Quality Control and Radiation Safety

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Introduction to Quality Control

- Critical component of routine NM practice
- Ensures that the performance of a procedure or instrument is within a predefined acceptable range
- Involves description, data recording, action, archiving
- All comparable measurements should be within 10%

Components of NM Quality Control

1. Standards/ reference sources
2. Survey Meters
3. Dose Calibrators
4. Well Counters
5. Intraoperative Gamma Probe
6. Gamma / SPECT Camera
7. PET Scanner
8. CT component of PET-CT or SPECT-CT
9. PET –CT / SPECT-CT image registration
1. Standards and Reference Sources

- Long lived surrogate radionuclides
- Flood sources, markers
- **DAILY Q/C**: checked for leakage, inventoried, returned / disposed
Pen Point Marker

Used to mark a point of interest during a camera study or to trace the outline of anatomical features on a patient. It contains Co-57.
2. Survey Meters

• Portable, battery operated, gas filled, ionization detectors used to monitor ambient radiation levels

• **Cutie Pies:** used for high fluxes of X or γ rays, amplitude of signal depends on the energy of radiation

• **GM counters:** high sensitivity, used for low level survey/contamination, Signal amplitude is independent of energy

• **DAILY Q/C:** battery, background, and constancy
Survey Meter

For dose measurements, surveys of incoming/outgoing packages, general radiation surveys over a broad range of energies: Alpha, beta, gamma surveying
3. Dose Calibrator

• Pressurized gas filled ionization chamber used for assaying activities

• **DAILY Q/C**: constancy (using reference source)

• **QUARTERLY Q/C**: accuracy and linearity (shield method)

• **AT INSTALL / SERVICE**: geometry
Dose Calibrator

radionuclide activity measurements. Activity is displayed on a LED readout in either Curie or Becquerel units. Activity measurements are performed by a microprocessor controlled electrometer located within the detector assembly of the ionization chamber.
4. Well Counters

• Used for high sensitivity counting of radioactive specimens and samples / wipes.
• Made of cylindrical thallium-doped Sodium Iodide crystal coupled to Photomultiplier tube, often equipped with Multichannel analyzer.
• **DAILY Q/C:** energy peaking, background, and constancy
Well Counter
5. Intraoperative Gamma Probe

- Handheld collimated counting device used for identification and localization of sentinel nodes
- **DAILY Q/C:** battery check, bias check, energy peaking, background, and constancy
Gamma Probe

Intra-operative sentinel node localization.
6. Gamma / SPECT Camera

- Most widely used imaging device in Nuclear Medicine.
- **DAILY Q/C**: energy peaking, uniformity (flood phantom)
- **WEEKLY Q/C**: spatial resolution (semi quantitative assessment with 4 quadrant bar phantom) and COR alignment
- **QUARTERLY Q/C**: tomographic uniformity and overall system performance (Jaszczak phantom)
Dual Head Gamma Camera
Triple Head Gamma Camera
SPECT-CT Scanner
Bar Phantom

Determination of camera intrinsic resolution, collimator spatial resolution, field size and linearity.
7. PET Scanner

- **DAILY Q/C:** blank scan
- **WEEKLY Q/C:** tomographic uniformity
PET-CT Scanner
8. CT Scanner

• **DAILY Q/C:** warm up, tomographic uniformity, accuracy of water number, noise

• **QUARTERLY Q/C:** laser alignment, image slice thickness, spatial resolution, linearity, high contrast resolution, low contrast resolution
9. Image Registration

• Applies to SPECT-CT and PET-CT
• **QUARTERLY Q/C:** quarterly check of accuracy and CT based attenuation correction
Radiation Exposure & Waste Disposal

- Sealed sources - standards, markers and QC sources.
- Total exposure = exposure rate (quantity) × time (duration); inverse square law
- I131 becomes air borne in acid solution, so liquid waste is stored in NaOH
- HVL for 511 keV photons is 16 times that of Tc99m (140 keV) = 4 mm of lead
- Release of patient after I131 therapy = exposure rate at one meter - 5 mR/hr
- GM survey meters - monitor rooms, counters, and tables.
- Frequency of survey is as specified in radioactive materials license.
- Reading >3 SD of the background is considered positive – Monitor & wipe test
- Wipe testing - to detect low levels or weak radiation contamination.
- T1/2 < 65 days - Decay in Storage = 10 T1/2, same as background.
- EPA sets limits for radionuclide emissions into air
Effects of Radiation

- Nonstochastic effect - one onetime exposure
- < 20 rem whole body exposure - no symptoms.
- >20 rem whole body exposure - acute radiation syndrome
- Stochastic effect - prolonged low level radiation - cancer/ leukemia
- Natural sources of radiation (82%) - radon> internal> terrestrial> cosmic
- Artificial sources of radiation (18%)- x-rays > nuclear medicine > consumer products
- Background radiation in U.S. - 295 mrem/yr
- Sensitivity to radiation is directly proportional to reproductive activity and inversely proportional to degree of differentiation (Law of Bergonie and Tribondeau) (exception - lymphocytes, highly differentiated, yet sensitive)
- Oxygen is most outstanding chemical sensitizer of tissues to radiation
- Neurons are least sensitive to radiation.
- Acute radiation syndrome - bone marrow syndrome - GI syndrome - CNS syndrome
- Radiation Measurement - Thermoluminescence dosimetry, more sensitive than films, reliable up to 1 mrem, not affected by weather, reusable, expensive
NRC - Nuclear Regulatory Commission

- Enforces radiation safety laws in the United States.
- All users must prepare, practice, and revise yearly an ALARA program.
- Broad scope licenses require RSC and RSO, RSC - meets quarterly
- RSO - investigates all radiation safety incidents
- NRC - abides by the title 10 of CFR (code of federal regulations).
- 18 States - receive regulations from NRC.
- 32 States (agreement states) - manage their own radiation safety program.
- 10CFR part 19: notices, instructions, report to workers, inspection and investigation
- 10CFR part 20: standards for protection against radiation
- 10CFR part 30: rules applicable to licensing of by product materials
- 10CFR part 35: medical use of by product materials.
- **DOT** - Department of Transportation is responsible for setting standards for proper packaging, labeling and transport of radioactive materials.
- **FDA** is responsible for approval of new pharmaceuticals - IND must demonstrate that is safe and effective. NDA status on approval.
Dose Limits

• **Occupational dose limits:**
  • Whole body total effective dose equivalent (TEDE) - 5 rem/yr
  • Total organ dose equivalent - 50
  • Lens dose equivalent - 15-150
  • Pregnant patient - 500 mrem/9 months and 50 mrem/month

• **General public dose limits:**
  • TEDE - 100 mrem/yr

• **Female, Pregnant, & Breastfeeding Patient**
  • 10 day rule for ♂- injected and scanned within 10 days after the onset of menses.
  • In female patients the benefits should outweigh the risks of the procedure.
Radiation Safety Procedures

• No eating, drinking or smoking or using cosmetics in working areas. No chewing gum or use of mints or lozenges. No lab coats, gloves, radioactivity in lounge room and waiting room.
• Caution Radiation Area - dose rate >5 mrem/hr at 30 cm
• Caution High Radiation Area - dose rate >100 mrem/hr at 30 cm
• Danger Very High Radiation Area - dose rate >500 mrem/hr at 1m
• Danger Radioactive materials - storage of significant amount of radionuclides
• Medical Event (formerly misadministration) -- wrong patient, wrong tracer, wrong route, > 20 percent of the prescribed dose and >5 rem effective dose equivalent exposure – reported within 24 hrs to the RSO
• Nuclear medicine packages are categorized based on dose rate on surface and at one meter distance (mrem/hr) :
  • Category I - 0.5/ background
  • Category II – 50/ 1 Category III – 100/ 3
• Packages are monitored within 3 hrs of arrival.
**Radiation Spill**

**Minor Spill**: - release of microcurie dose of activity, - decontaminated immediately, - inform RSO, - incident report prepared.

**Major Spill**: - release of millicurie dose of activity, - warn other workers, - close area to traffic, - call RSO

**Decontamination procedure**: - disposable protective clothing, - absorbent paper towel, - 18 inch forceps, - spiral in technique, - monitor < 2 mR/hr

**Lost/stolen radioactive source**: telephone report to licensing agency immediately, written report to licensing agency in < 30 days
Shielded Decay Drum/ Waste Container

safe handling and storage of radioactive waste material
Compact L-Block Shield with built-in Dose Calibrator Shield

convenient shielded access and viewing of the work area
Rectangular Lead Brick

shielding/storage
Xenon System

Ventilation study, Soda-Lime absorbs CO2, Charcoal traps Xe
Radioaerosol Administration System

radioaerosol ventilation studies using Tc99m DTPA
Mobile Radiation Shields

Radiation protection
Sharps Container Shields

simple, safe and convenient way to dispose of used syringes that may contain low-energy gamma radiation residue
Shielded Syringe Carrier

reduce exposure while storing or transporting radioactive material
Shielded Syringe Holder

Protection/transport
Syringe Shield

reduces hand exposure
Thyroid Uptake System
safe and efficient radiopharmaceutical handling procedures
Flood Phantom

Determines field uniformity of scintillation cameras.
Fill able on the left and Cobalt-57 on the right
Collimators
Ultra-TechneKow DTE
(Technetium Tc99m Generator)

• Fission produced molybdenum Mo 99 is adsorbed on alumina in a lead shielded column.
• Sterile, non-pyrogenic, isotonic solutions of Sodium Pertechnetate Tc99m are obtained by periodic elution of the closed system.
• **Molybdenum Mo99 Breakthrough Limit:** 0.15 microcuries Mo 99 per millicurie of Tc99m
• **Aluminium Ion Breakthrough Limit:** 10 micrograms per milliliter of eluate.
• T1/2 of Mo99 = 2.75 days.
• Optimum elution (milking) time is 24hrs.
• Typically lasts for 1 week.