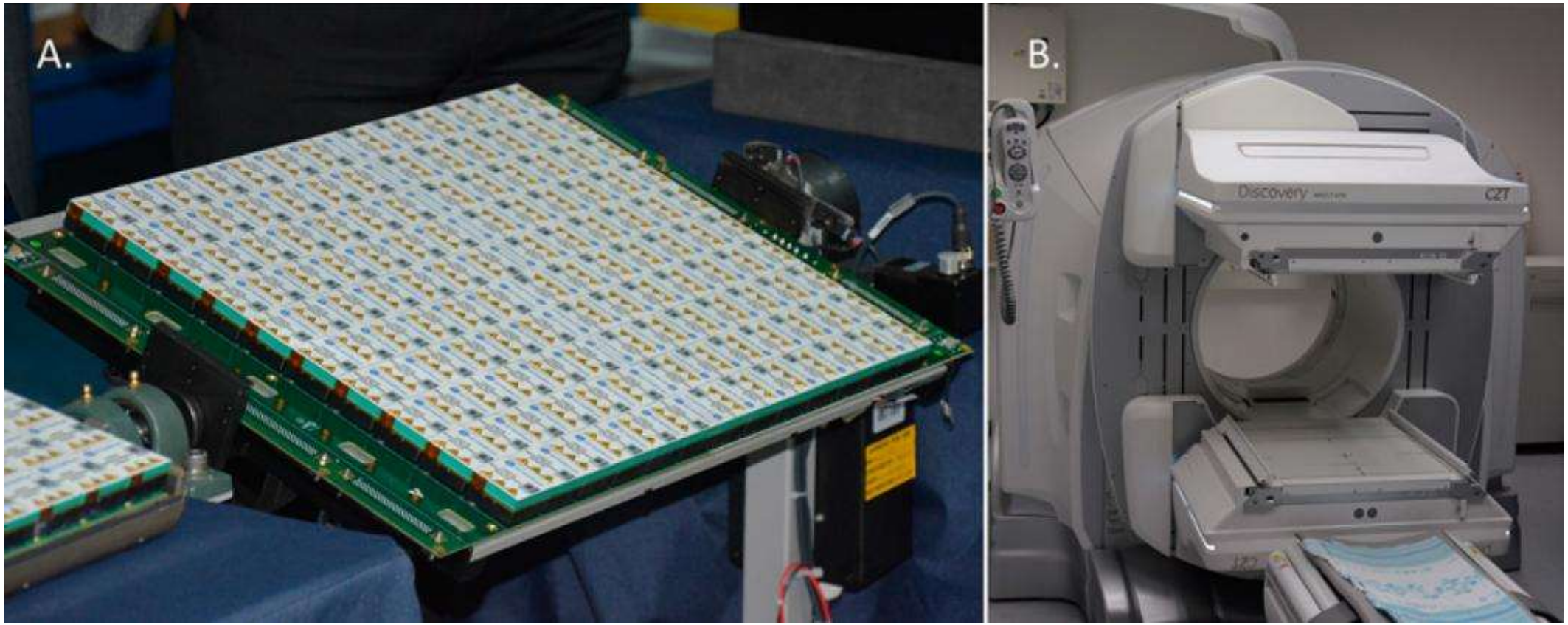


Standard PMT Tube



Solid State Detector

CZT Detector



NaI(Tl) Detector



Advantages of Solid State Gamma Camera

- Compact detector
  - Smaller, lighter, more manoeuvrable
- Better energy resolution
  - E.g. ability to determine 140keV as 140keV
  - Because more electrons created
- Robust
  - Not susceptible to shock or moisture
- Direct position information
  - Detector/pixel correlation

	NaI(Tl)	CZT
Number of electrons for one 140keV gamma	1,000	30,000

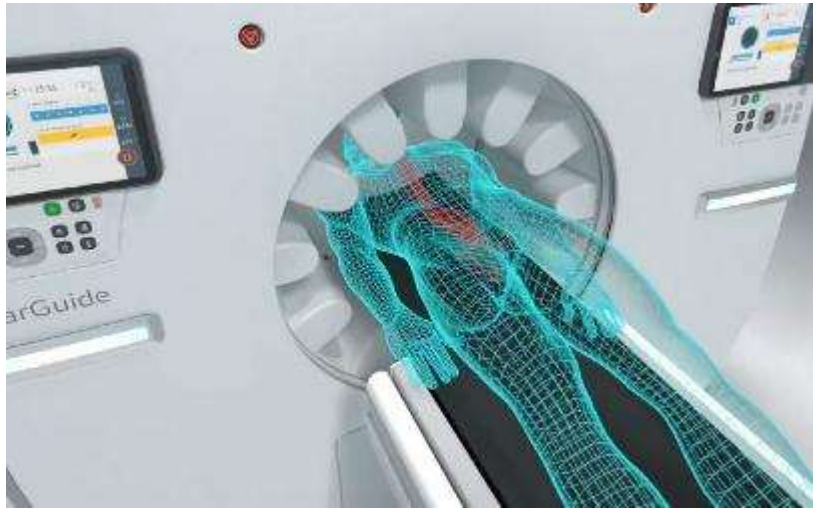
GE StarGuide

- 12 CZT detectors
- SPECT only system
- Fixed collimation on each head

- Faster scans – 12 heads
- Improved energy resolution







The Future in NM at HUTH…

- MIRC – Molecular Imaging Research Centre
- Starguide Gamma Camera (SPECT)
- Omni (PET)

Omni Legend PET Scanner

- Longer patient coverage
  - Longer Field-Of-View (FOV)
- Higher sensitivity camera
  - Different crystal (BGO)





Scintillator Crystals

Crystal	Relative Light Output (%)	Decay Time (ns)	Density (g/cm^3)	Effective Atomic Number (Z)	Energy Resolution at 511 keV (%)
NaI(Tl)	100	230	3.7	51	7.8
BGO	15	300	7.1	75	10.1
LSO	75	40	7.4	65	10.0
GSO	35	60	6.7	59	9.5

All crystals emit light with wavelengths ranging from 410 to 480 nm

Detectors based on BGO are still common, but crystals such as LSO and GSO (and those with similar properties) are increasingly being used. Both potentially offer improved count rate performance due to shorter decay times and improved energy resolution

Omni Legend PET Scanner



- Longer patient coverage
  - Longer Field-Of-View (FOV)
- Higher sensitivity camera
  - Different crystal (BGO)
  - ‘digital photomultiplier tubes’
- Scope to add on detector rings
  - Extending PET part of scanner
  - Moving closer to whole-body PET
  - More detectors = greater measured counts = greater sensitivity
  - Scope for reducing administered activity/ speeding up scan time



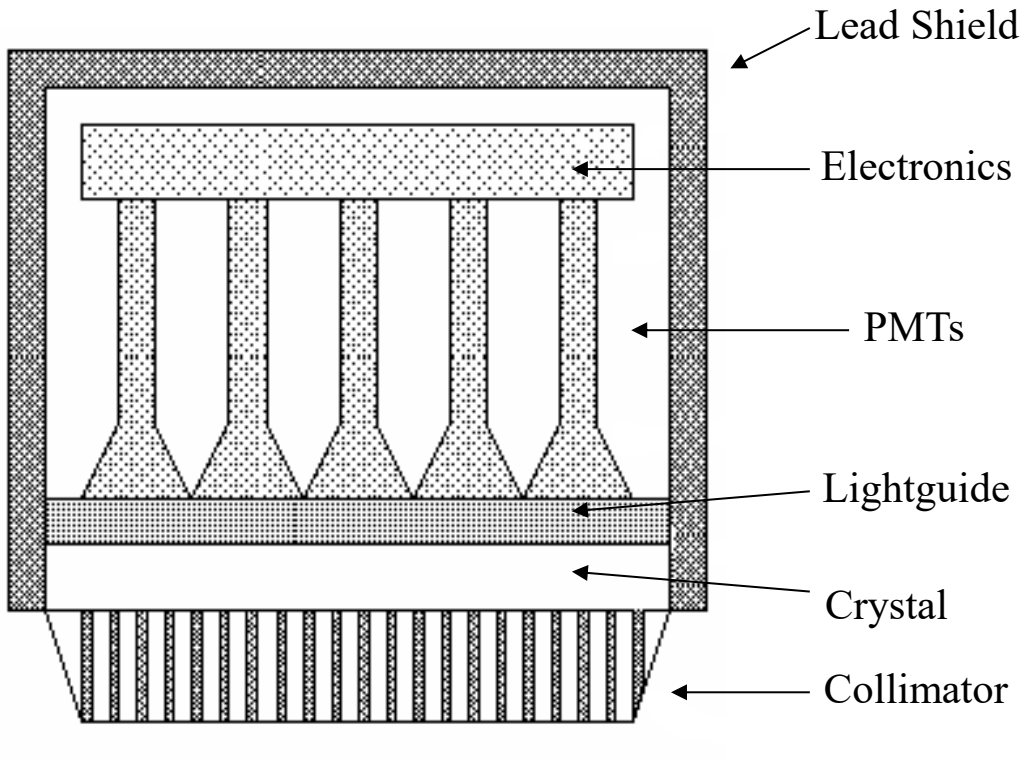
Today

- Bone Scan Pathway – a closer look
- QC testing in NM
- Artefacts
- Future parts in NM
  - MIRC
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1. Which of the following is one of the advantages of nuclear medicine studies over routine radiography?

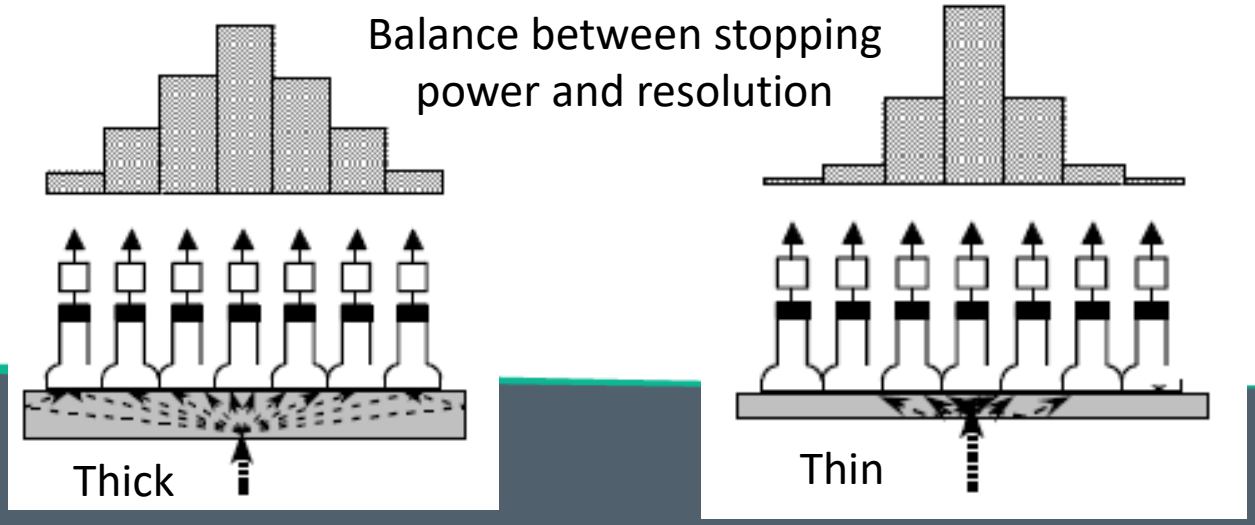
A. Radiation dose is less
B. No need for preparation
C. Ability to get functional information
D. Less expensive

2. What are the key components of a gamma camera detector?



3. Which of the following is the effect of increasing the thickness of the scintillation detector on sensitivity and resolution?

A. Increased sensitivity and increased resolution.
B. Decreased sensitivity and increased resolution.
C. Decreased sensitivity and decreased resolution.
D. Increased sensitivity and decreased resolution.



4. Which of the following is the primary function of the gamma camera photomultiplier tube?

A. Convert radioactivity into light and amplify it.
B. Convert light into electrical signal and amplify it.
C. Filter out photons and limit the energy range.
D. Minimize the scattered radiation in the final image.

5. Which of the following sentences correctly describes a positron?

A. A particle having a mass equal to the proton but opposite charge
B. A particle having a mass equal to the electron but opposite charge
C. A particle having a mass equal to the proton and no charge
D. A particle having a mass equal to the electron and no charge

6. What scintillation crystal is typically used in a gamma camera detector?

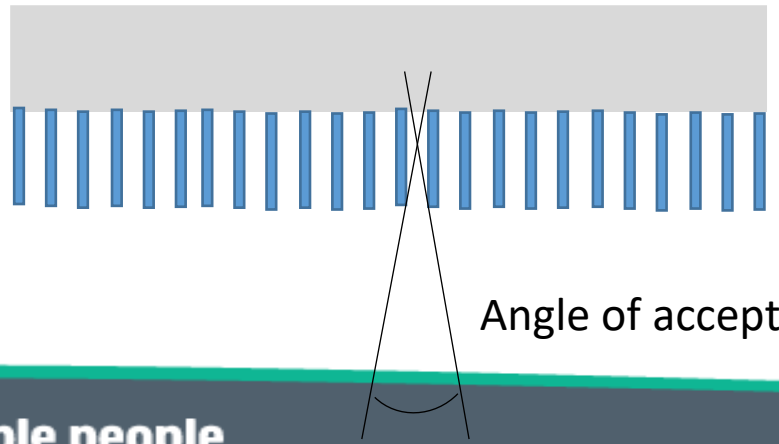
A. LSO
B. BGO
C. LYSO
D. NaI(Tl)

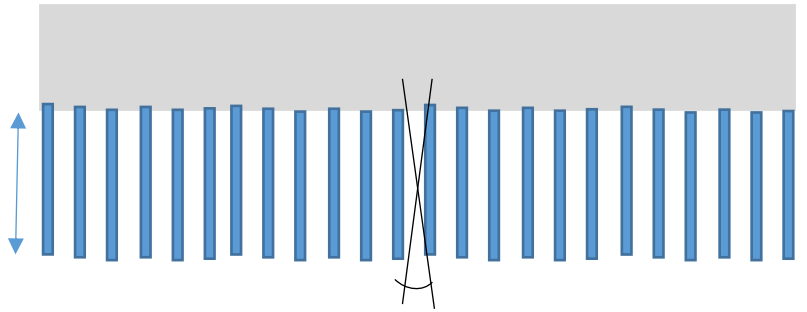
7. In an Anger gamma camera, low energy electrons are ejected when light strikes the:

A. Cathode of the PMT
B. Anode of the PMT
C. The NaI(Tl) crystal
D. The dynode array of the PMT

8. Which of the following would result in increased system spatial resolution for a gamma camera with a parallel-hole collimator:

A. Making the collimator holes larger in diameter
B. Making the collimator septa thinner
C. Making the collimator holes longer
D. Moving further away form the face of the collimator





Less get through
More accurate position

9. Which of the following filters is ALWAYS employed in the SPECT reconstruction using filtered back-projection?

A. 9-point smoothing filter
B. Hann filter
C. Ramp filter
D. Butterworth filter

10. An MPS study using Tc-99m is acquired with the energy window centered around the Tl-201 photopeak. Which of the following statements is correct?

A. The acquisition will need to be repeated using the correct energy window
B. Tomographic images should be reconstructed using the filter settings for Tl-201
C. The raw images should be evaluated with the final report indicating that the study was suboptimal
D. The raw data should be corrected using a Tl-201 uniformity correction map prior to reconstruction

11. A patient has extreme needle phobia and only 70% of the required activity for the exam has been injected. What can be adjusted in the acquisition parameters of the SPECT scan to try compensate for this?

A. Matrix size
B. Number of projections
C. Time per projection
D. None of the above

12. Which of the following are key differences between a gamma camera and a PET scanner?

A. Detector configuration
B. Scintillation crystal material
C. Location of CT in the scanner
D. All of the above

13. Which of the following will impact diagnostic image quality in Nuclear Medicine?

A. Injected Activity
B. Scan Duration
C. Reconstruction Parameters
D. Uptake Time

14. How are collimators stored/handled?

A. On carts wheeled to the camera and lifted onto the detector head.
B. On carts wheeled to the camera and slid onto the detector head.
C. On shelves carried to the camera and lifted onto the detector head.
D. On shelves carried to the camera and slid onto the detector head.

15. True or false: In PET imaging the positron range impacts resolution and is typically 1-2mm.

FALSE – range dependent on positron energy

16. True or false: The gamma camera measures the amount of radioactivity in the patient.

FALSE – it measures the radiation coming from the patient in the form of counts. Radionuclide calibrator measures activity.

17. True or false: LEHR collimators should be used for diagnostic investigations involving looking at small lesions.

TRICK – only if they use a low energy radionuclide!



18. True or false: Pulse Height Analysis (PHA) is used to determine the energy of the detected gamma in a gamma camera but not in PET.

FALSE – used in both

19. True or false: In planar imaging, the gamma camera can only detect gamma radiation

FALSE – any photon

20. True or false: CT images in Nuclear Medicine are typically used for attenuation correction and are not of diagnostic quality.

TRUE – AC or ACL but diagnostic quality not needed

21. True or false: All radiopharmaceuticals are administered intravenously in Nuclear Medicine.

FALSE – orally, inhalation

22. True or false: Time of Flight in PET imaging improves contrast.

TRUE – time of detected events used to narrow down position of annihilation location on LOR.

24. True or false: Collimator holes have a hexagonal honeycomb structure to maximise the number of holes

TRUE

25. True or false: PMTs can be circular or hexagonal in shape.

TRUE

26. True or false: In a Tc99m scan all gammas used in the final image have an energy of 140keV

FALSE – energy window used normally 140 keV ± 10%

27. True or false: The CT image is a measure of attenuation at different angles

TRUE

28. True or false: PET resolution is impacted by positron range and positron non co-linearity

FALSE – photon co-linearity!



Today - recap

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Thank you for listening