Shielding for Multislice CT Scanners

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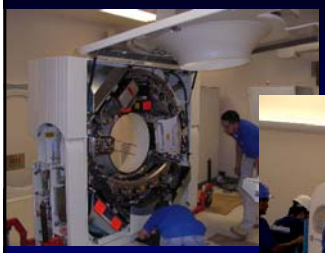

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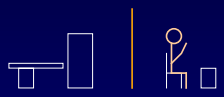
Site Planning for CT

- Location, room dimensions
- Equip type
- Electrical
- HVAC
- Water
- Structural loading
- Shielding

… and one or two $$$$$$

The Shielding Problem

- An administrator's office is adjacent to a CT scan room. The administrator sits 4m from the scanner. How much shielding is required?



3 mm Pb

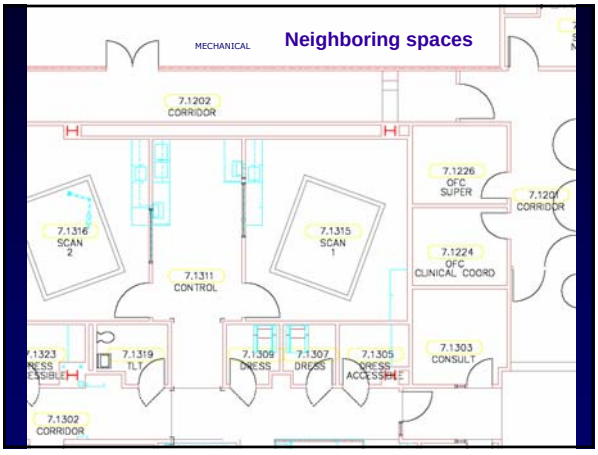
If only it were this easy!!!

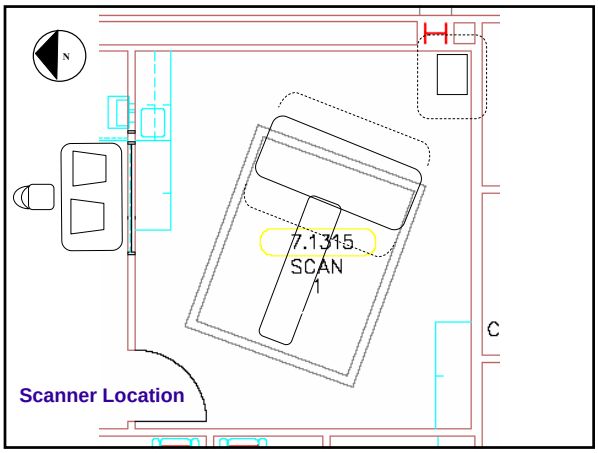
Project Planning

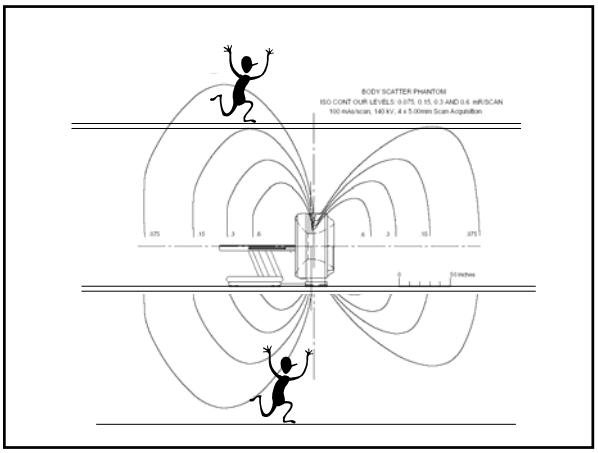
- Neighboring spaces
  - Adj occup factors if needed
  - Dist of closest approach, ≥ 0.3m
- Design goals or limits
  - Public, Controlled, Pregnant worker
  - Adjust if needed
- Workload estimate

Preliminary Information

- Architectural drawings (Plan view) of exam room,
  floor above, and floor below
  - Elevation sections for floor and ceiling
  - Occupancy factors for floors above and below
  - Two rooms away or across hall (remote areas may be more sensitive than adjacent)
- Composition of walls, ceilings and floors
  - Materials and thickness
- Scanner placement from vendor
  - Distance to protected areas beyond barriers
- Scatter contributions from other rooms/floors







Workload Estimates

- Number procedures per week
  - 3 patients per hour
  - 1 to 5 procedures per patient
- Body% and Head%
- Contrast and non-contrast scans
- 120kVp vs other kVp
- Scan parameters of protocol

Multi-Slice Helical CT Shielding

- Thinner slice protocols may require more dose – create more scatter
  - More photons needed to generate adequate photon statistics per slice (smaller voxels, higher noise)
  - Environmental radiation levels typically increase with increase in beam width
  - However, fewer rotations are needed to produce the scan

Multi-Slice Helical CT Shielding

- Over-scan at ends of volume add scatter

  - Worst with widest beams
- Ceiling and floor deserve close scrutiny

Barrier Determination

- NCRP 147, section 5.6, pg 94
- CTDI method
- DLP method
- Scatter plots

CTDI Method

- What we need to know:
  - Pitch = table/beam
  - Beam width: T_b or (nT)
  - Rotation time
  - Peripheral CTDI100
  - – measure (can scale by kVp2)
  - – Look on ImPACT website

CTDI Method

Unshielded weekly exposure calculation:

Secondary exposure per procedure at one meter K $\left[\frac{1}{s}\right]$

$$= \kappa \times \left[\frac{L}{p}\right] \times \left[\text{mAs/Rotation}\right] \times \left[\text{CTDI}_{100,\text{ peripheral}}/\text{mAs}\right] \times \left[\frac{\text{Scan kV}}{\text{CTDI kV}}\right]^2$$

Where:

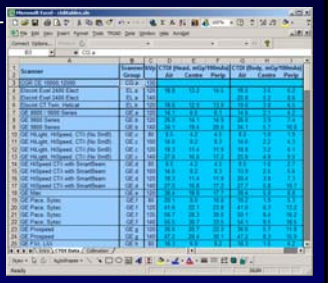
κ is the scatter fraction at one meter per cm scanned.
L is the length of the scanned volume.
p is pitch.

κ (head)	9×10^{-5} cm^{-1}
κ (body)	3×10^{-4} cm^{-1}

CTDI Method

- ImPACT (the UK's CT evaluation center)
- measured axial and peripheral $CTDI_{100}$
- for most scanners on the market
- Excel format

www.impactscan.org



NCRP 147 DLP Method

DLP (Dose-Length Product)

- – $CTDI_W$ = 1/3 ctr $CTDI_{100}$ + 2/3 Surf $CTDI_{100}$
- – $CTDI_{VOL}$ = $CTDI_W$ / Pitch
- – DLP = $CTDI_{VOL}$ * L
- – L = Scan length for average ***series*** (cm)
- – Units of mGy-cm
- – From scanner display … verify these values!

$$DLP = [{}^1/_3\ CTDI_{100,\text{ Center}} + {}^2/_3\ CTDI_{100,\text{ Surface}}] * L/p$$

NCRP 147 DLP Method

- Weekly Air Kerma at 1m (K^1_{sec})

K^1_{sec} (head) = κ_{head} * DLP
K^1_{sec} (body) = 1.2 * κ_{body} * DLP

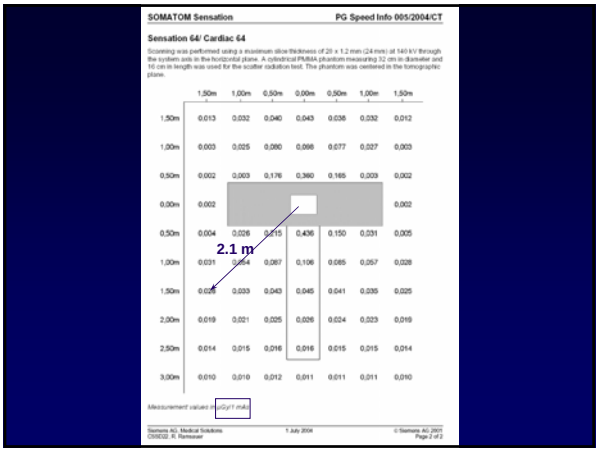
Factor of 1.2 assumes peripheral $CTDI_{100}$ = 2*Center $CTDI_{100}$ for Body

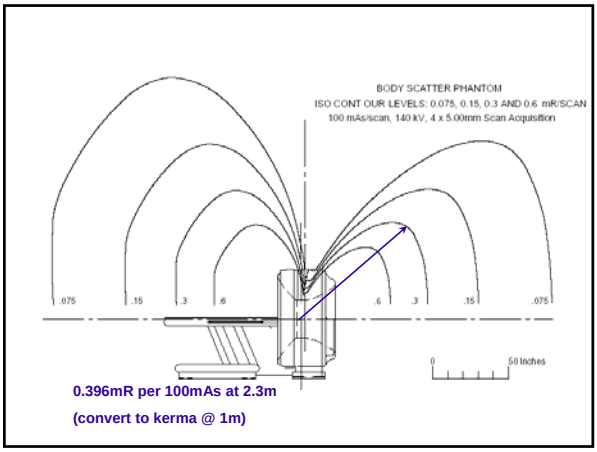
$\kappa_{head} = 9\times10^{-5}$ cm^{-1}
$\kappa_{body} = 3\times10^{-4}$ cm^{-1}

Use inverse square to find unshielded weekly exposure at barrier from K^1_{sec}

Scatter plot Method

- Assume an isotropic exposure distribution w/ the vendor-supplied scatter distribution plots (max is approx. 45° to the scanner axis).
- Overestimates shielding for gantry shadows
- W, in mA*min per week ⚠
- Determine weekly exp at shielded point
- Pay attention to
  - – Beam width
  - – kVp and mAs
  - – phantom





⚠ Use Caution with Scatter Plots

- Choice of plot (Head vs Body)
- Normalization of data
  - kVp of plot vs clinical
  - mAs per scan
  - Beam width of plot vs clinical
- Total mAs per scan
  - Pitch, rotation, total beam-on time
  - Accounts for scan acquisition time for diff beam width

Question

Do I really need to put lead in the ceiling of a 64-slice CT scan room?

Method

- Calculate the unshielded weekly exposure rate at 0.5 m beyond the floor above
  - Find the maximum weekly exposure at 1 m from isocenter and inverse-square this out to the occupied area beyond the barrier.
- Perform barrier thickness calculations
  - Occupancy, permissible dose, attenuation of concrete, etc.

Example

- 180 Procedures/week
  - 150 Abdomen & Pelvis L= 60cm + 0.4*30cm
  - 30 Head L= 1.4 * 15cm
- 40% w&w/o contrast
- 13.0' (4.2 m) ceiling height (finished floor to finished floor) D_{sec}= 3.7m
- GE LightSpeed 16
- Ignores overscan at ends!
  - Effect Worsens with wider beams (64-slice)

Protocols

	kVp	mA	Time (sec)	Pitch	Beam (mm)	Table (mm/rot)
Head	120	240	1.0	1.375	10	13.75
Body	120	265	0.8	0.938	20	18.75

NCRP 147 DLP Method

Procedure	$CTDI_{Vol}$ (mGy)	Scan Length (L, cm)	DLP (mGy-cm)
Head	60	20	1200
Body	15	35	525
Abdomen	25	25	625
Pelvis		20	500
Body (Chest, Abdomen, or Pelvis)			550

Unshielded Weekly Exposure at Barrier

- Average Air Kerma/procedure at 1m (K^1_{sec})
  - 40% w&w/o contrast

K^1_{sec} (head) = 1.4 * κ_{head} * DLP
= 1.4 * $9x10^{-5}$ cm^{-1} * 1200 mGy-cm
= 0.15 mGy

K^1_{sec} (body) = 1.4 * 1.2 * κ_{body} * DLP
= 1.4 * 1.2 * $3x10^{-4}$ cm^{-1} * 550 mGy-cm
= 0.28 mGy

Unshielded Weekly Exposure at Barrier

- Weekly Air Kerma (K_{sec}) at Ceiling:
  - 30 head procedures/wk
  - 150 body procedures/wk
  - D_{sec}= 4.2 m + 0.5 m – 1 m = 3.7 m

K_{sec} (head) = 30 * 0.15 mGy * $(1m/3.7m)^2$
= 0.33 mGy

K_{sec} (body) = 150 * 0.28 mGy * $(1m/3.7m)^2$
= 3.04 mGy

Unshielded Weekly Exposure at Barrier

- Weekly Air Kerma (K_{sec}) at Ceiling:

K_{sec} (Total) = K_{sec} (head) + K_{sec} (body)

K_{sec} (Total) = 0.33 mGy + 3.03 mGy

K_{sec} (Total) = 3.37 mGy

Required Transmission (B)

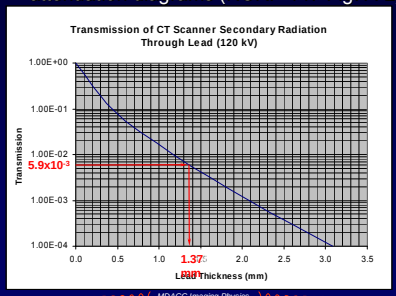
$$B = \frac{P}{K_{sec} * T}$$

P = Maximum permissible weekly exposure
T = Occupancy Factor

$$= \frac{0.02 \text{ mGy}}{3.37 \text{ mGy} * 1} = 5.9x10^{-3}$$

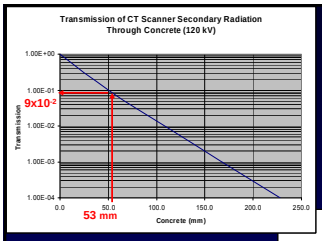
Total Shielding Required

Use Simpkin curve fit equations or look up on published attenuation diagrams (NCRP 147 Fig. A-2)

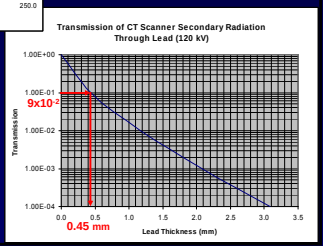


Existing Shielding

- Determine attenuation of existing barriers with Tc-99m source and Na-I detector
- Determine lead-equivalence of barrier
- Floors and ceilings
  - Find lead equivalence from documentation of concrete thickness.
  - If necessary, Find thickness by drilling a test hole and measuring.
  - Always assume light weight concrete, unless proven otherwise (30% less dense than standard density, coefficients used in NCRP 147)



3" light concrete = 2.1" std concrete
= 53 mm std concrete
B = $9x10^{-2}$
= 0.45 mm Pb-equivalent



Existing Shielding

- Subtract existing lead-equivalence from total required
- Convert to 1/32 inch multiples (round up)
- Total lead to add = (Total required) – (Existing)

= 1.37 mm– 0.45 mm

= 0.9 mm

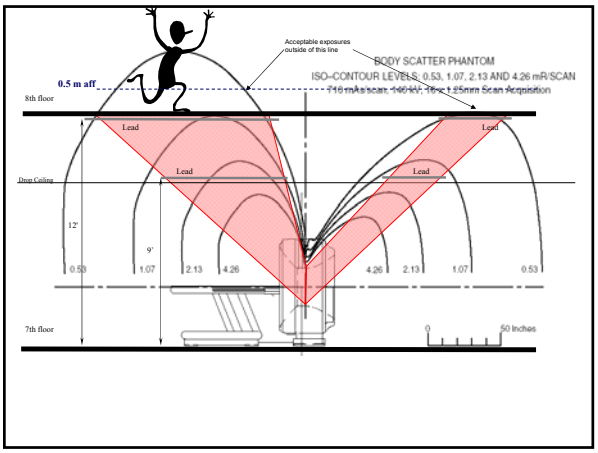
Round up to 1/16" Pb

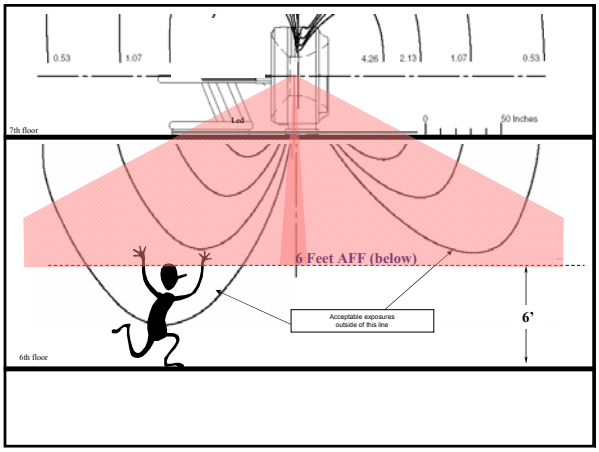
Comparison of Methods

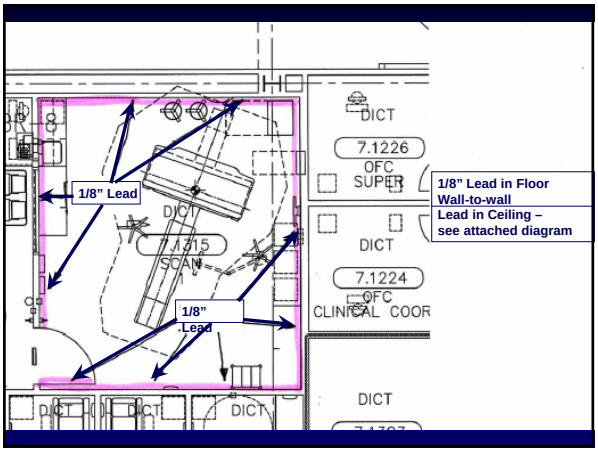
	DLP NCRP 147		$CTDI_{100}$		Scatter plot	
	Head	Body	Head	Body	Head	Body
K^1_{sec} @ 1m	4.5	42	2.0	101	2.9	95
Weekly kerma @ 3.7m	3.37		7.53		7.11	
Total Barrier (mm Lead)	1.4		1.7		1.7	

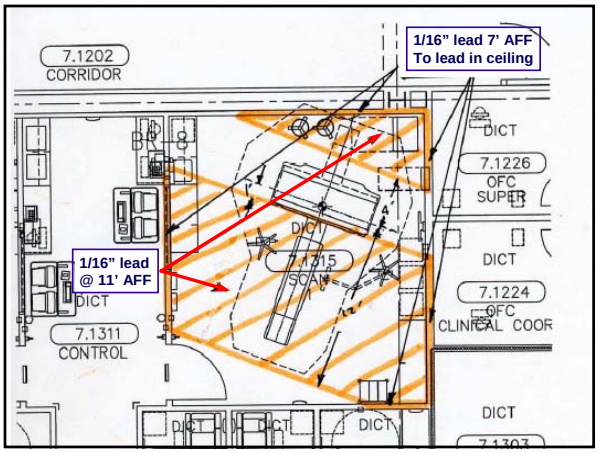
Ceiling Considerations

- Pb mounting in ceiling is manually applied and très cher! (very expensive!)
- Isotropic distribution is conservative, but not so realistic
- Consider % of scans helical w/o gantry tilt (tilted axials usually for Head only)
- Smaller area of ceiling to cover = smaller cost … THIS time
- Additional cost possibly incurred in future renovation







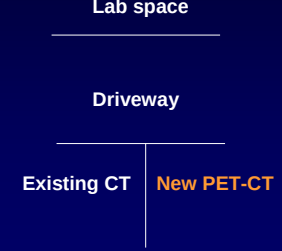


Watcha Gonna Do? #1

- Attended waiting room adjacent to CT room
- New PET-CT to be installed on floor below

Watcha Gonna Do? #2

- CT room on 3rd floor, exterior wall, standard windows
- Lab area across driveway
- Current kerma in labs OK, but close to limit
- New PET-CT to be added adj to existing CT



Thank you!

Acknowledgements:

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