SPECT/PET:
Shielding and Radiation Protection

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Disclosures

None other than that I do not know any good physics jokes
Learning Objectives

- Discuss the overall approach to nuclear medicine and hybrid PET/CT, SPECT/CT shielding and radiation protection problems
- Review the TG-108 approach to designing PET/CT facilities
- Outline difficulties encountered in practical nuclear medicine shielding design
Motivation for Attention to PET/NM Shielding

<table>
<thead>
<tr>
<th>#HVL's</th>
<th>Lead Thickness Required cm (to next 1/16)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X-ray $^1$ (average primary for rad room)</td>
</tr>
<tr>
<td>1</td>
<td>0.044 (&lt; 1/16)</td>
</tr>
<tr>
<td>2</td>
<td>0.103 (&lt; 1/16)</td>
</tr>
<tr>
<td>4</td>
<td>0.278 (&lt; 1/16)</td>
</tr>
<tr>
<td>8</td>
<td>0.718 (&lt; 1/16)</td>
</tr>
<tr>
<td>10</td>
<td>1.366 (&lt; 1/16)</td>
</tr>
</tbody>
</table>

Even a single half-value layer for PET is an expensive proposition!

1. NCRP 147: Structural Shielding Design for Medical X-Ray Imaging Facilities
2. Simpkin, 2004, developed for AAPM Task Group on PET Facility Shielding
In Diagnostic \(x\)-ray, we can apply the 3 models from NCRP 147 and find that 1/16" is (usually) the answer, with some to spare. We often calculate just the "closest" point.

Not true in PET. As we will see, it is true that normally we need 1-3 HVL's of shielding. We tend to put in just what we need, due to $$$.

Implication: At every protection point, we need to include all sources that can be contributing to the dose at that point (i.e. multiple injection rooms, scan rooms, etc.), because we do not have built in extra HVL's.
Overview: Shielding Guidance for NM/PET

• NCRP #147 (2004) addresses x-ray modalities and should be used for the CT component of SPECT/CT and PET/CT scanners
• NCRP Report #49 (1976) had guidance for isotopes in the context of brachytherapy and teletherapy sources (Cs-137, Au-198, Ir-192, Co-60, Radium)
• AAPM TG108 (2006) addressed PET and PET/CT Shielding Requirements
• Currently no up-to-date official shielding guidance for general diagnostic nuclear medicine
Typical Tasks We May Need to Address

- Hospital room for I-131 ablation patient
- PET/CT uptake room and scan bay in PET center
- SPECT/CT scan bay in NM department
The General Problem

Dose in Protected Location (per week) =

Dose from weekly isotopic workload in shielded location
(all isotopes, all studies) +

Dose from weekly CT workload in shielded location
(all studies)

and must be less than or equal the assigned protection limit; we hit this target by changing the barrier transmission, B, through adjustments to the barrier material and thickness.

SPECIAL ISSUES FOR NM: Self-attenuation in patient, correct attenuation coefficients for isotopes.
**Formal Approaches I**

CT: NCRP 147

\[ B = \frac{P}{T} \cdot \frac{d^2}{K^1 N} \]

Isotopes: Modified AAPM TG108

\[ B = \frac{P}{T} \cdot \frac{d^2}{(\Gamma A_0 F_{tot} R_t t) N} \]

\( B \) = allowed fractional barrier transmission  
\( P \) = assigned dose limitation goal per wk at protected location  
\( T \) = occupancy factor (see NCRP 147, Table 4.1)  
\( d \) = distance from source to protected location  
\( N \) = number of patients per week  

\( K^1 \) = average air KERMA per patient at 1 m for given workload  
\( \Gamma A_0 F_{tot} R_t t \) = average air KERMA per patient at 1 m for given isotopes, studies,
Formal Approaches I

<table>
<thead>
<tr>
<th>NCRP 147</th>
<th>Modified AAPM TG108</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B = \frac{P}{T} \cdot \frac{d^2}{K^1 N}$</td>
<td>$B = \frac{P}{T} \cdot \frac{d^2}{K^1 N}$</td>
</tr>
</tbody>
</table>

- $B$ = allowed fractional barrier transmission
- $P$ = assigned dose limitation goal at protected location
- $T$ = occupancy factor (see NCRP 147, Table 4.1)
- $d$ = distance from source to protected location
- $N$ = number of patients per week

$K_1$ = average air KERMA per patient at 1 m for given workload

Modification: air KERMA is used here (to match NCRP 147) instead of effective dose, $E$, as per AAPM TG108

$\Gamma A_0 F_{tot} R_t t$ = average air KERMA per patient at 1 m for given isotope, study,
**Formal Approaches II**

\[ B = \frac{P}{T} \cdot \frac{d^2}{(\Gamma A_0 F_{tot} R_t t)N} \]

- \( \Gamma \) = specific dose or air KERMA rate constant for isotope
- \( A_0 \) = injected activity
- \( F_{tot} \) = combined physical decay and biological elimination of activity between injection and the time the patient enters the shielded location
- \( R_t \) = dose reduction factor reflecting decay of isotope during stay in shielded location
- \( t \) = time patient spends in shielded location
What about multiple sources?

\[ K_{tot,prot} = \sum_i K_{i,prot} + K_{CT,prot} \]

Total KERMA (or dose) at protected location  
Sum of isotopic contributions at protected location  
CT contribution at protected location

\[ K_{tot,prot} = T \cdot \sum_i B_i(x) (\Gamma A_0 F_{tot} R_t t)_i N_i + B_{CT}(x) K_{CT} N_{CT} \]

Adjust shield thickness, x, (thus changing \(B_{CT}\) and all \(B_i's\)) until \(K_{tot,prot}\) is less than the protection goal.

Note assumption that d is the same for isotopes, CT.
# Regulations and P, the Protection Limit

<table>
<thead>
<tr>
<th>Group</th>
<th>Limitation per 10CFR20</th>
<th>ALARA Action Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation Workers</td>
<td>50 mSv/yr</td>
<td>5 mSv/yr</td>
</tr>
<tr>
<td></td>
<td>(5000 mrem/yr)</td>
<td>500 mrem/yr</td>
</tr>
<tr>
<td>Pregnant worker's fetus</td>
<td>5 mSv/term</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(500 mrem/term)</td>
<td></td>
</tr>
<tr>
<td>Members of public</td>
<td>1 mSv/yr</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(100 mrem/yr)</td>
<td></td>
</tr>
<tr>
<td>in any hour, not to exceed</td>
<td>.02 mSv</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2 mrem)</td>
<td></td>
</tr>
</tbody>
</table>

**P Targets**
- **controlled areas:**
  - 100 µSv/wk or 10 mrem/wk
- **uncontrolled areas:**
  - 20 µSv/wk or 2 mrem/wk
  - < 20 µSv in any hr
T, the Occupancy Factor

Use occupancy factors from NCRP Report No.147, *Structural Shielding Design for Medical X-ray Imaging Facilities*, or other values chosen by the qualified expert (you!) as appropriate. Pay attention to the discussion that goes with this table in 147.

<table>
<thead>
<tr>
<th>Location</th>
<th>Occupancy Factor (T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative or clerical offices; laboratories, pharmacies and other work areas fully occupied by an individual; receptionist areas, attended waiting rooms, children’s indoor play areas, adjacent x-ray rooms, film reading areas, nurse’s stations, x-ray control rooms</td>
<td>1</td>
</tr>
<tr>
<td>Rooms used for patient examinations and treatments</td>
<td>1/2</td>
</tr>
<tr>
<td>Corridors, patient rooms, employee lounges, staff rest rooms</td>
<td>1/5</td>
</tr>
<tr>
<td>Corridor doors (^b)</td>
<td>1/8</td>
</tr>
<tr>
<td>Public toilets, unattended vending areas, storage rooms, outdoor areas with seating, unattended waiting rooms, patient holding areas</td>
<td>1/20</td>
</tr>
<tr>
<td>Outdoor areas with only transient pedestrian or vehicular traffic, unattended parking lots, vehicular drop off areas (unattended), attics, stairways, unattended elevators, janitor's closets</td>
<td>1/40</td>
</tr>
</tbody>
</table>
CT Component (NCRP 147)

Total scattered air kerma at 1m for 1 week under expected workload (kVp, mAs, collimation, pitch, AEC, types of studies, number of patients)

Three ways of estimating $K^1$ from NCRP 147:
1) CTDI (peripheral) and suggested scatter values per cm collimation

$$K^1 = \kappa \frac{(L/p) \times mAs \times nCTDI_{100}}{T}$$

$\kappa$ = 9 x 10^-5 cm^-1 (head) or 3 x 10^-4 cm^-1 (body)
$p$ = pitch, $L$ = axial length of scan
$mAs$ = mAs per rev***
$nCTDI_{100}$ = peripheral CTDI per mAs

2) Isodose curves (allows correction for anisotropy)
3) DLP

$$K^1_{(head)} = \kappa_{head} \times DLP$$

$$K^1_{(body)} = \kappa_{body} \times 1.2 \times DLP$$
\( \Gamma \) for Nuclear Medicine: Not Simple


2) For patient as a source, the situation is more uncertain!!!

Measurements reflecting different times post injection, disease states, projection, etc. Corrected for decay and activity.

\( \Gamma \) for Nuclear Medicine: Not Simple


Aside:
For F-18 PET, the patient as a source is about 0.093 uSv/hr-MBq at 1 m.
Barrier Transmission $B$ for NM

- As in all shielding problems, must use broad-beam attenuation coefficients.
- NCRP 49 has values for Pb, Fe, concrete, but only for a few isotopes (Cs-137, Au-198, Ir-192, Co-60).
- For lead, the recent Smith and Stabin paper (previous slide) is very useful.
- For other materials, data is limited and must resort to attenuation coefficient tables and build-up tables for each gamma energy.
Finding the Transmission Data

Wachsmann and Drexler curves (1975), found in NCRP 151.

Various sources for buildup factors at energy E and thickness x:

\[ B = \frac{X}{X_0} = BU(E,x) \times e^{-ux} \]

Watch out for build-up factors -- some are for realistic shielding configurations (Kharrati for Pb), but conventional BU is for infinite media (which will show backscatter!) (Shimizu, ANS 6.4.3)
Shielding Example: I-131 Hospitalization

A thyroid cancer ablation patient must be held for approximately 24-48 hours after treatment with 150 mCi I-131 to meet release criteria (1 cases/wk). Is shielding required for the work area?

Look at how modeling of effective half-life affects requirement.
### I-131 Example Setup

\[
B = \frac{P}{T} \cdot \frac{d^2}{(\Gamma A_0 F_{tot} R_t t) N}
\]

- \( \Gamma = 0.052 \text{ (uGy/hr)/MBq at 1 m (Smith and Stabin value, converted to air kerma rate)} \)
- \( P = 20 \text{ uSv (uncontrolled)} \)
- \( d = 15 \text{ ft} \)
- \( A_0 = 150 \text{ mCi} \)
- \( t = 8 \text{ hours (shift length for protected personnel, assume treatment started at beginning of shift)} \)
- \( R_t = 0.984 \text{ (no appreciable decay during the shift)} \)
- \( F_{tot} = 1 \text{ (no appreciable decay before entering room)} \)

Half-life of I-131 is 8.04 d; NUREG 1556 indicates that for first 8 hours, should use physical half-life without correction for biological elimination.
I-131 Example Results

\[ B = \frac{P}{T} \cdot \frac{d^2}{(\Gamma A_0 F_{tot} R_t t) N} \]

NUREG 1556 I-131 two compartment washout model allows 95% of retained I-131 to be assigned \( T_{\text{eff}} = 0.32 \) day and the other 5% to be assigned \( T_{\text{eff}} = 7.3 \) day after the initial 8 hours post treatment.

1) Check for initial air kerma rate at the unshielded location. It is 14 uGy/hr (1.4 mrad/hr), less than 20 uSv in any one hour limit.

2) Assuming the patient is released before the shift comes back on duty, \( B = 0.184 \) to protect to 20 uSv/wk.

3) If a second personnel exposure (shift starting 24 hr after treatment) can occur, then \( B \) must be decreased to \( B = 0.096 \) if only physical decay is considered. If NUREG 1556 washout model is used, \( B \) would be decreased to \( B = 0.154 \) [either approach done by calculating total kerma, then \( B \)].
Getting the Shield Thickness

B = 0.184 => x = 7.04 mm Pb = 5/16" Pb (single day scenario)

B = 0.153 => x = 7.92 mm Pb = 5/16" Pb (two day with washout)

B = 0.096 => x = 10.2 mm Pb = 7/16" Pb (two day, no additional washout)
PET Shielding in More Detail

AAPM Task Group 108: PET and PET/CT Shielding Requirements

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Erratum, Med. Phys. 33(9),
3579
September 2006
PET Shielding: AAPM TG-108 Approach

Some Conservative Aspects of TG-108

1) Gantry absorption is not included
2) Spectrum of γ-rays scattered in patient and its effect on attenuation coefficients is not included
## Dose Rate Constants Listed by TG108

<table>
<thead>
<tr>
<th></th>
<th>SI Units</th>
<th>Conventional Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>18F Rate Constants</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure Rate Constant</td>
<td>15.5 ((\mu\text{R/hr}) m(^2)/MBq)</td>
<td>0.5735 (mR/hr) m(^2)/mCi</td>
</tr>
<tr>
<td>Air Kerma Rate Constant</td>
<td>0.134 ((\mu\text{Sv/hr}) m(^2)/MBq)</td>
<td>0.4958 (mrem/hr) m(^2)/mCi</td>
</tr>
<tr>
<td>Effective Dose Equivalent (ANS-1991)</td>
<td>0.143 ((\mu\text{Sv/hr}) m(^2)/MBq)</td>
<td>0.5291 (mrem/hr) m(^2)/mCi</td>
</tr>
<tr>
<td>Tissue Dose Constant</td>
<td>0.148 ((\mu\text{Sv/hr}) m(^2)/MBq)</td>
<td>0.5476 (mrem/hr) m(^2)/mCi</td>
</tr>
<tr>
<td>Deep Dose Equivalent (ANS-1977)</td>
<td>0.183 ((\mu\text{Sv/hr}) m(^2)/MBq)</td>
<td>0.6771 (mrem/hr) m(^2)/mCi</td>
</tr>
<tr>
<td>Maximum Dose (ANS-1977)</td>
<td>0.188 ((\mu\text{Sv/hr}) m(^2)/MBq)</td>
<td></td>
</tr>
</tbody>
</table>

TG-108 recommends 0.143 (\(\mu\text{Sv/hr}\)/MBq) 0.53 (mrem/hr)/mCi for F-18 bare source.
The $^{18}\text{F}$ Injected Patient as a Source

Dose Rate from $^{18}\text{F}$ Injected Patient at 1 m

Sources of variation:
- delay time to measurement,
- micturation status, exposure-to-dose conversion, etc.

TG-108 recommends
- ($0.092 \ \mu\text{Sv/hr})/\text{MBq}$
- ($0.34 \ \text{mrem/hr})/\text{mCi}$

About 20% of dose will be in bladder after 1-2 hours; TG108 uses 15%
**Simplified TG108 Formalism**

B, the required barrier transmission factor, can be calculated as

**Uptake Room:**

\[
B = \frac{10.9 \times P[\mu \text{Sv}] \times d[m]^2}{T \times N_w \times (A_0[\text{MBq}] \times t_U[\text{hr}] \times R_{tU})}
\]

10.9 is \(1/\Gamma\) in \((\text{hr}/\mu \text{Sv})(\text{MBq}/\text{m}^2)\);

\(F_{\text{tot}} = 1\) (no physical decay prior to injection, no elimination)

\(R_{tU} = \text{reduction factor for uptake time } t_U\)

**Scan Bay:**

\[
B = \frac{12.8 \times P[\mu \text{Sv}] \times d[m]^2}{T \times N_w \times (A_0[\text{MBq}] \times F_U \times t_I[\text{hr}] \times R_{tI})}
\]

12.8 includes \(\Gamma\) and the effects of voiding 15% of injected activity before scan

\(F_U = \exp(-0.693t_U/T_{1/2})\), the physical decay of the isotope before the scan
**R_t for PET: Significant Correction for Decay**

**Correction for Decay of F-18**

\[
R_t = 1.443 \times \left( \frac{T_{1/2}}{t} \right) \times \left( 1 - \exp\left( -0.693 \times \frac{t}{T_{1/2}} \right) \right)
\]
NET Effect of Decay, Self-Shielding, Voiding

Effect of Corrections
Cumulative Dose 1 m from Patient, 370 MBq F-18

Dose [microSv]

Time [minutes]

Inject @ 5 minutes
Void @ 65 minutes

A factor of 2 = 1/4" of lead

Uncorrected
Corrected for Physical Decay
Corrected for Physical Decay, Self-Shielding
Corrected for Physical Decay, Self-Shielding, Voiding
Barrier Transmission to Barrier Thickness

Monte Carlo Calculations by Douglas Simpkin (2004)

Curves and fitting parameters for iron and concrete are also found in the report.

Monte Carlo Simulation (Broad Parallel Beam)
Constant TVL 16.6 mm

\[ x(B) := \frac{1}{\alpha \cdot \gamma} \cdot \ln \left( \frac{B^{-\gamma} + \frac{\beta}{\alpha}}{1 + \frac{\beta}{\alpha}} \right) \]
Fitting Parameters are Provided for $B, x$

For PET
(511 keV)

$B(x) = \left[ \left( 1 + \frac{\beta}{\alpha} \right) \cdot e^{\frac{-1}{\gamma}} \right] - \frac{\beta}{\alpha}$

$B(x) = \left[ \left( B^{-\gamma} + \frac{\beta}{\alpha} \right) \cdot \ln \left( \frac{\beta}{1 + \frac{\beta}{\alpha}} \right) \right]$

Archer Parameters

<table>
<thead>
<tr>
<th>Material</th>
<th>$\alpha$ [cm$^{-1}$]</th>
<th>$\beta$ [cm$^{-1}$]</th>
<th>$\gamma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>1.543</td>
<td>-0.4408</td>
<td>2.136</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.1539</td>
<td>-0.1161</td>
<td>2.0752</td>
</tr>
<tr>
<td>Iron</td>
<td>0.5704</td>
<td>-0.3063</td>
<td>0.6326</td>
</tr>
</tbody>
</table>
An **Uptake Room**

An uncontrolled area with 100% occupancy is 4m from the patient. 40 patients a week are injected in this room with 555 MBq (15 mCi) of FDG and held for a 1hr uptake time.

How much shielding is needed?

**Ans:** 1.2 cm of Pb or 15.2 cm of concrete
A Scan Bay

An uncontrolled area with 100% occupancy is 3m from the patient. 40 pts/week, 555 MBq (15 mCi) FDG/pt, 1hr uptake time. Patients void (15% of the dose) at 1 hr. 30 minutes in scan bay.

How much shielding?
Ans: 0.8 cm of Pb or 11.3 cm of concrete
Site Evaluation for PET Shielding

Uses of adjacent spaces (including above and below) and occupancy factors for them

# patients/week
isotopes to be used, activity/pt
types of PET studies to be performed (brains, WB, cardiac)
uptake time and scan time for this equipment/study/center

dose delivery schedule (once a day?, multiples?); maximum activity on hand

CT technique factors (kVp, mAs/scan [depends of # beds])
# scans per patient (additional diagnostic scans?)
amount of "non-PET" CT workload expected
General Suggestions

• At each point, include all principal sources
  – Patient in uptake room
  – Patient in scanner bay
  – Patient in hot toilet
• Spread the lead (multiple thin vs single thick)
• Avoid doors with more than 1/8" Pb
• Planning beforehand to separate hot areas (patient uptake rooms) from uncontrolled areas will pay off!

(Pasciak and Jones -- this month's Med Phys. looks at optimization routines for PET shielding)
Example: Grid Calculation Before Shielding

Sources: Injection room, HL, HWC, Scanner, CT, Cal Source 4 pts/day, 1 hr in uptake, 2 hrs in scan room

Ratio of calculated dose to target dose, adjusted for occupancy
Example Grid Calculation, After Shielding

No shielding in walls in excess of 5/16" Pb; did require ceiling, floor shielding. Was not necessary to run "box" to ceiling.
Example Grid Calculation, After Shielding

OOPS's happen with complicated schemes: Both floor and ceiling needed lead, installed as lead sheet bonded to plywood panels and held in brackets fastened to structural web, but different thickness for ceiling, floor.

The contractor switched them in spite of drawings and well-labeled pallets; did not call for inspection until after ductwork, electricals in.

A very skinny construction worker was needed for the fix.

No shielding in walls in excess of 3/16" Pb, did require ceiling, floor shielding. Was not necessary to run "box" to ceiling.
University Medical Center PET Facility

3 Bays, 4 Uptake Rooms. Overall design: No lead in excess of 3/8". Shell space beyond north wall of injection rooms, hot lab shielded with 16" of dry-laid, full-density concrete block.
Considerations Above and Below

Duct penetrations in ceiling required separate shielding.

Floor Plan

Relative Dose Map on Floor Above
Shielding for SPECT/CT

- Need to know workload (patients per week, isotopes used, activities per patient, CT techniques and usage, etc.)
- CT will often be the main determinant for shielding, but presence of isotope load may require more lead than CT calculation shows.
- Calculating barrier transmission for other materials than Pb may present problems; may be useful to make very conservative assumptions
- Uncontrolled spaces above and below may require attention
An Example SPECT/CT

8 pts/day
4 MDP (27 mCi Tc-99m)
2 renal (16 mCi Tc-99m)
1 Octreotide (6 mCi In-111)
1 Ga-67 (10 mCi);

4 studies w CT,
150 mAs
130 kVp
p = 1
66 cm length
## Shielding for SPECT/CT

Spreadsheet calculates distances, attenuations, doses

<table>
<thead>
<tr>
<th>Point</th>
<th>Description</th>
<th>Floor</th>
<th>Horizontal Distance (ft)</th>
<th>CT Dose (uSv)</th>
<th>Isotope Dose (uSv)</th>
<th>P/T Limit (uSv)</th>
<th>Pb (mm)</th>
<th>Concrete (mm)</th>
<th>CT Dose (uSv)</th>
<th>Isotope Dose (uSv)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rm 5</td>
<td>Same</td>
<td>12.5</td>
<td>426</td>
<td>29</td>
<td>100</td>
<td>0.8</td>
<td>0</td>
<td>14</td>
<td>5</td>
<td>OK</td>
</tr>
<tr>
<td>2</td>
<td>Control</td>
<td>Same</td>
<td>6.6</td>
<td>1344</td>
<td>91</td>
<td>100</td>
<td>0.8</td>
<td>0</td>
<td>45</td>
<td>16</td>
<td>OK</td>
</tr>
<tr>
<td>3</td>
<td>Stub Corridor</td>
<td>Same</td>
<td>6.3</td>
<td>1442</td>
<td>98</td>
<td>100</td>
<td>0.8</td>
<td>0</td>
<td>49</td>
<td>17</td>
<td>OK</td>
</tr>
<tr>
<td>4</td>
<td>Main Corridor</td>
<td>Same</td>
<td>15.7</td>
<td>277</td>
<td>19</td>
<td>100</td>
<td>0.8</td>
<td>0</td>
<td>9</td>
<td>3</td>
<td>OK</td>
</tr>
<tr>
<td>5</td>
<td>Basement (Central Sterile)</td>
<td>Below</td>
<td>0.0</td>
<td>562</td>
<td>38</td>
<td>20</td>
<td>0</td>
<td>82.55</td>
<td>22</td>
<td>11</td>
<td>NOT OK</td>
</tr>
<tr>
<td>6</td>
<td>First Floor (Gift Shop)</td>
<td>Above</td>
<td>0.0</td>
<td>504</td>
<td>34</td>
<td>20</td>
<td>0</td>
<td>184.15</td>
<td>1</td>
<td>2</td>
<td>OK</td>
</tr>
<tr>
<td>9</td>
<td>Hot Lab</td>
<td>Same</td>
<td>22.2</td>
<td>431</td>
<td>10</td>
<td>100</td>
<td>0.8</td>
<td>0</td>
<td>5</td>
<td>2</td>
<td>OK</td>
</tr>
<tr>
<td>10</td>
<td>Toilet</td>
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## Shielding for SPECT/CT

8 pts/day (4 MDP (27 mCi Tc-99m), 2 renal (16 mCi Tc-99m), 1 Octreotide (6 mCi In-111), 1 Ga-67 (10 mCi); 4 studies w CT, 150 mAs, 130 kVp, 66 cm length

Spreadsheet calculates distances, attenuations, doses

<table>
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<tr>
<th>Point</th>
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<th>Floor</th>
<th>Horizontal Distance ft</th>
<th>CT Dose uSv</th>
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1/32 Pb in walls is adequate; needed some in the floor, too

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Some Other Things to Consider

If PET and SPECT are both present in a facility, additional shielding may be necessary to suppress noise from the PET isotopes entering the NM camera.
In Parting, Some of the Problems

1) Patient as source for NM: much of the data is 10-40 years old and is inconsistent.
2) Broad beam attenuation coefficients for concrete, other materials, are not available in an accessible form for many users.
3) Watch out for build-up factors: not all are the same!
3) Layered shielding materials (say lead followed by concrete) present problems
4) Some new PET isotopes (Y-86, Zr-89, I-124) may have larger values of TVL (about twice!) than conventional PET isotopes; some have higher exposure rate constants: may have implications for some scan suites.
People will do the Darnedest Things

In spite of the best planning and design, things on the ground may fail to live up to your expectations. Leaded wallboard mounted upside down!
Acknowledgements

- Michael Viguet, CNMT
- Alice Griego-Garcia, CNMT
- George Jacob, CNMT
- Dana Mathews, MD
- William Erdman, MD
- Richard Massoth, PhD
- Larry Windedahl
- Doug Simpkin, PhD
- Mark Madsen, PhD
The End
Useful Resources

• The x-ray part and general shielding design information:

• Still useful:

• Also useful, for information in appendices

• For information on radioactive patients:
Useful Resources

• Smith DS and Stabin MG, Exposure Rate Constants and Lead Shielding Values for over 1100 Radionuclides, Health Phys. 102(3) 271-291 (2012)
• Shimizu A, et. al., Calculation of Gamma-ray Buildup Factors up to Depths of 100 mfp by the Method of Invariant Embedding (III), J. Nucl. Sci. and Tech. 41(4) 413-424 (2004)
Useful Resources