Total Body Irradiation (TBI)

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Medical Goals of TBI

- Immunosuppression – Eliminate lymphocytes for grafting of donor bone marrow in hematopoietic stem cell transplantation
- Eradication of malignant cells – Leukemia, lymphoma
- Eradication of cells with genetic disorders: Fanconi's anemia, thalassemia

Benefits of TBI

- No sparing of “sanctuary sites” such as the testes
- Dose is homogenous throughout the body independent of blood supply
- No cross-resistance with other agents
- No alteration of dose through detoxification or excretion, independent of hepatic/renal function
- Dose distribution can be tailored by blocking normal tissues and boosting areas at risk

TBI sequelae

- Acute: Nausea, parotitis, xerostomia, diarrhea, skin erythema, alopecia, fatigue, headaches.
- Late: Pneumonitis, cataracts, growth/developmental delay, infertility, thyroid dysfunction, cardiac toxicity, veno-occlusive disease, renal damage, secondary malignancies

Physics Goals of TBI

- Deliver Whole Body dose
- ±10% Dose homogeneity
- 8-12 cGy/minute dose rate

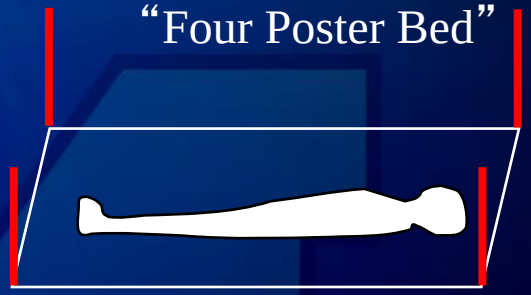
Tx Techniques

- Multiple Radioactive Sources
- Two Fields using Linac
  - AP/PA
    - Lying on Side
    - TBI Stand
  - R/L Lateral

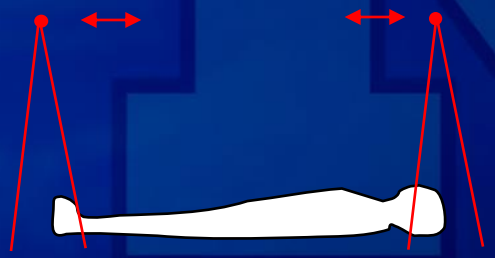
Multiple Radioactive Sources

Cs-137
or
Co-60

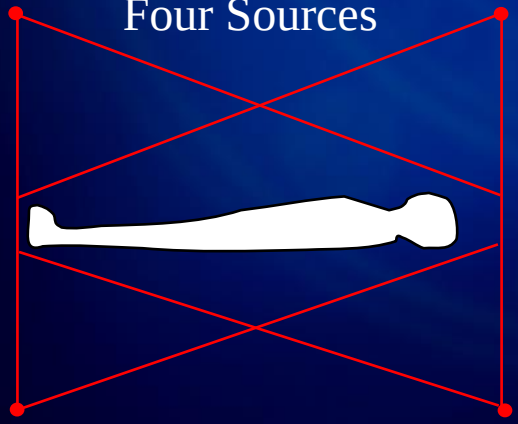
"Four Poster Bed"



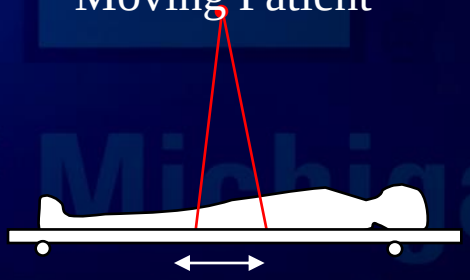
Moving Sources



Four Sources

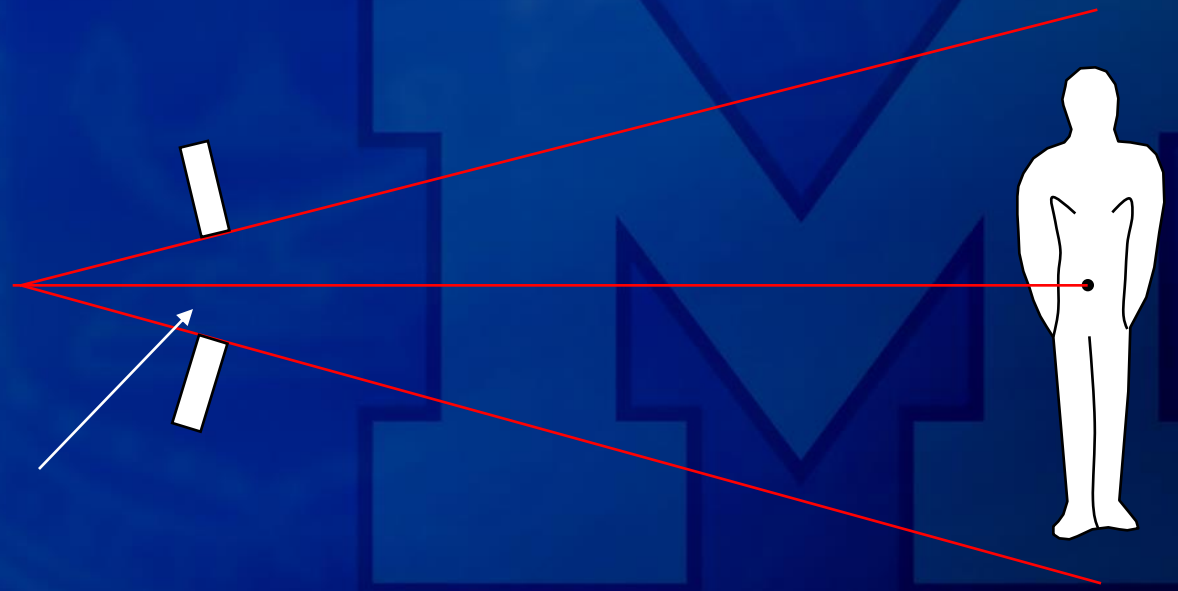


Moving Patient



Large Field – Extended SSD

Two Fields
Four Fields



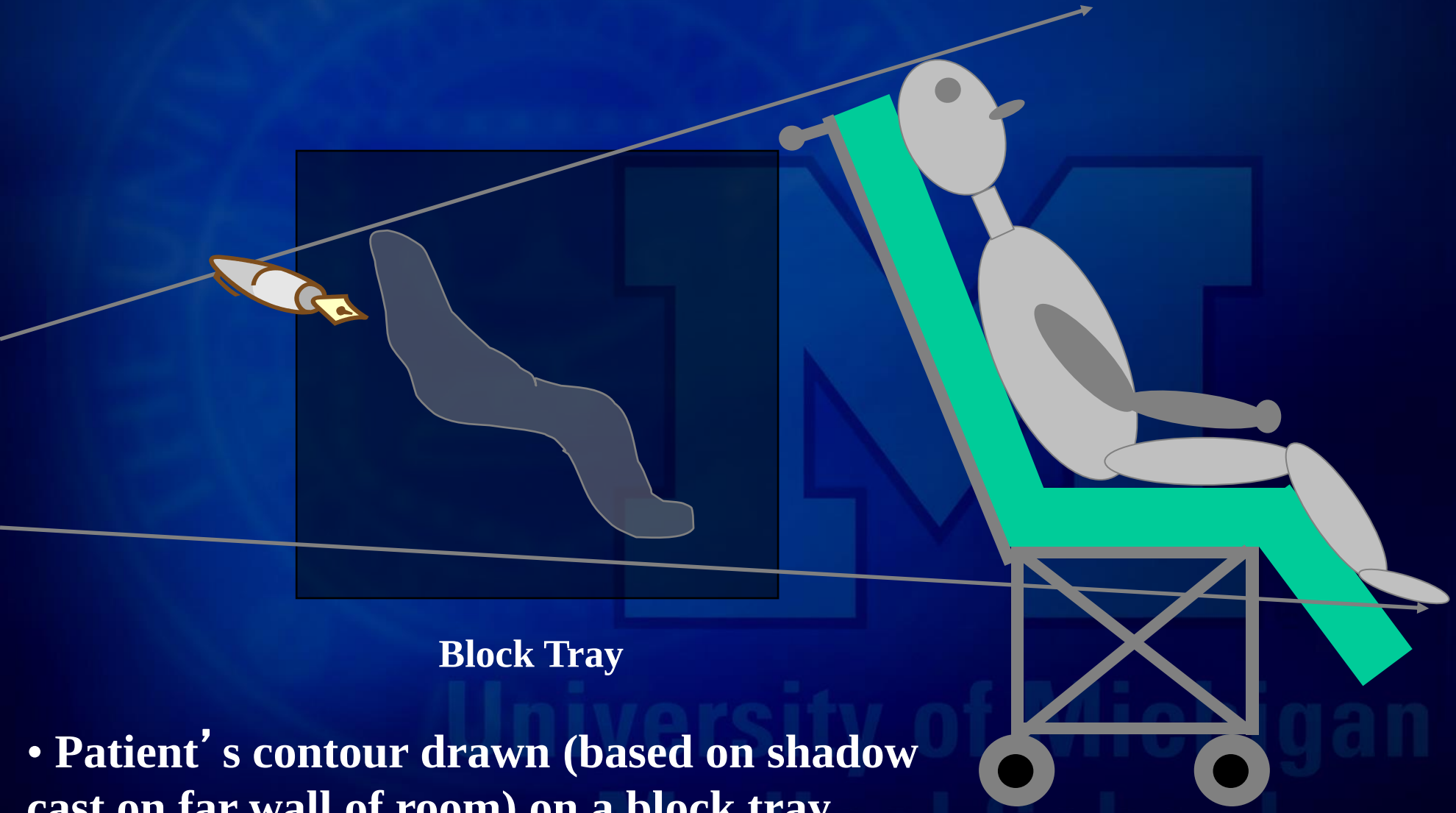
Large jaw setting

Loooong SSD

Patient Simulation for a Lateral TBI Setup

- Gantry is set to 90º.
- TBI tray is inserted into gantry head.
- Patient positioned in lateral orientation relative to beam.
- Chair is translated and inclines adjusted until patient is comfortable and completely within light field.

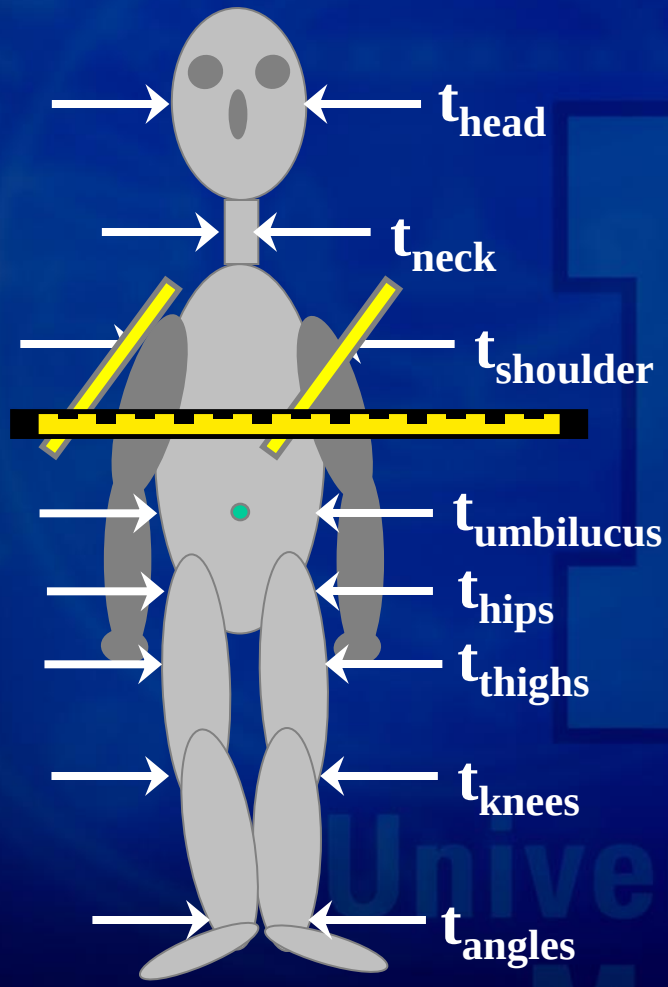
Patient Simulation

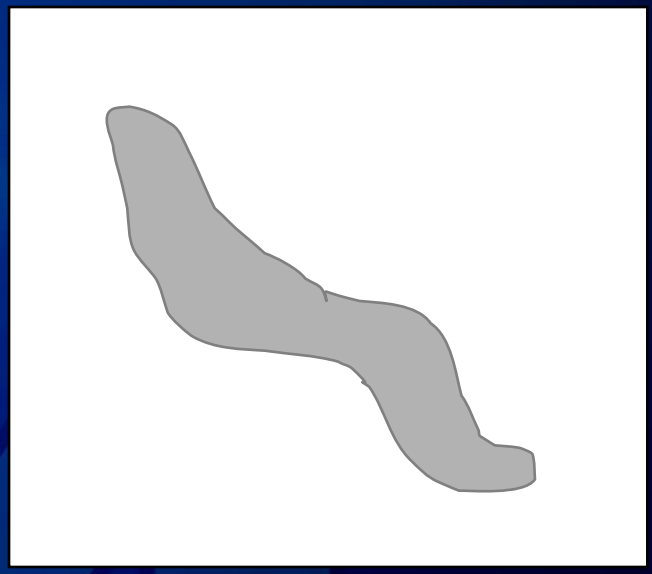


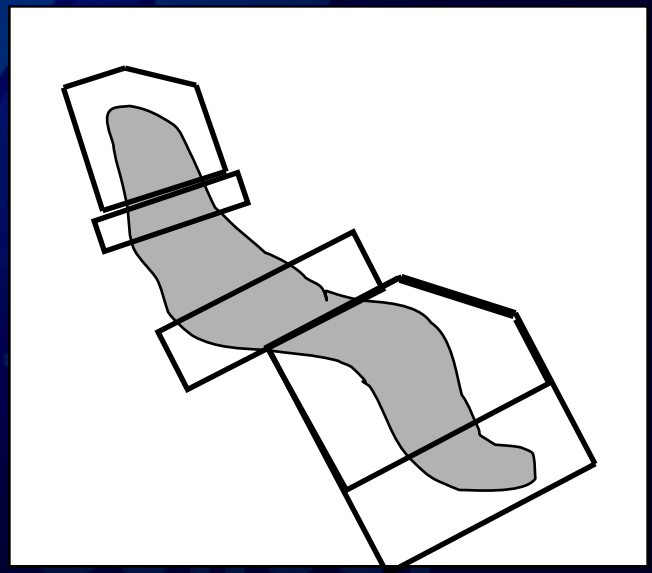
Block Tray

• **Patient's contour drawn (based on shadow cast on far wall of room) on a block tray.**

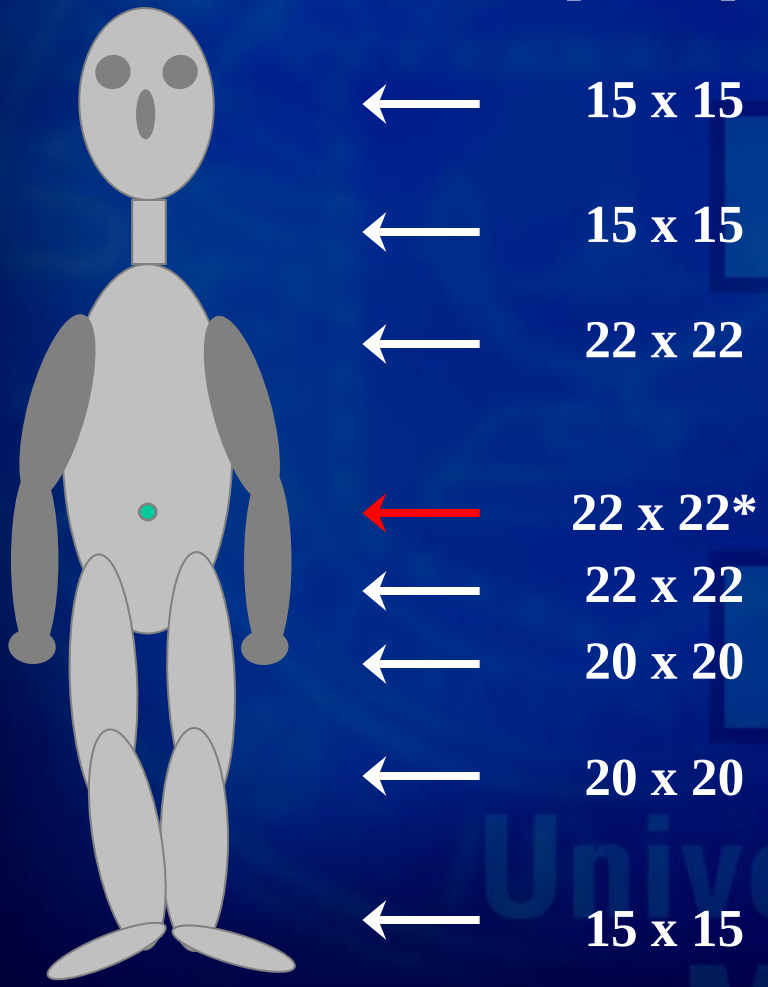
Constructing a Compensator







Treatment Planning (Mayo)



- Prescribed dose of 13.2 Gy to the umbilicus with 6 MV beam.
- Source-to-midplane distance 400 cm.
- Dose to entire body calculated by dividing body into smaller field sizes.

Dose Calculation

To calc. MU to umbilicus:

$$MU = \frac{TD}{TPR(d, r_d) \times IVS \times S_c(r_{40x40}) \times S_p(r_{blocked}) \times TF}$$

Dose to other parts of the body:

$$Dose = MU \times TPR(d, r_d) \times IVS \times S_c(r_{40x40}) \times S_p(r_{blocked}) \times TF$$

Total thickness of Pb compensator for each region calculated:

$$t = -\frac{\ln(Dose/TD)}{\mu} = -\frac{\ln(Dose/TD)}{\ln(2)/HVL}$$

Treatment Setup and Delivery

- Diode measurements acquired for first three fractions.
- If readings too high or low, number of Pb compensators adjusted.
- Physics present for all fractions to verify position of patient and compensators.

Pro's and Con's of Lateral Technique

Pro's

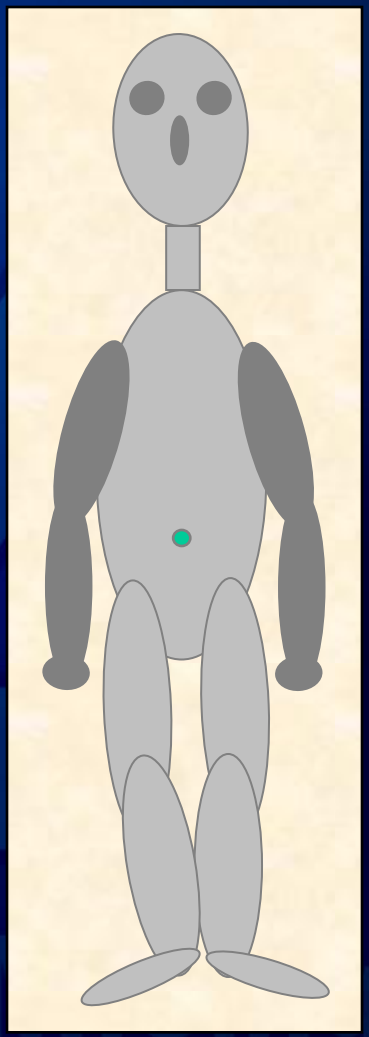
- Dose to lung and kidneys less of an issue compared with AP/PA technique.

Con's

- Labor intensive:
  - –Patient specific compensators required.
  - – Doses should be verified at least for the first two treatments.
- Although positioning arms at sides limits lung dose, could also results in underdose of marrow at the manubrium and ribs.

Lateral Option

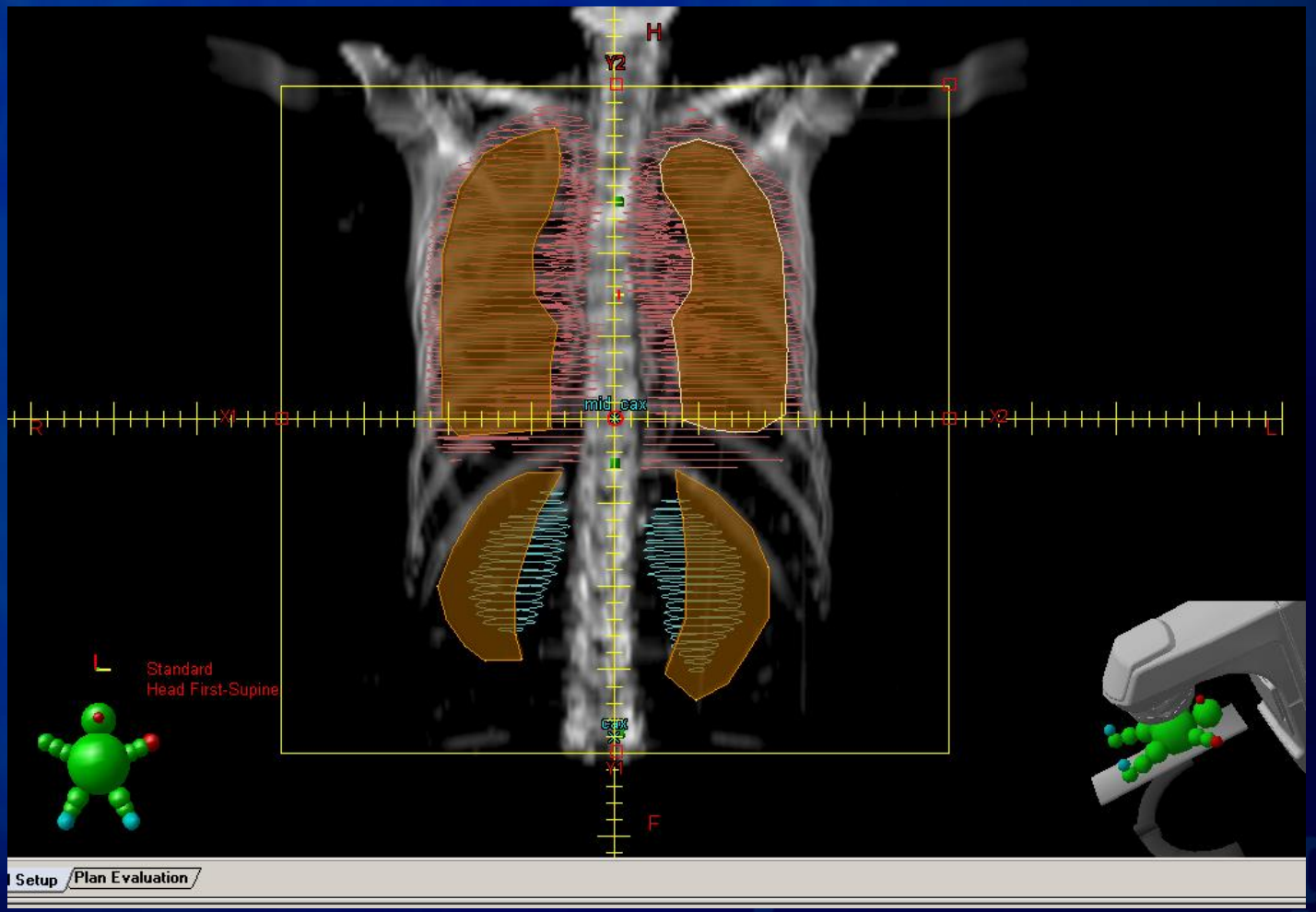
- Patient in a box of bolus
  - Plexi Glass Box
  - Fill with rice bolus
  - Equalizes separation



TBI Stand

- Standing position
- Bicycle seat and hand holds
- Rapid block placement
- Beam Spoiler

Blocking for Systemic Sclerosis

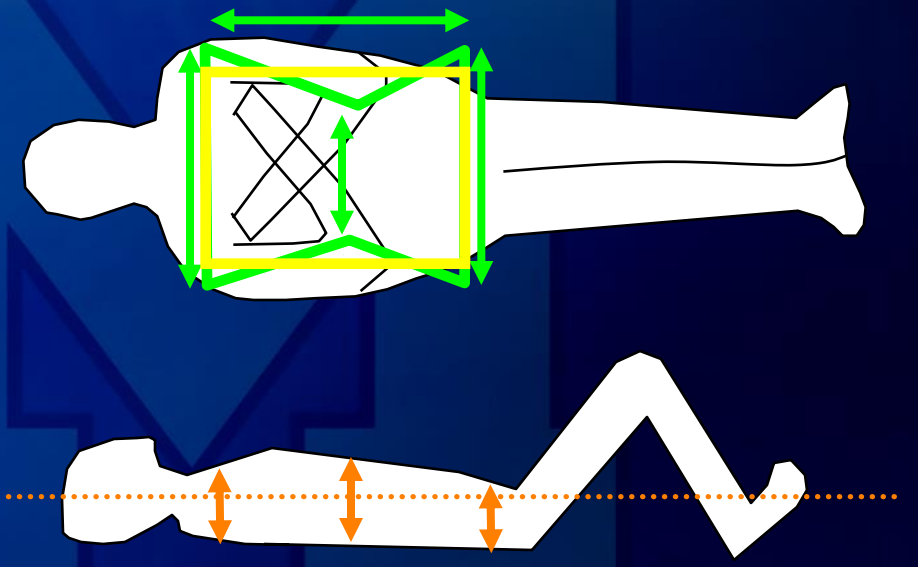


Large Field AP/PA

- AP/PA, 16MV, MPD Rx
- Patient Decubitus
- Arms Crossed to cover chest
- Legs Bent

Simulation

- Patient is a box!
- Length
- Three Widths
- Three Separations
  - MPD Calc’ on umbilicus



Calculation

- Rx to MPD to umbilicus
  - Depth (separation/2)
  - SSD (6m- depth)
  - EQSQ for S_p (patient is a box)

- ~ 4500 MUs per Beam

Example Calculation

- 2Gy/fx, MPD, 12 Gy
  Total BID 6 hours
  - Length 59cm
  - Shoulders 42/19
  - Umbilicus 32/25
  - Pelvis 35/24

  4498 MU per beam!

Department of Radiation Oncology, University of Michigan Medical Cen

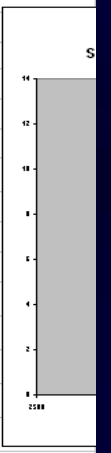
Patient Name:	$bob, billy	Nick Name:	$bob007
Reg#:	02112007		

Dose/Fx (Gy)	1	1
Script Dose (Gy)	12	12
No. of Fractions	6	6
Machine:	EX-3	EX-3
Field/Seg #	1	2
Field Name	PA	AP
Energy	16X	16X
Gantry Angle	90	90
Colimator Angle	0	0
Table Angle	0	0
SSD @ CX	587.5	587.5
MDP Depth	12.5	12.5
Coll width	30	30
Coll Length	40	40
Sc EqSq@iso	28.2	28.2
Sc	**1.038**	**1.038**
TPR	**0.953**	**0.953**
Sp EqSq@iso	7.50	7.50
Sp	**1.038**	**1.038**
ISL	**0.028**	**0.028**
Yes Spoiler	**0.976**	**0.976**
Plan Dnorm(%)	**50**	**50**
Dose (Gy)	**1**	**1**
cGy/MU (Table)	0.0223	0.0223
cGy/MU (Calc)	0.0223	0.0223
Dose rate mu/min	400	400
Dose rate cGy/min	8.90	8.90
Check %Error	-0.01%	-0.01%
MU	**4493**	**4493**
Backup Timer	11.3	11.3

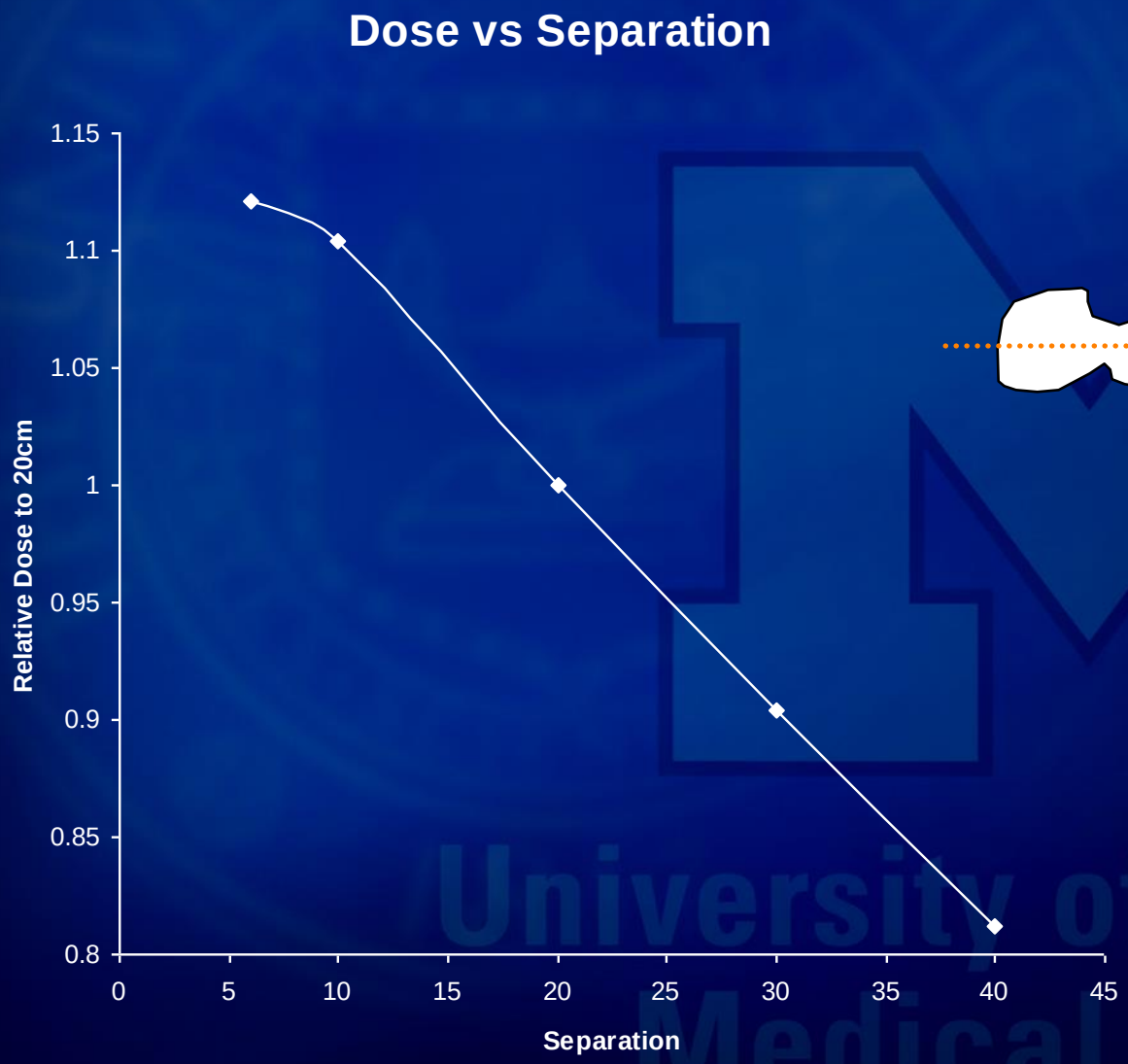
Dosimetry by Scott W Hadley

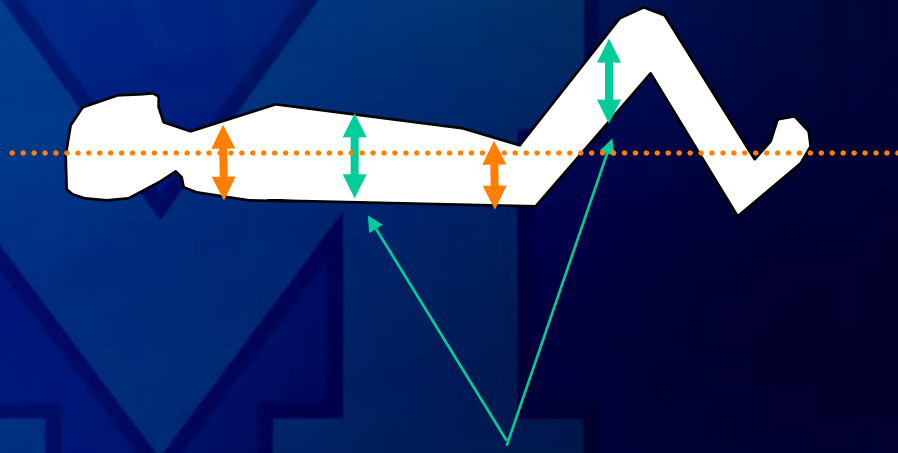
Checked by _____

MU=Rx(Gy)*Dnorm/(TPR*Sc*Sp*ISL*Spoil*Cal)



Separation

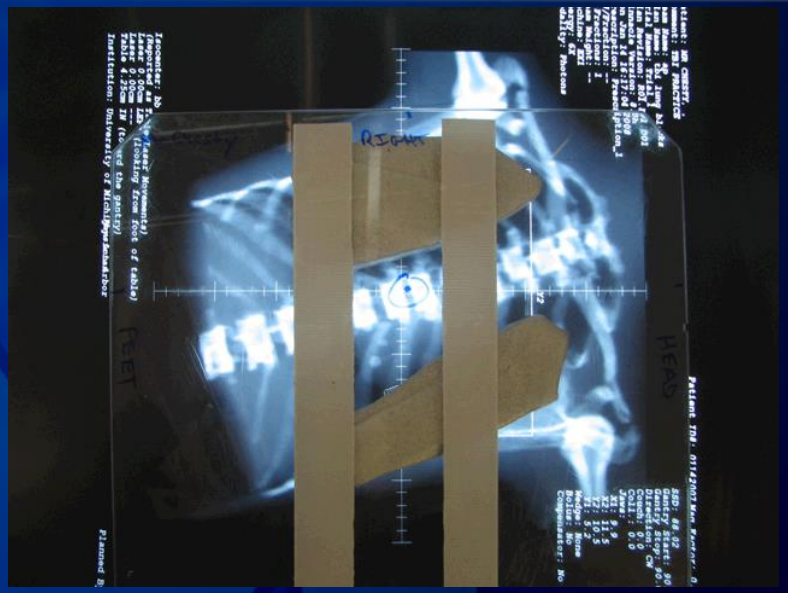


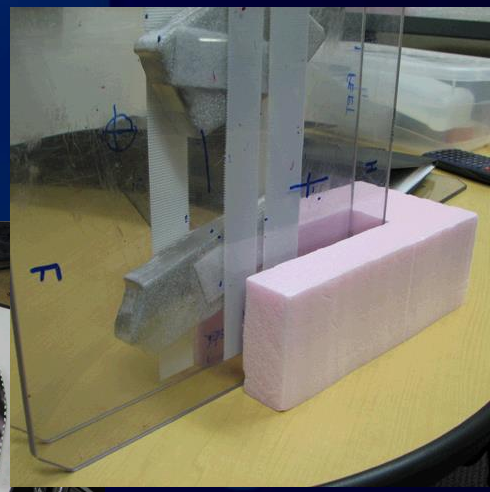


Try to get the same separation with bent legs!

Lung Dose

- ↑ Dose to lung due to ↓ density
- Cross arms over chest
  - 110% of Rx Dose
- Lung Blocks
  - Difficult to place at treatment



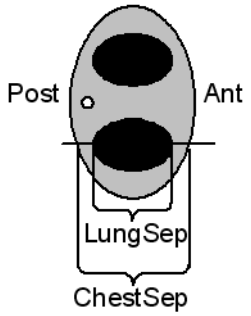


Block Thickness Calculation

Umbilicus Separation for MU Calculation	Sep_C =		cm
S_p equivalent square (S_pEQSQ)			cm

Lung Block Calculation: Measurements at center of larger block. Pick an area that represents the separation of the lung well.

Chest separation from CT			cm
Lung separation from CT			cm
Equivalent path length of chest (EPL) (SepChest-SepLung) + 0.3 x SepLung =			cm
Lung TMR_L(EPL, S_pEQSQ) =			
Calculation TMR_C(Sep_C, S_pEQSQ) =			
Transmission Factor	LDR x TMR_C / TMR_L =		Between 0 and 1
(from Transmission Table) Lung Block Thickness =			cm
(measured using caliper) Block Thickness as Made =			cm

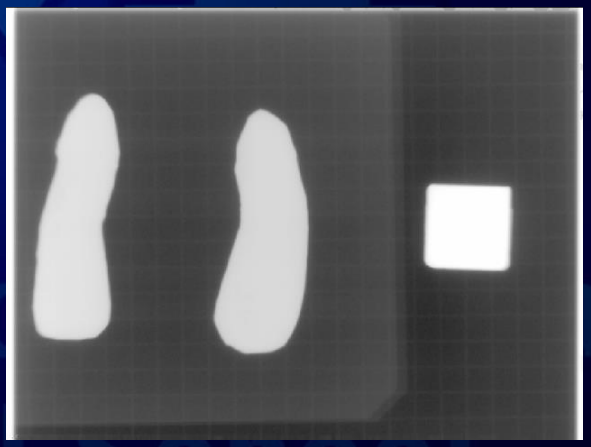


Transmission Table: Circle the value used for block thickness.

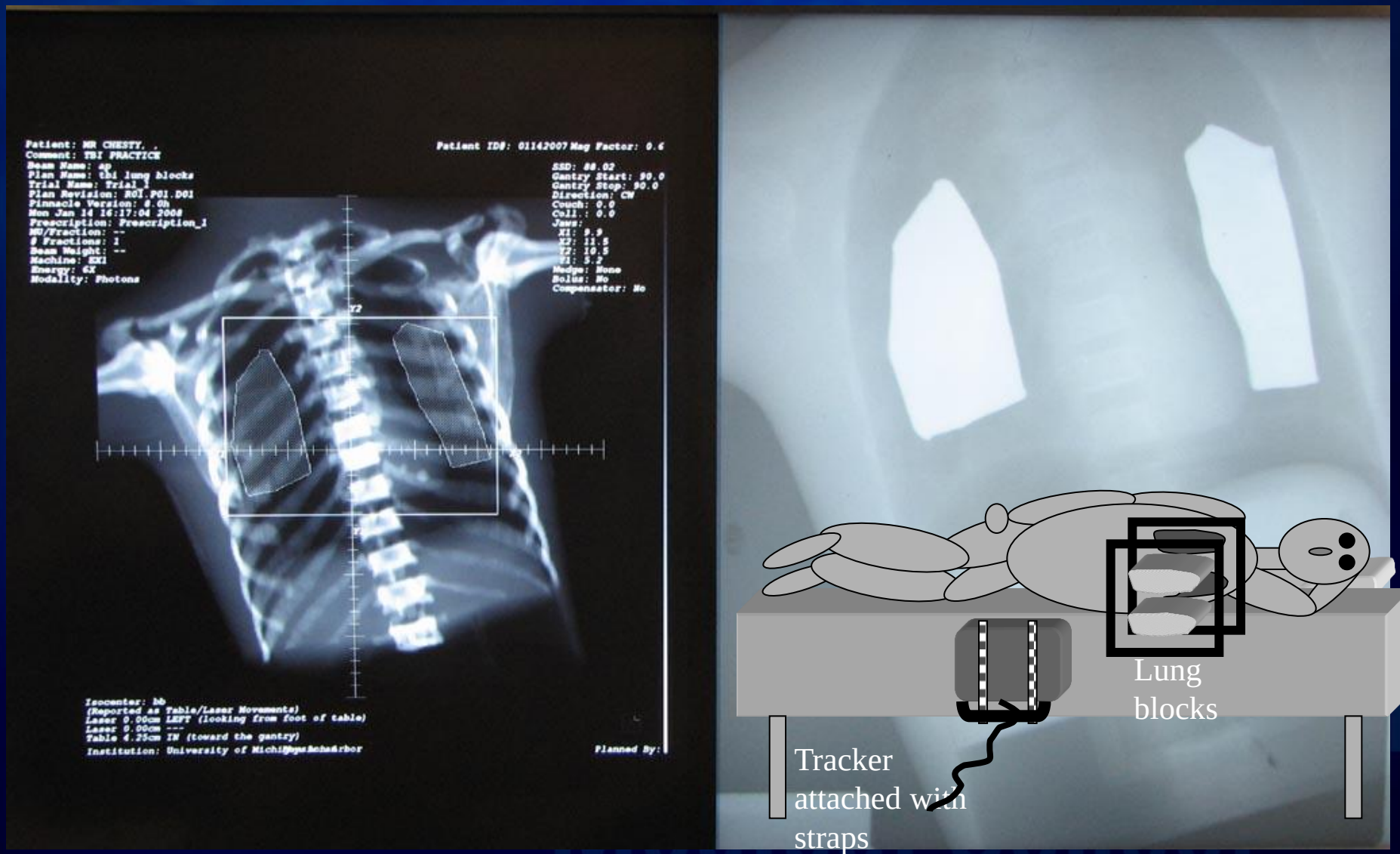
T	Block Thickness (cm)
0.20	5.0
0.25	4.1
0.30	3.5
0.35	3.0
0.40	2.6
0.45	2.2
0.50	1.9
0.55	1.7
0.60	1.4
0.65	1.2
0.70	1.0
0.75	0.9

Lung Block QA

- Measure Transmission of Blocks
  - Transmission = PV Block/PV Open + 0.038
- Look for defects

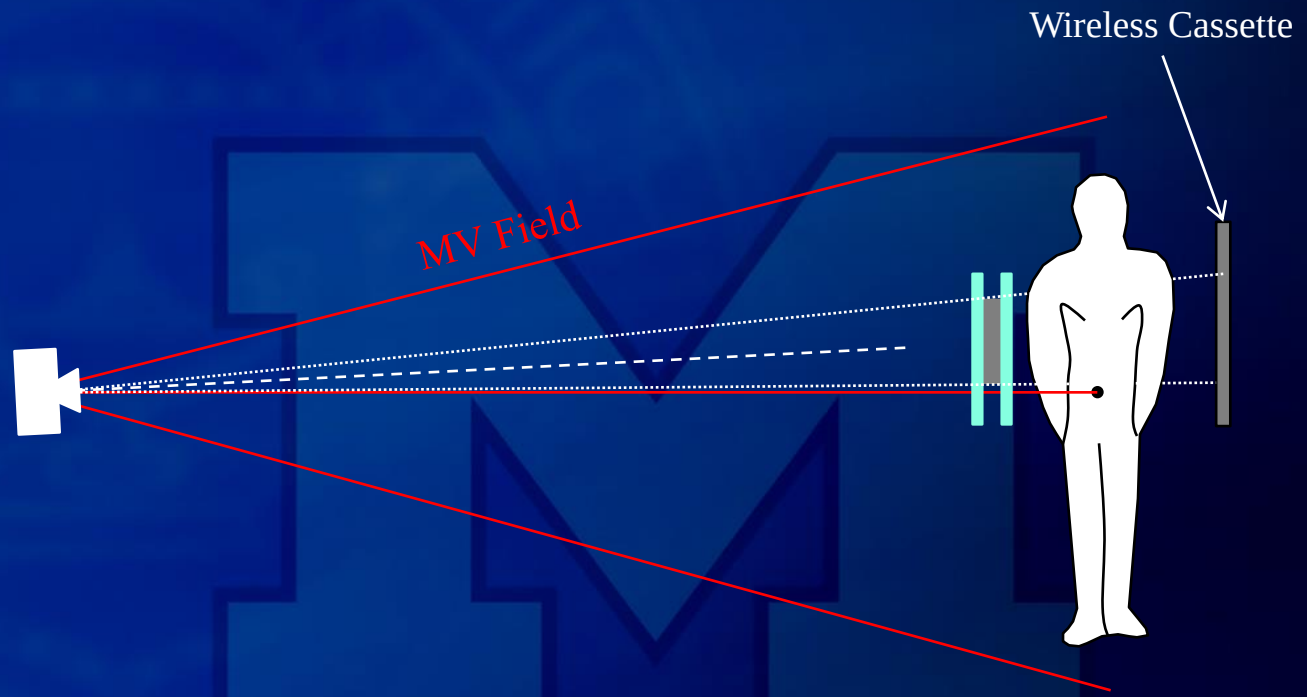


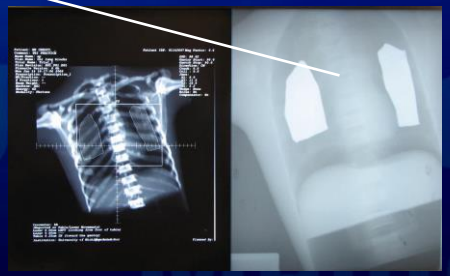
Lung Block Filming



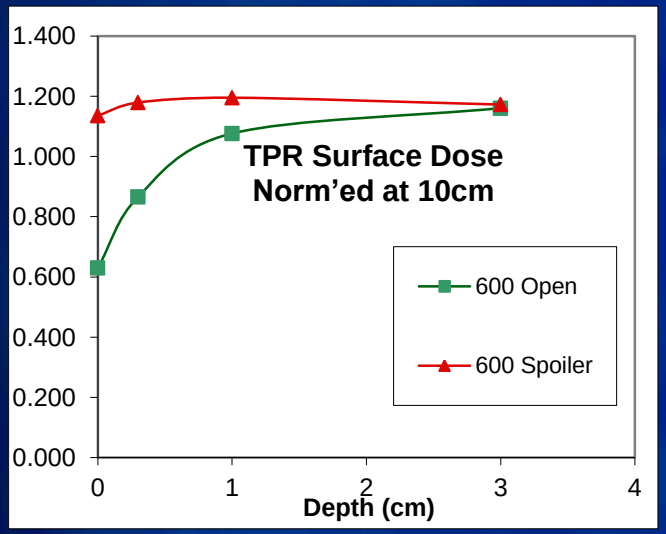
Portable X-Ray Unit for TBI Blocks

bye bye film processor





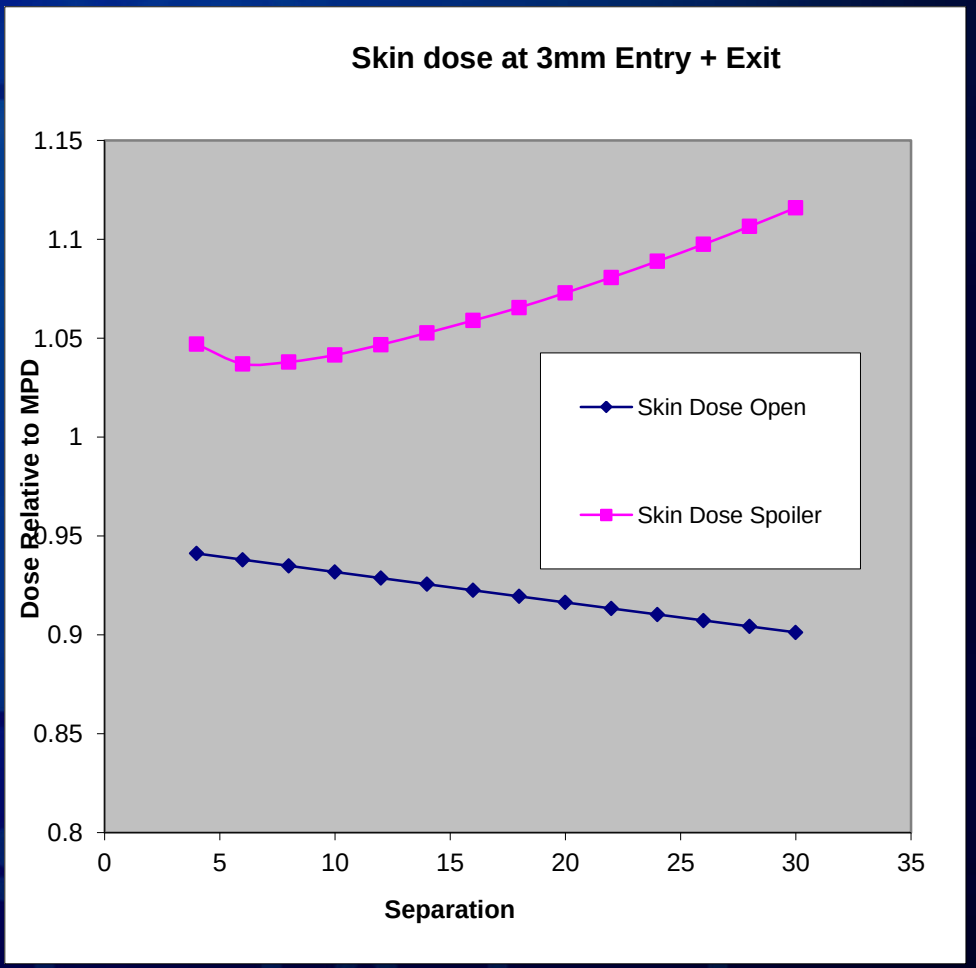
Beam Spoiler`



- 4x8 Feet Plastic Sheet
- ~1cm Thick
- Increase the skin dose
- Pre-Build Up

Skin Dose

- No Spoiler
  - As Sep’ ↑
  - Skin Dose ↓
- With Spoiler
  - As Sep’ ↑
  - Skin Dose → 110%



In-vivo Dosimetry

Site	Monday AM	Monday PM	Tuesday AM
Post Back	97%	96%	96%
Ant Belly	95%	98%	95%
Post Neck	101%		
Right Flank	109%		
Ankle	116%		
Lt Arm Pit		113%	
Testicles		104%	
Inner Thigh		101%	
Knee Cap		108%	

Typical Prescriptions

- 2 Gy/fx to 12 Gy BID
- 2 Gy/fx for single fraction
- 1 Gy/fx for single fraction

Dose Rate

- Targeted for 10cGy/Min
- 2Gy/fx dose → 10 Min/beam

EX3 Treatments

- 16MV Photons
- 6 meters Source to MPD
  - Distance from wall
- 30x40
- TBIX accessory to allow 1000s of MUs

EX2 vs EX3

	EX2	EX3
Source to MPD	383.5cm	600cm
Field Size	40x40 45º Coll’	40x30
FS at MPD	< 217cm	240cm