Dosimetric Effects of Couchtop and Immobilization Devices (AAPM TG 176)

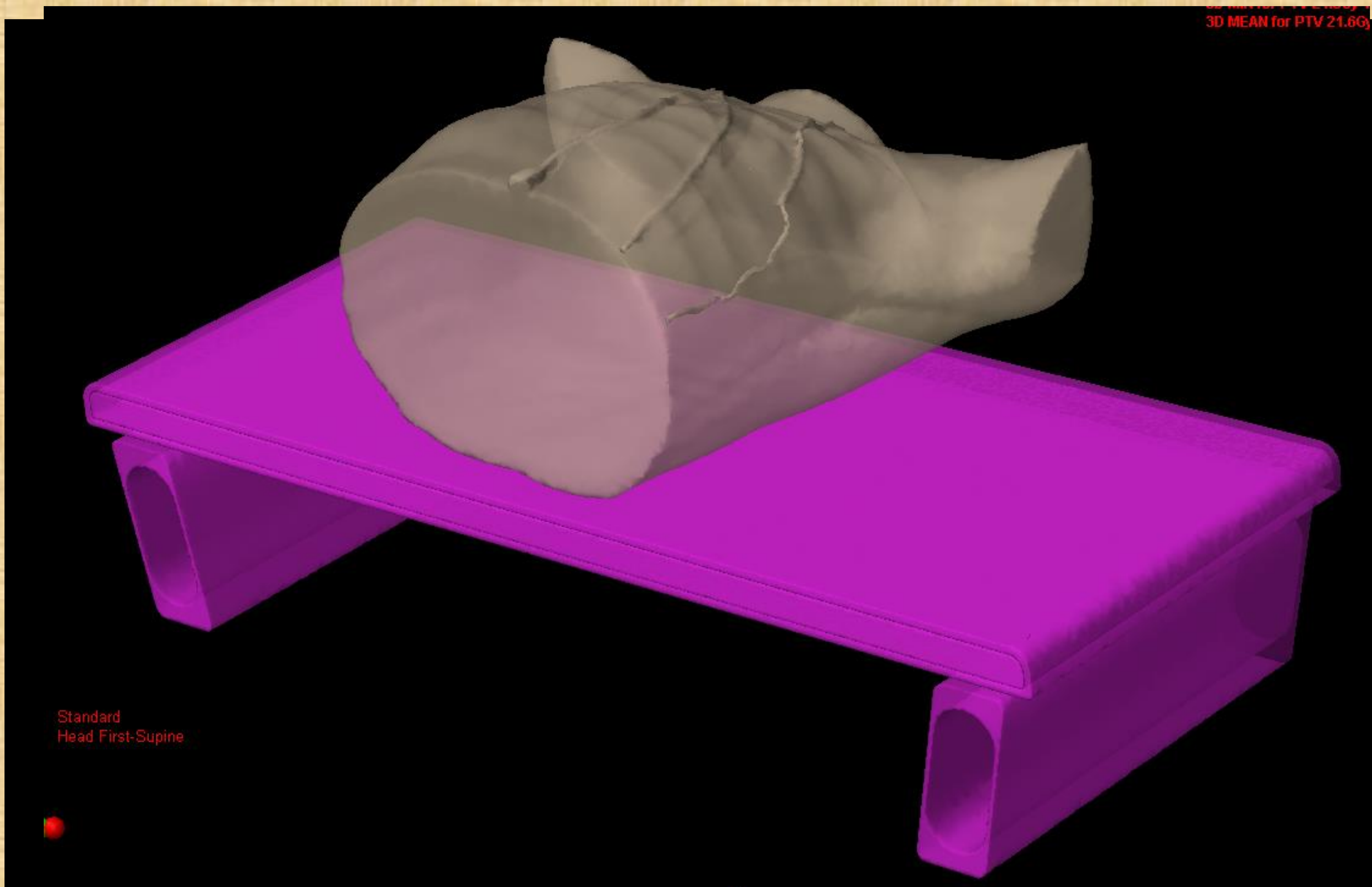
A Preview

Arthur Olch, Ph.D., Chair TG 176

University of Southern California Keck School of Medicine, Los Angeles CA,

Childrens Hospital Los Angeles

We don’t treat patients suspended in mid-air



Motivation for Formation of TG 176

1. To accurately include all external devices between the source and patient in dose calculations.
2. The error made in ignoring couch tops and immobilization devices can be large, both for tumor dose and skin dose.
3. When the PTV dose error is small as it frequently is, around 3%, we should still correct this, we do for blocking trays, Temp-pressure factor, TG21 to TG51 change – each about 2%.
4. We live in an age where the TPS can do this accurately if the patient is indexed to the couch.

What’s Different Now

1. Patients are more likely now to be indexed so that the relationship between the external device and the patient is constant, enabling accurate correction strategies.
2. “IGRT” carbon fiber sandwich couchtops unbiquitous -Better image quality but nearly full skin dose from posterior beam and several % attenuation. Can have nonuniform regions.
3. Immobilization devices are constructed to well immobilize the patient but can have thick, solid carbon fiber or plastic parts which attenuate the beam, increase skin dose.
4. Opposed laterals for H&N are rarely used, instead multiple beam plans which include posterior beams which pass through baseplates, masks, couchtops.
5. Arc therapy becoming available means that at least 40% of the dose comes from the posterior.
6. For most, currently no accurate way to know magnitude of errors. Our treatment planning systems don’t readily allow the calculation of the dose perturbation from any external device, especially treatment couches which are almost never in the planning CT.

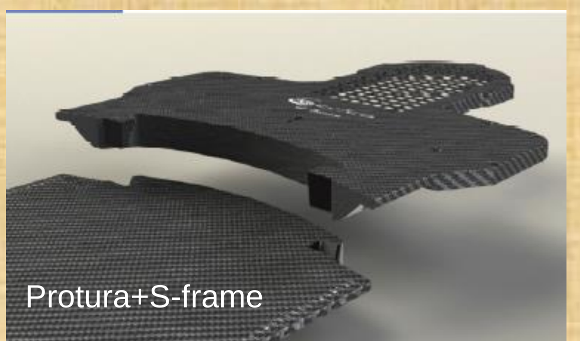
TG 176 Outline

- **Introduction**
  - magnitude of tumor and surface dose errors that exists without accounting for external devices.
  - Scope of report includes photons and particle therapy, includes major vendor products, includes calypso.
- **Dosimetric errors due to external devices**
  - Couchtops
    - Literature review
    - Varian, Siemens, Elekta, plus cyberknife
  - Immobilization devices
    - Literature review
    - masks, headfix, bodyfix, vaclock, S-frame head ext., alpha cradle
- **Ability of TPS to accommodate these devices in planning and calculations**.
  - Review of literature
  - Include Eclipse, Pinnacle, Xio.
- **Recommendations for attenuation and surface dose measurements- dosimeters and methods specifically for external devices**
    - Photons
    - Protons
- **Recommendations for external structures avoidance strategies**
- **Recommendations to the TPS and device vendors**

Variety of Couchtops

WFR dosemax

Siemens ZXT



Protura+S-frame

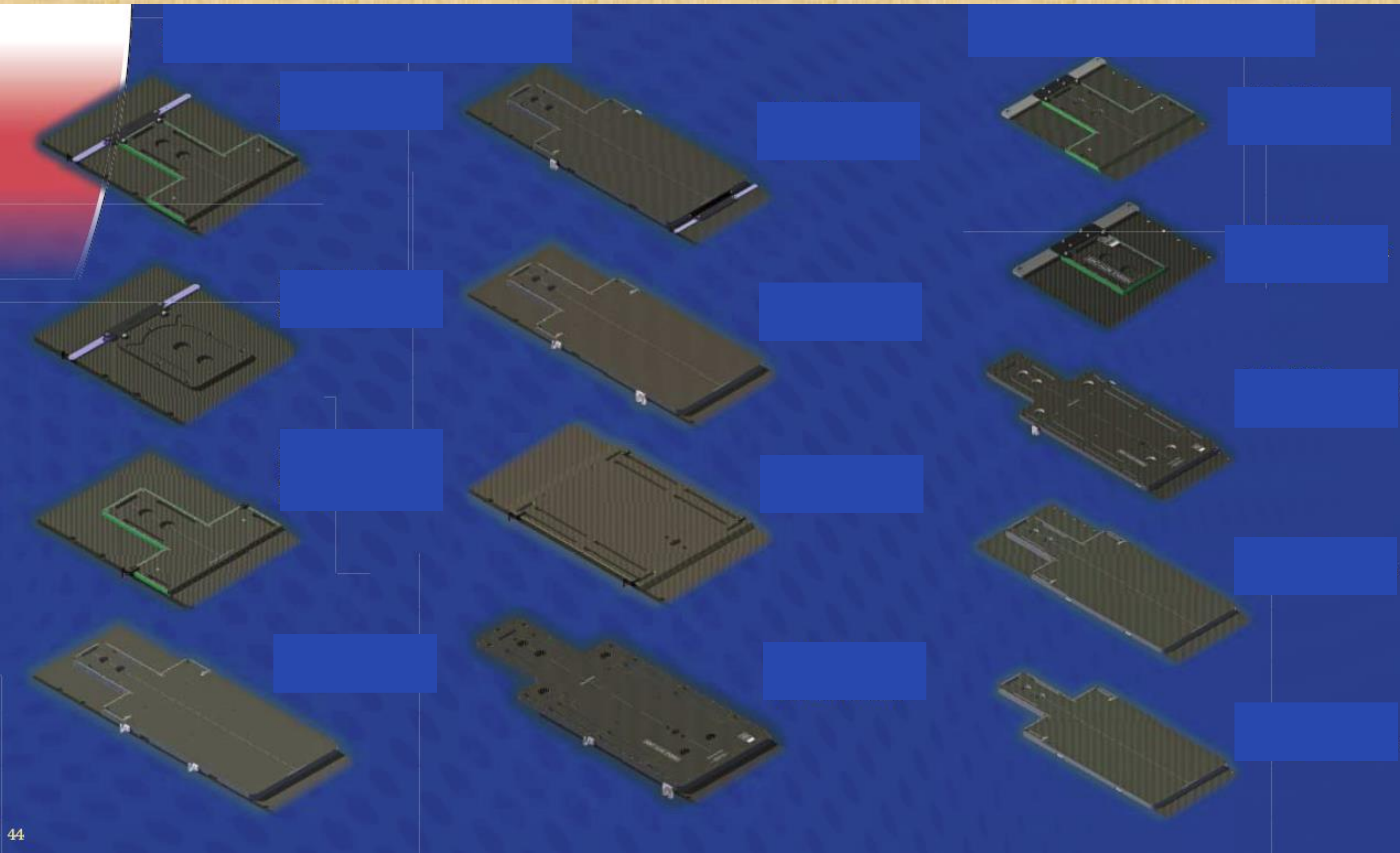
M.I. I-beam

Varian IGRT

WFR KVUE

WFR split frame

An Array of Baseplates



Wide Variety of Indexed Immobilization Devices







Couchtops and Immobilization Devices Affect:

Attenuation

Surface dose

Dose Distribution

Beams Arrangement Considerations

- Single PA or PAOBL beam- maximum attenuation and surface dose effect
- APPA beams- ½ the attenuation but maximum surface dose effect
- Multiple beams predominantly posterior – maximum attenuation, reduced surface dose effect
- Multiple equally spaced beams- minimizes both
- Volumetric arc – minimizes both – still > opp lats

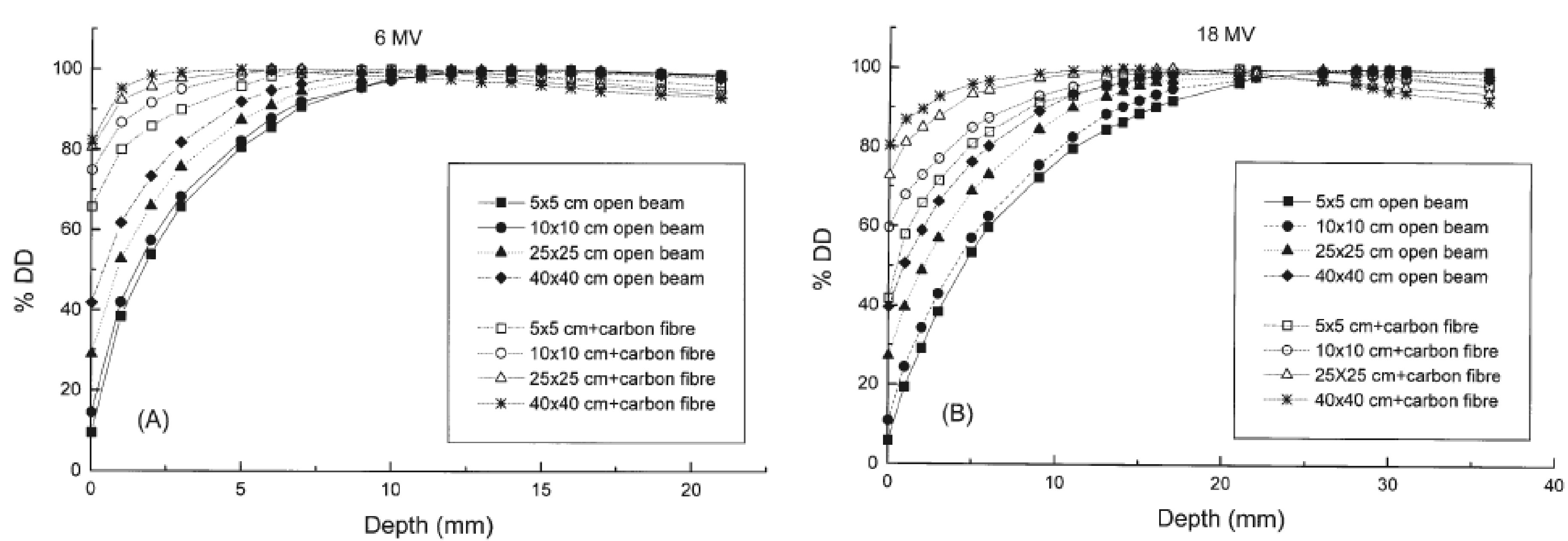
This Conclusion is Representative in Literature

The carbon fiber tabletop significantly decreases the skin-sparing effect and increases the surface dose, which is clinically important. The presence of the tabletop decreases the isocenter dose between 3.0%–5.6% depending on the gantry angle at 6 MV. The assumption that carbon fiber is radiotransparent is not valid; and ignoring the table attenuation can be clinically significant. The dosimetric effect of the tabletop may be higher especially for IMRT depending on the beam's orientation. Attenuation of the carbon fiber tabletop should be considered and corrected, such as is done for any material under the patient at the time of treatment planning.

Build-up and attenuation

Meydanci, Radiat Med 2008

Radiat Med (2008) 26:539–544 543



Ion Chamber Measurement of Attenuation by Couch

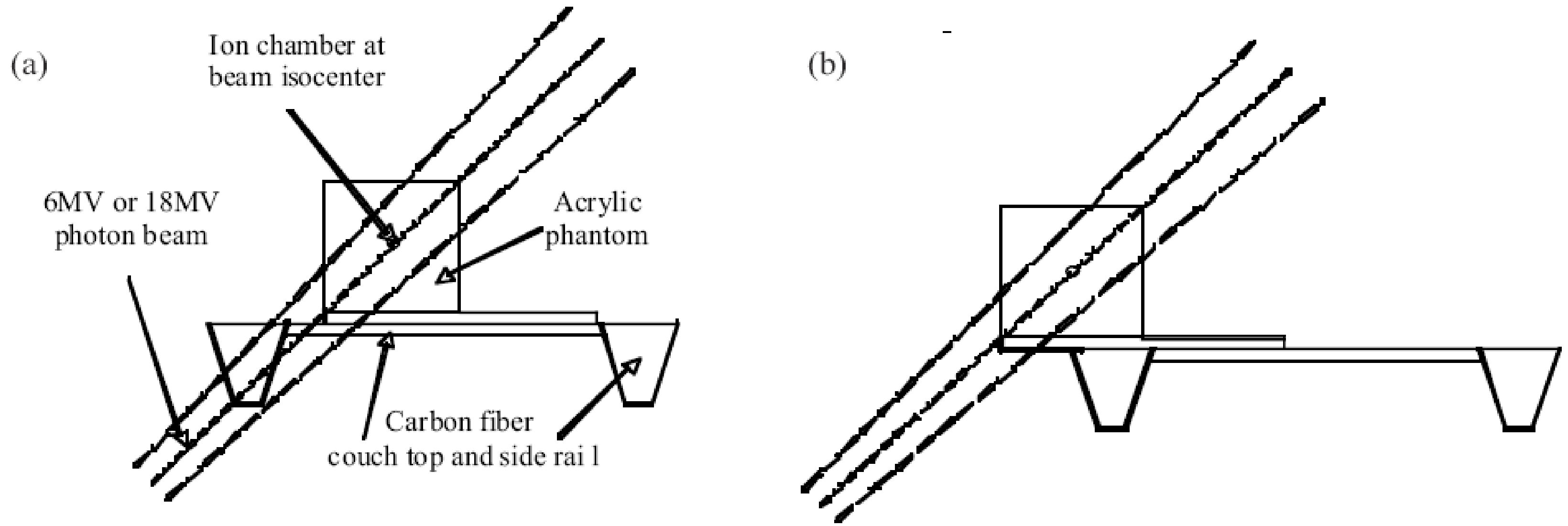


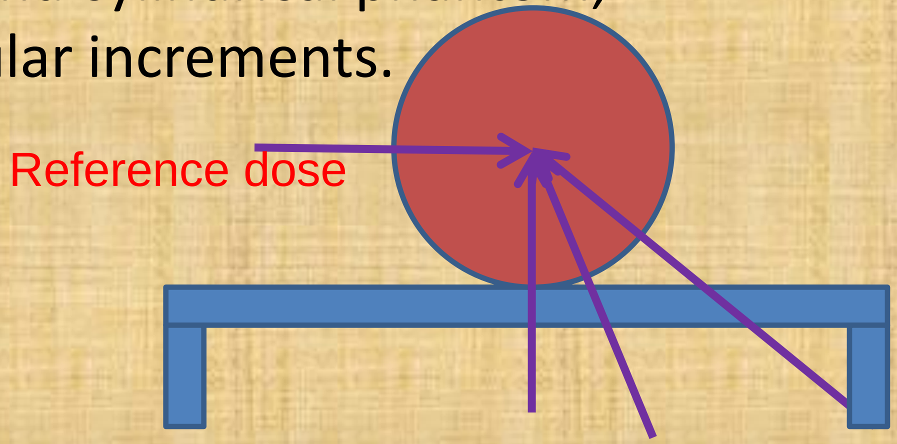
Fig. 1. The experimental geometry for in-phantom measurement of dose reduction, calculated by the ratio of readings (a) with and (b) without the couch. In-air measurements were made under identical geometry except the phantom is replaced with brass buildup caps.

Myint JACMP 2006

Recommended Measurement Methods

prior to TG 176, NO standard for how to measure

- Attenuation
  - Ion chamber. We recommend cylindrical phantom, measure at 10 degree angular increments.
  - Can get WET from PDD and attenuation



- Surface dose:
  - parallel-plate chamber (recommended), film, TLD, OSL. Can use the WET from attenuation measurement to infer the surface dose

Use WET to Infer Surface Dose

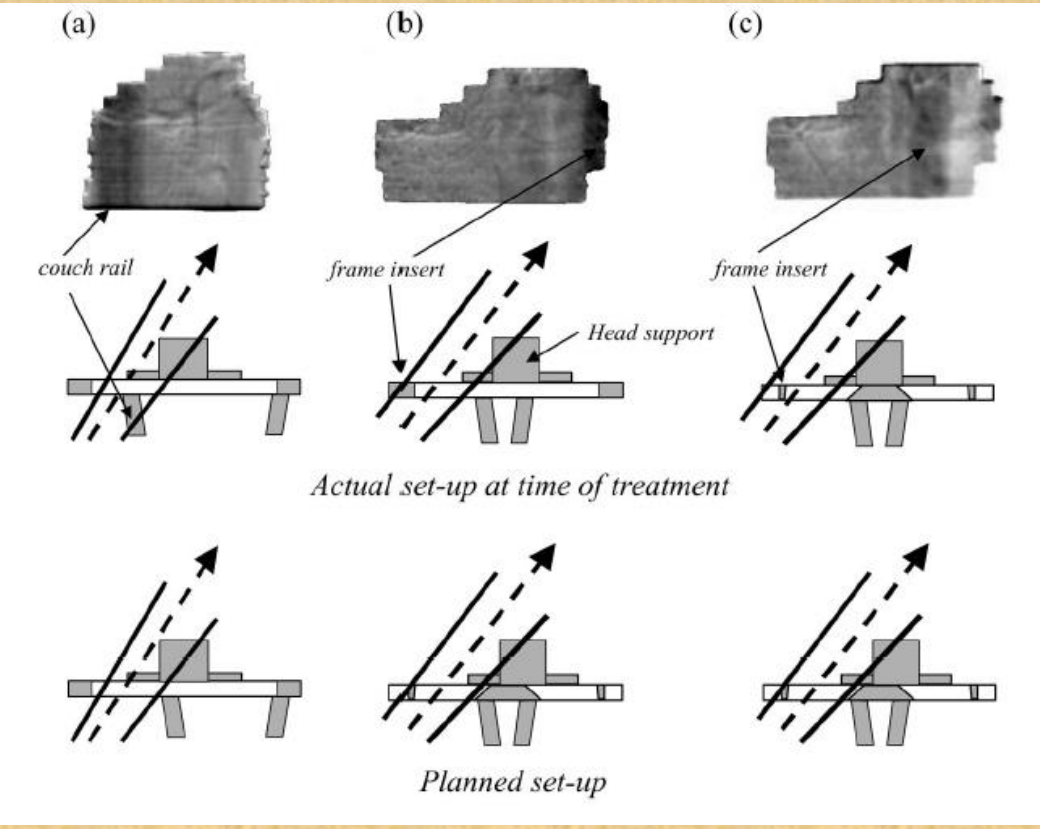
6 MV Buildup PDD

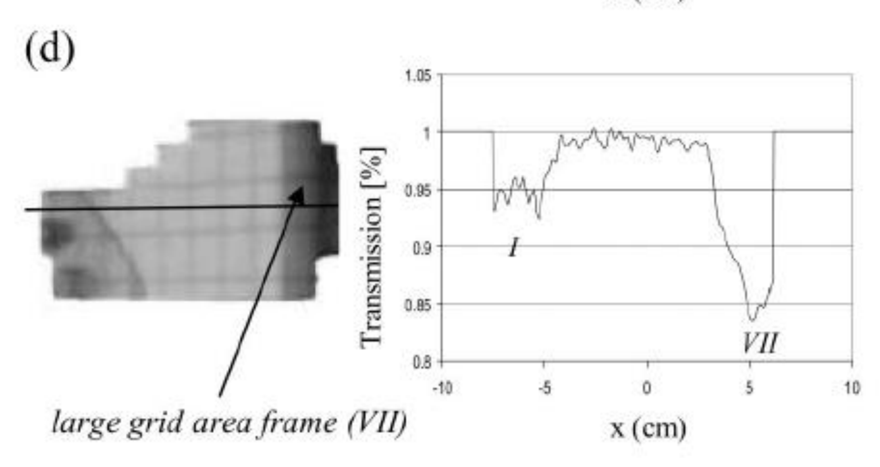
Square field Size (cm)

depth (mm)

	4	6	8	10	15	20	30
0	9	11	14	16	22	28	40
1	33	35	37	39	44	49	59
2	52	53	55	56	61	64	72
3	65	66	67	69	72	75	80
4	74	75	76	77	79	82	85
5	81	82	82	83	85	86	88
6	85	86	87	87	88	89	90
7	89	89	90	90	91	91	92
8	91	92	92	92	93	93	93
9	93	94	94	94	95	95	95
10	95	95	96	96	97	97	97
11	97	97	97	97	99	99	99
12	98	98	99	99	99	100	100
13	99	100	100	99	99		
14	100	100	100	100	100		
15	100	100	100	100			

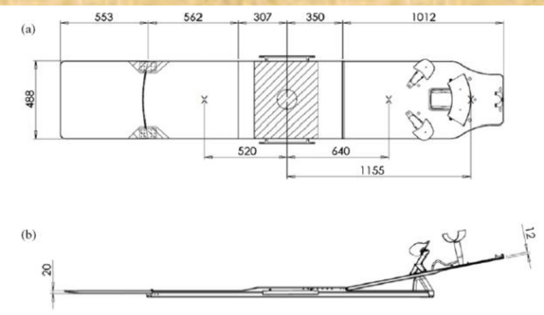
Measurement of Beam Attenuation By Couch and Immobilization Devices Using an EPID

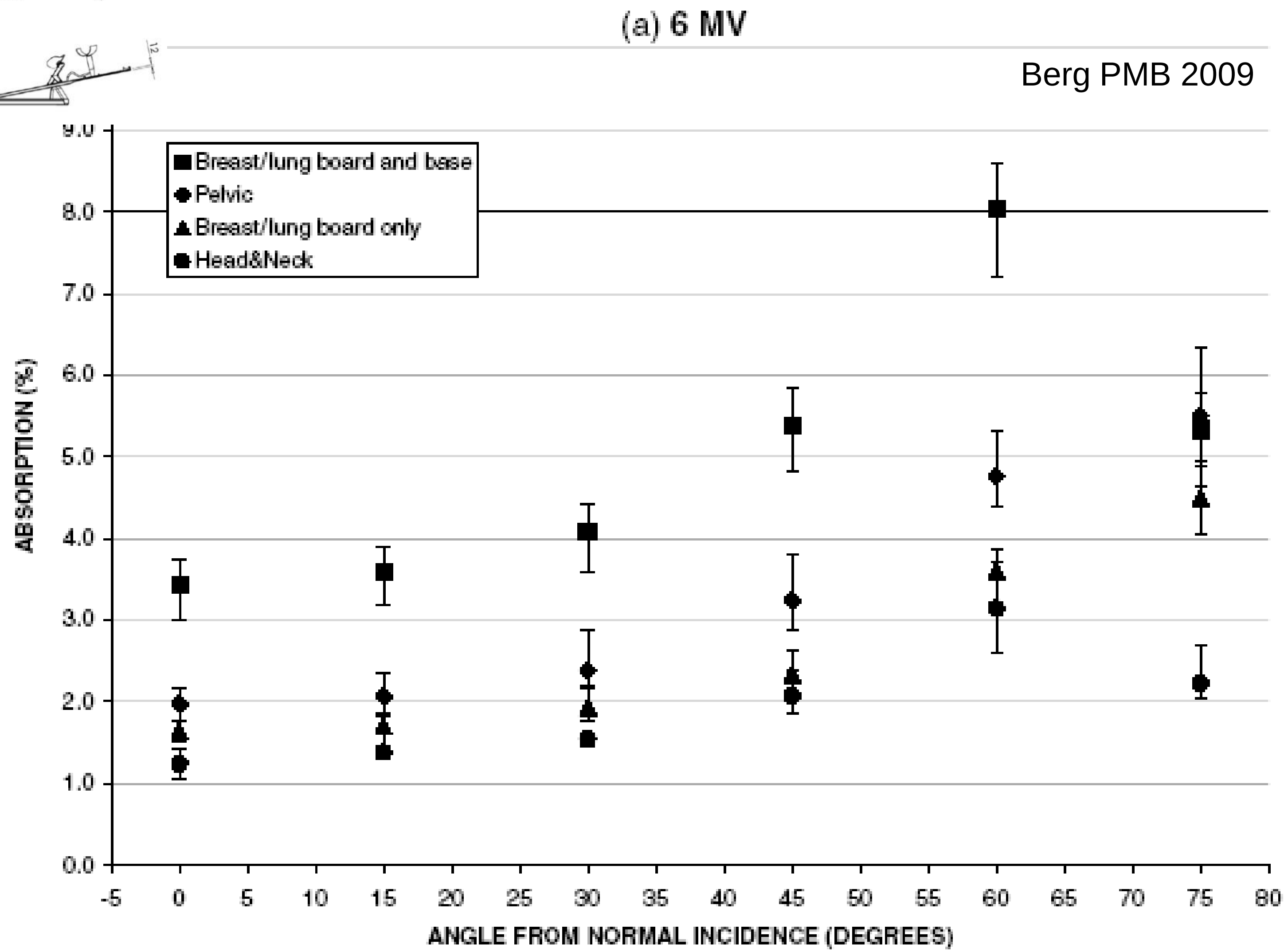




Viera Med Phys 2003

Attenuation Measurements for Contesse Couchtop





Berg PMB 2009

Attenuation Effects -sample

(19 published studies)

Study reference	Device	Delivery type	Beam Angle(s)	Attenuation (energy)	Detector type
Krithivas et. al.[1]	Metalic centerspine bar for Clinac 4/100 couch	conformal arc	0°(*) – 60°(†)	8%-12% (4MV)	XV film/Ion chamber cylindrical (PTW)
Meydanci et. al.[2]	Carbon fiber tabletop (Reuther MedizinTechnik)	single beam	180°(*) 120°(†)	3.0% (6MV) 2.0% (18MV) 5.6% (6MV) 4.0% (18MV)	Ion chamber cylindrical PTW

Some Vendors Supply Attenuation and WET for Their Devices for one location

We recommend they

1) use the cylindrical phantom, beams every 10 degrees, provide attenuation and WET and,
2) identify highest attenuation regions

External Devices Increase Skin Dose

- Most significant clinical effect - a single PA beam (CSI) and/or large daily doses.
- Most people don’t have two couchtops, one for minimizing skin dose and one for maximizing image quality.
- New carbon fiber couchtops typically don’t come with inserts, they are single solid panels. So you may be stuck with this problem.

Radiation Effects on Skin (and hair)

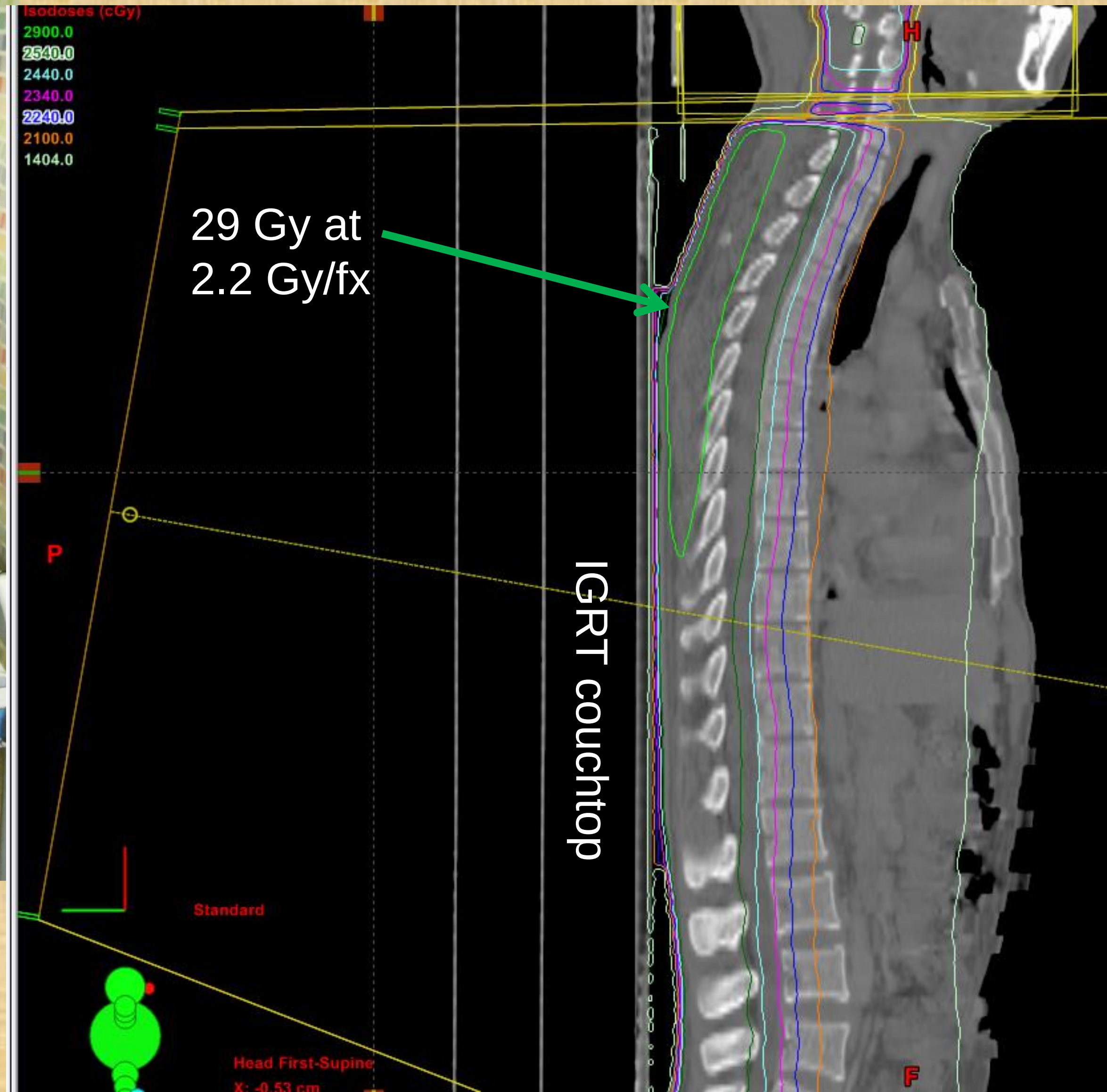
1178 I. J. Radiation Oncology ● Biology ● Physics Volume 31, Number 5, 1995

Table 2. Changes produced by increasing total dose

Schedule dose range Dose fraction single (cGy)	Multiple (200 cGy/day)	Gross change	Onset of change	Functional change
500–700	~ 2,000	Epilation	~ 18 days	
1000–2000	2000–4000	Erythema	12–17 days	Hyperemia
2000–3000			2–6 days	
1000–2000	~ 4500	Pigmentation		None
1000–2000	~ 4500	Dry desquamation	30–70 days	
2000–2400	4500–5000	Moist dequamation that heals	30–50 days	Serum leakage; healing regenerates functional barrier
> 2400	> 5000 > 6000	Moist desquamation does not heal > 50%	30–50 days	Loss of protective barrier
1700–2400	4500–5000	Telangiectasia	6 months-years	None
> 2700	> 6000	Necrosis nonhealing	Months, years	Loss of protective barrier

Archambeau RJ 1995

23.4 Gy single PA oblique to 5 cm depth created 29 Gy dose at skin due to decreased SSD, off axis factor, PDD, and couchtop/vacloc headrest,sometimes FinF also used superiorly



ACUTE SKIN TOXICITY FOLLOWING STEREOTACTIC BODY RADIATION THERAPY FOR STAGE I NON–SMALL-CELL LUNG CANCER: WHO'S AT RISK?

Bradford S. Hoppe, M.D.,* Benjamin Laser, M.D.,* Alex V. Kowalski, B.A.,† Sandra C. Fontenla, B.A.,† Elizabeth Pena-Greenberg, R.N.,* Ellen D. Yorke, Ph.D.,† D. Michael Lovelock, Ph.D.,† Margie A. Hunt, M.S.,† and Kenneth E. Rosenzweig, M.D.*

Fig. 1. Patient who developed Grade 4 skin necrosis from stereotactic body radiation therapy.

7/50 patients had ≥ grade 2 skin toxicity

From Hoppe RJ 2008

Conclusions: SBRT can be associated with significant skin toxicity. One must consider the skin dose when evaluating the treatment plan and consider the bolus effect of immobilization devices.

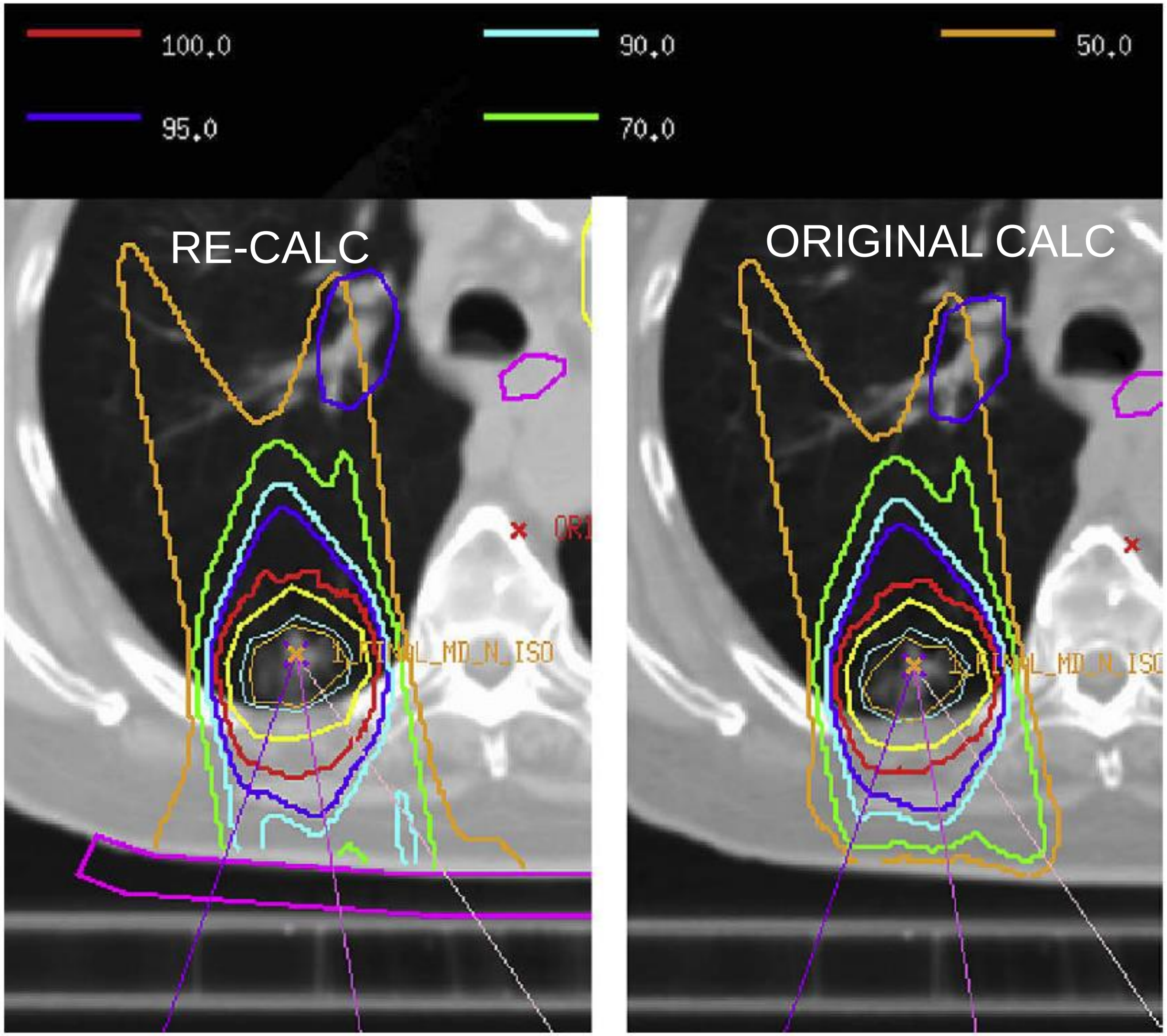


Fig. 2. Treatment plan for the patient that developed Grade 4 skin toxicity with out any corrections for treating through the couch and mobilization device (right) and with 1 cm of bolus to account for the couch and mobilization device (left).

3-field plan gave good dose distribution. 44-60 Gy in 3-4 fx

Targets close to the skin surface susceptible even with many beams

From Hoppe RJ 2008

From Hoppe Paper

With our current image-guided radiotherapy technique, posteriorly directed beams must traverse the couch top (3.5-cm carbon fiber sheath plus foam core), custom immobilization cradle (2 cm of balsa wood and laminate), and between 1 and 7 cm of polyurethane foam, which, when considering the thickness, CT number, and measured attenuation factor of the immobilization material and couch top, we estimate collectively, can result in 1–2 cm of tissue equivalent material. In-house phantom measurements confirm that almost all skin sparing is lost for the beams that pass through this set of devices. In our clinical

In our clinical planning process, treatment aids are not accounted for in dose calculation.

Vac-lock Bags Increase Skin Dose

Table 1
Percentage of maximum dose increases in skin dose caused by introduction of Vacbag material into 6 MV X-ray beam path

	Field size (cm × cm)	Vacbag thickness (cm)		
		0.3	2.5	10
		Percentage increase (of maximum dose) in dose using Vacbag compared to open field		
0.1 mm (Basal layer)	5	11	31	49
	10	14	36	57
	15	18	39	57
	20	23	37	56
	25	21	35	52
	30	22	36	51
1 mm (Dermal layer)	5	8	16	33
	10	8	16	35
	15	9	20	35
	20	8	22	33
	25	8	21	31
	30	7	19	29

Cheung, *Radiation Measurements* 2002

Masks Contribute to Increased Skin Dose

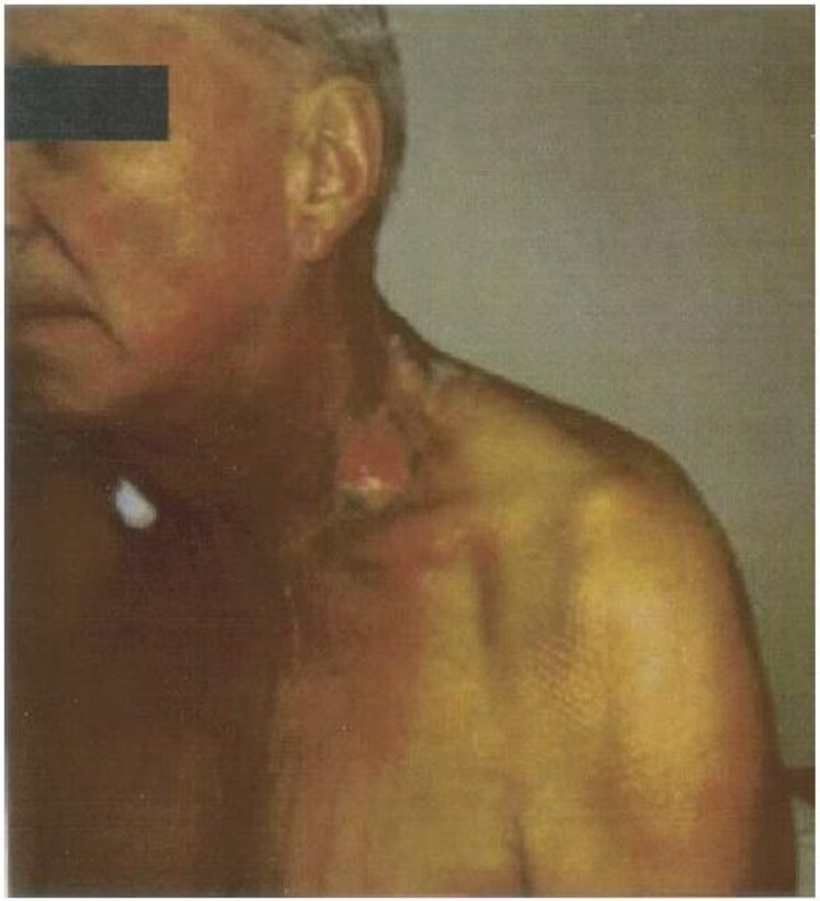


Fig. 2. Patient with T2N2c carcinoma of the base of tongue who underwent EF-IMRT. This patient had RTOG Grade 3 skin toxicity in the middle of the treatment and required a treatment break.

Table 3. TLD measurements for EF-IMRT plan with CTV contoured 5 mm away from skin

Location	With mask (Gy)	Without mask (Gy)	Difference* (%)
TLD 1	1.52	1.24	22.6
TLD 2	1.67	1.29	29.5
TLD 3	1.45	1.23	17.9
TLD 4	1.65	1.42	16.2
TLD 5	1.60	1.36	17.6
TLD 6	1.25	0.94	33.0
Average	1.52 ± 0.16	1.25 ± 0.17	22.2 ± 7.0

* Dose difference = 100(dose with mask − dose without mask)/dose without mask.

Abbreviations: CTV = clinical target volume; other abbreviations as in Ta

Fig. 1. Example of patient immobilized with a head, neck, and shoulder mask.

Lee RJ 2002

Surface Dose with Mask Depends on Degree of Stretching

TABLE 3. Estimates of the surface dose relative to d_{max} each m
density and thickness of the mask are presented for comparison.

	% Area increase- nominal	Surface dose 6 MV
no mask		16%
small	0%	61%
holes	125%	48%
mask	300%	35%
	525%	29%

Hadley 2009 JACMP

Surface Dose Effects -sample

(19 published studies)

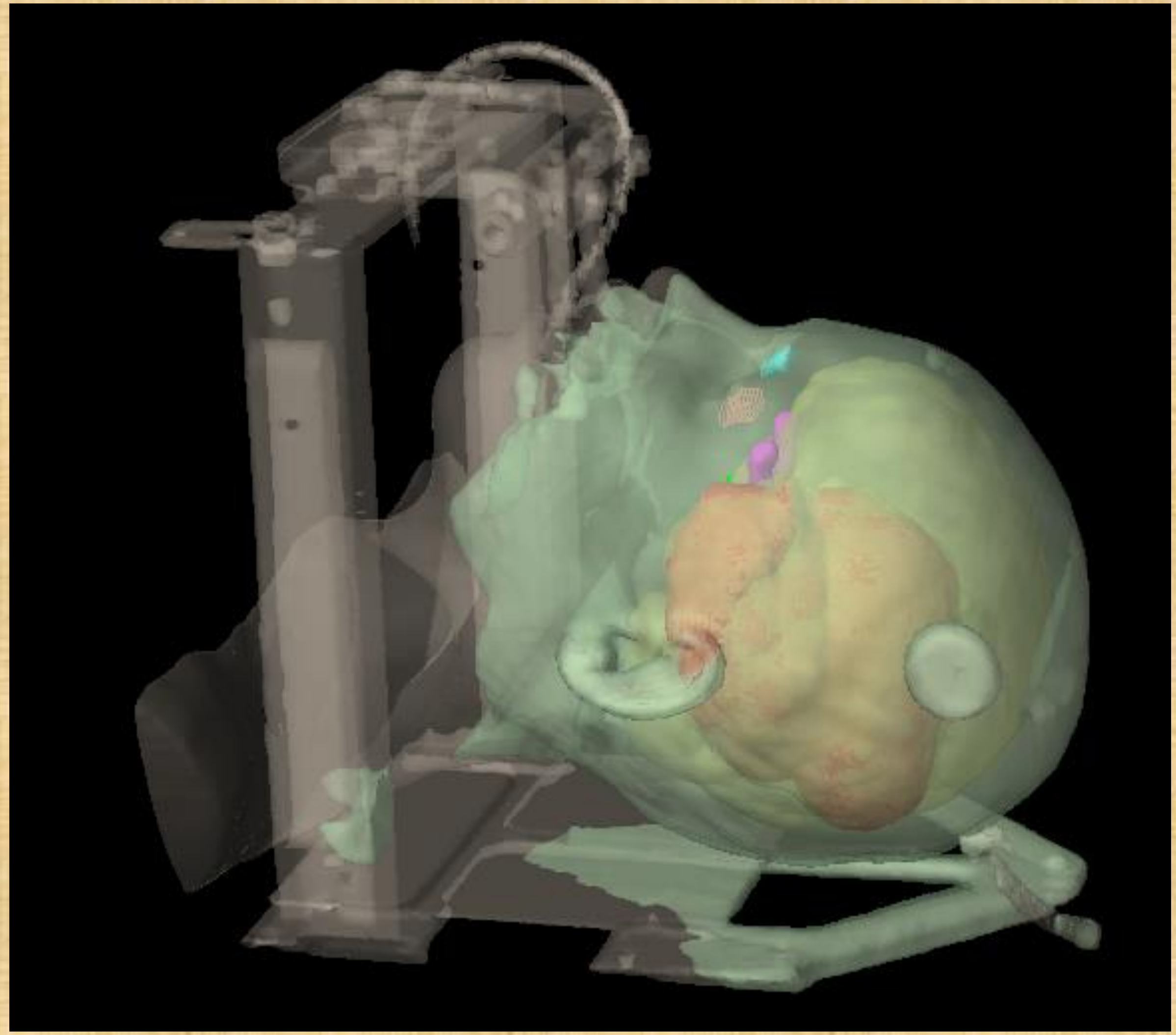
Study reference	**Device**	**Deliver y type**	**Beam Angle(s)**	**Depth on surface [cm]**	**Surface dose in % of D_{max} / Open field dose in % of D_{max}**	**Detector type**
Butson et. al.[19]	Carbon fiber grid tabletop (Varian)	single beam	0°(*) 15°(†) 30°(†) 45°(†) 60°(†)	0.015	32% (6 MV) / 19% 38% (6 MV) / 19% 41% (6 MV) / 19% 49% (6 MV) / 19% 62% (6 MV) / 19%	Ion chamber parallel-plate EBT Gafchromic film
Higgins et. al.[20]	Carbon fiber insert (Sinmed)	single beam	normal incidence	0.0	68% (8 MV) / 18%	Ion chamber parallel-plate (PTW)
Lee et. al.[21]	Carbon fiber tabletop + vacuum immobilization device	IMRT single fraction	5-field/ 2 posterior	0.0	58% (10MV) / NA	TLD
Berg et. al.[10]	Contessa tabletop Candor Aps Contessa tabletop + breastboard Candor Aps	single beam	0°(*) 0°(*)	0.5	97% (6 MV) / 83% 79% (18MV)/ 59% 100% (6 MV) / 83% 93% (18MV) / 59%	Ion chamber parallel-plate (PTW)

Transmission and surface dose measurements are important

but:

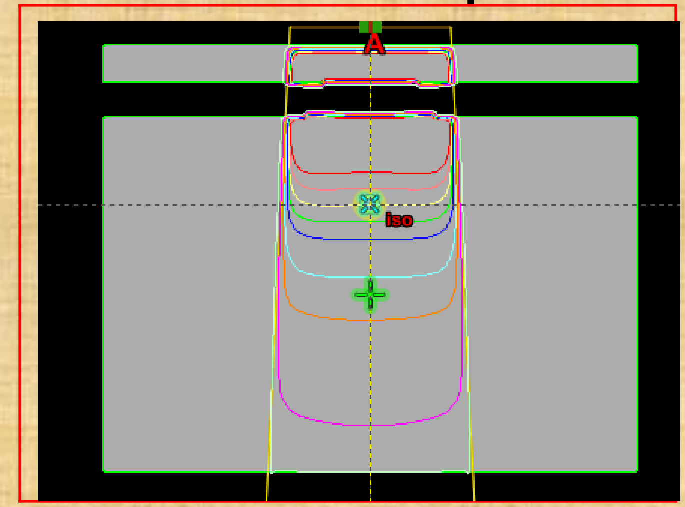
The best way to deal with external devices is for them to be present in the planning CT dataset and for the TPS to calculate the dose accounting for the external device

External Devices Can be Included in TPS Calc



Discover Your Treatment Planning System Limitations

Simple Calculation You Can Do



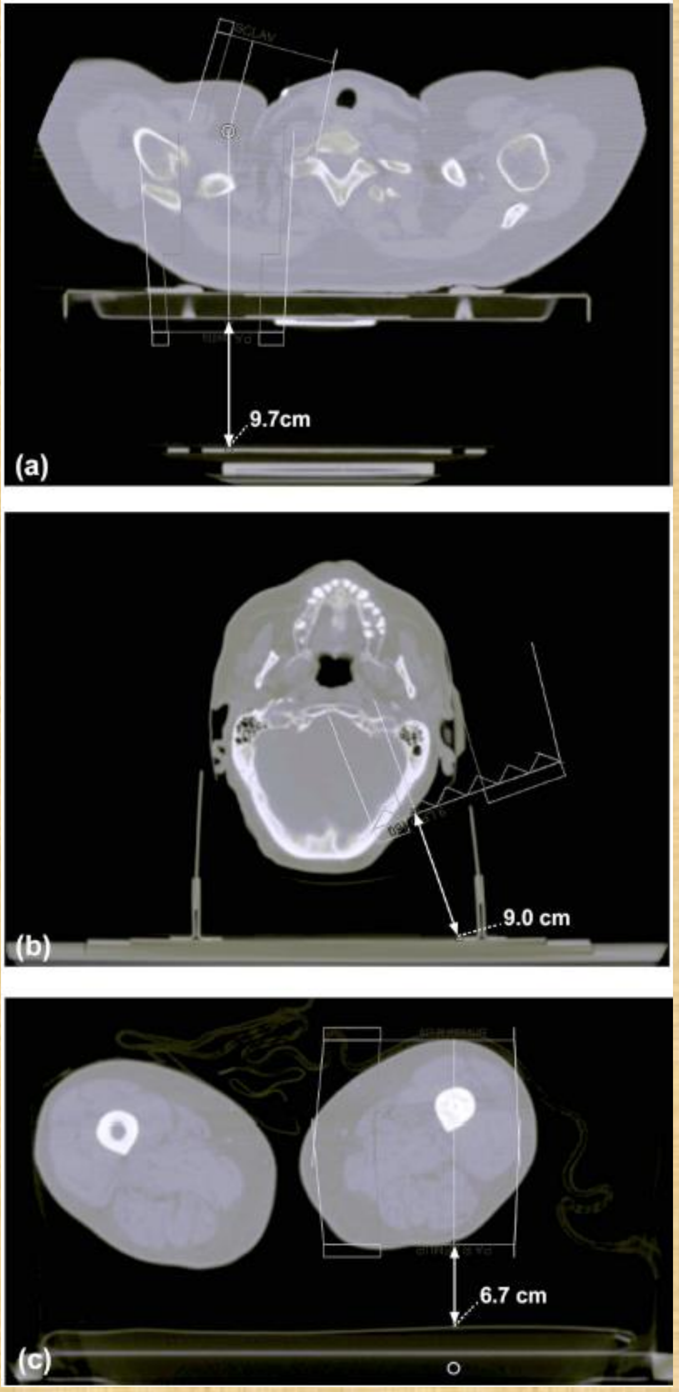
Two body contours : 2 cm slab + 2 cm air gap, then rest of phantom.
Attenuation calculation

One body contour enveloping 2 cm slab, 2 cm air gap, rest of phantom.
(***Inhomogeneity calculation***)

Same PDD after thin slab in either geometry - Eclipse and XIO

Hand Calc confirms correct dose within 1%.

Air gaps, loss of scattering from first object into second, decreases surface dose and dose at depth



Increasing air gap decreases surface dose

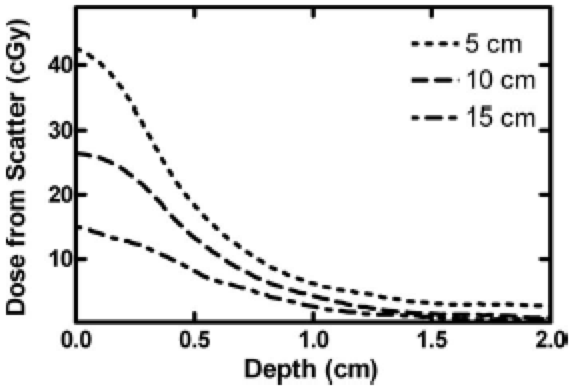


FIG. 7. The dose at depth produced from scatter created by a 2 cm water equivalent slab positioned before 5, 10, and 15 cm air gaps (100 MUs, 6 MV photon beam, 10×10 cm^2 field size, 100 cm SSD to the surface of the water phantom).

Gray MP 2009

D-max Increases with Air Gap Skin-Sparing Redevelops

TABLE IV. Depth of dose maximum (cm) in a water phantom determined experimentally for 0.2–4 cm of RW3 positioned before a 1–15 cm air gap (100 MUs, 6 MV photon beam, 10×10 cm^2 field size, 100 cm SSD to the surface of the water phantom). A value of zero indicates that the maximum dose was at the surface of the phantom. The depth of dose maximum measured for an open field was 1.34 cm.

Thickness of RW3 (cm)	Air gap (cm)						
	1	3	5	8	10	12.5	15
0.2	1.12	1.13	1.18	1.17	1.12	1.26	1.30
0.5	0.86	0.86	0.84	0.91	0.94	1.05	1.13
1	0	0.34	0.56	0.87	0.84	0.94	1.13
2	0	0	0.41	0.72	0.83	0.93	1.05
3	0	0	0.44	0.72	0.80	0.88	1.05
4	0	0	0.36	0.72	0.84	0.92	1.05
4 (AAA Calc)	0.20	0.48	0.73	0.95	0.98	1.20	1.20

AAA Calc

Gray MP 2009

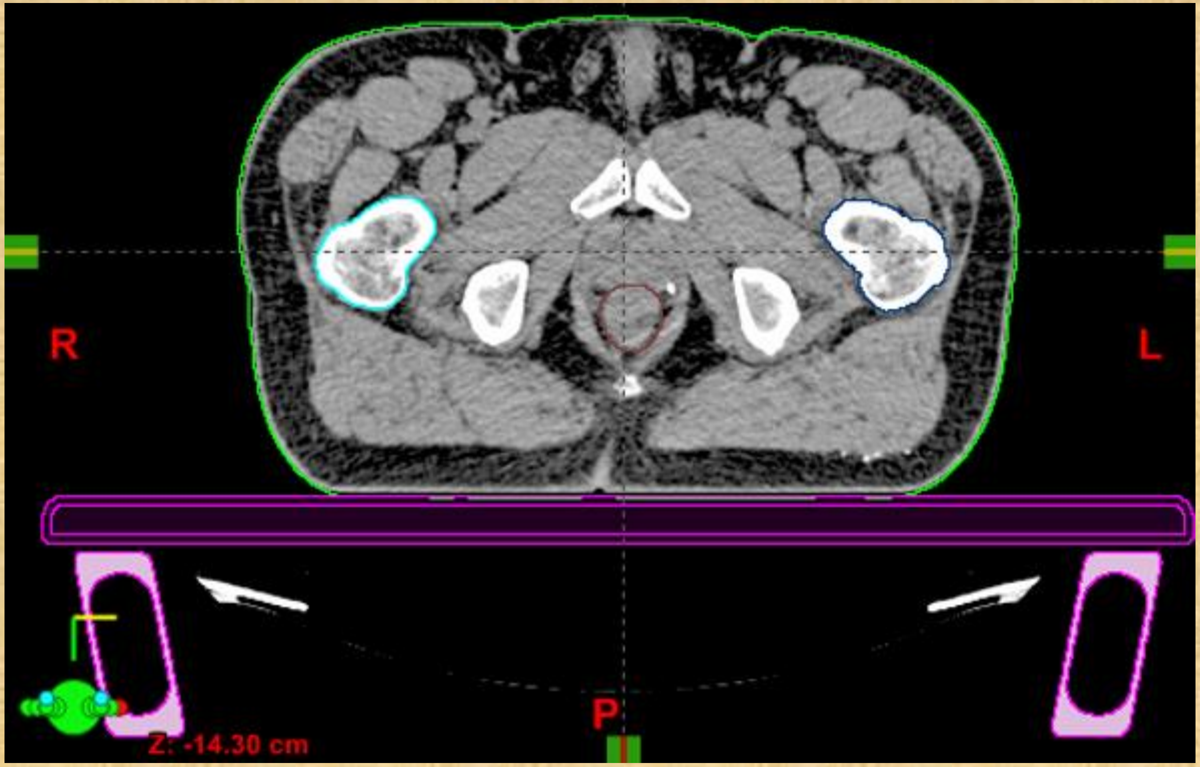
Eclipse Dose Errors 2-3% for Air Gaps Between 2cm Slab and Phantom (6MV)

	Air gap								
	1 cm					5 cm			
		PBC		AAA			PBC		AAA	
Depth (cm)	Measured dose (cGy)	Dose (cGy)	Difference (%)	Dose (cGy)	Difference (%)	Measured dose (cGy)	Dose (cGy)	Difference (%)	Dose (cGy)	Difference (%)
0	102.1	102.8	0.6	64.3	−37.0	95.5	102.5	7.4	79.5	−16.7
0.5	99.5	100.6	1.2	100.7	1.2	97.2	100.4	3.3	97.4	0.2
1	97.0	98.4	1.5	98.8	1.9	95.4	98.1	2.8	97.0	1.6
5	79.8	81.2	1.7	81.5	2.0	79.1	80.8	2.2	80.7	2.0
10	60.9	62.3	2.3	62.4	2.5	60.5	62.1	2.6	61.8	2.1
15	46.1	47.3	2.5	47.3	2.6	45.9	47.0	2.3	46.9	2.1

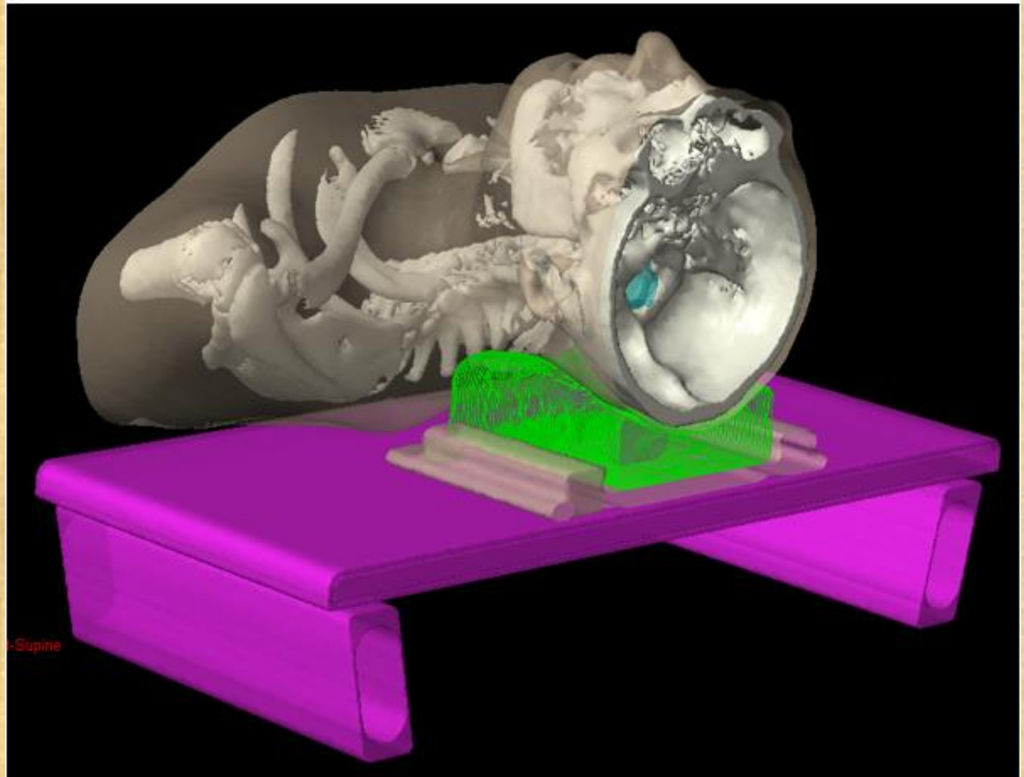
	Air gap									
	10 cm					15 cm				
		PBC		AAA			PBC		AAA	
Depth (cm)	Measured dose (cGy)	Dose (cGy)	Difference (%)	Dose (cGy)	Difference (%)	Measured dose (cGy)	Dose (cGy)	Difference (%)	Dose (cGy)	Difference (%)
0	79.4	102.8	29.4	72.9	−8.2	67.9	103.0	51.7	68.6	1.0
0.5	91.9	100.4	9.2	94.5	2.8	86.9	100.8	15.9	91.9	5.8
1	93.5	97.8	4.6	96.1	2.8	91.8	97.1	5.8	95.1	3.5
5	78.2	80.7	3.2	80.6	3.1	78.0	80.4	3.1	80.8	3.6
10	60.1	61.9	3.0	61.9	3.0	59.8	61.7	3.1	61.8	3.4
15	45.5	46.8	2.7	47.0	3.1	45.6	46.5	2.0	46.9	2.9

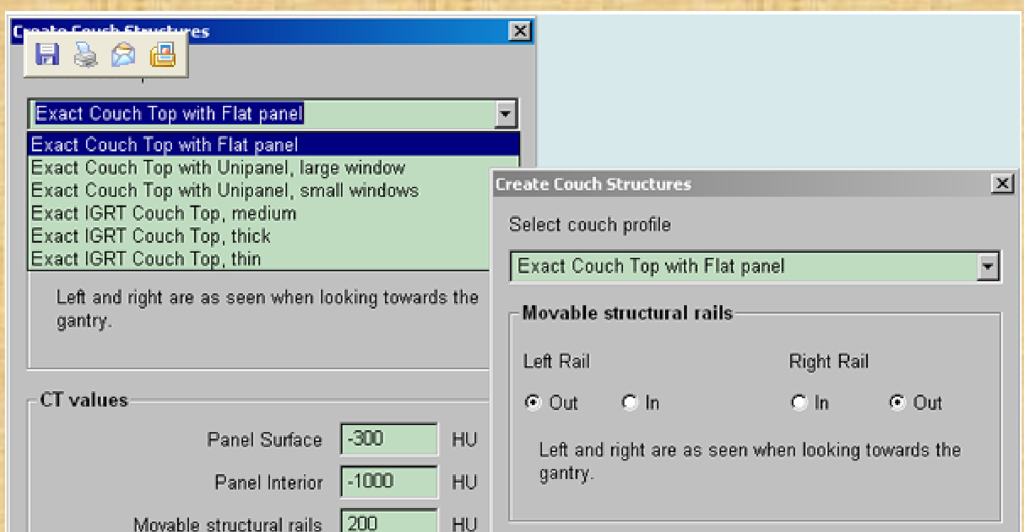
Gray MP 2009

TPS Vendors are Beginning to Provide Tools We Need



Eclipse Allows limited Couchtop Selection (Varian only) and Placement Under Patient





Vanetti – PMB 2009

The impact of treatment couch modelling on RapidArc

Table 1. Experimenta
15 MV beams and for
are expressed as couch

		Measurement PA180	OBL225
6 MV	TK	−3.1%	−4.4%
	MD		
	TN		
15 MV	TK		
	MD		
	TN		

Me
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S = couch surface, I = couch internal.
Attenuation = $100*(L_{couch} - L_{no\_couch})/L_{no\_couch}$.

Table 2. Difference between plans calculated for the thick couch model and for the no couch model.

Organ	6 MV Mean (Gy)	15 MV Mean (Gy)
PTVI	1.3 ± 0.3	0.9 ± 0.2
PTVII–PTVI	0.7 ± 0.2	0.5 ± 0.1
Rectum	0.6 ± 0.2	0.4 ± 0.1
Bladder	0.6 ± 0.2	0.4 ± 0.1
Femurs	0.04 ± 0.01	0.03 ± 0.01
Healthy tissue	0.2 ± 0.1	0.1 ± 0.1

1.3Gy/50 Gy=2.6%

Some centres apply a simplified procedure of increasing MU of fixed percentage (e.g. 2%) for beams crossing the couch. If this seems to be acceptable for fixed beam arrangements, it is less appropriate for rotational techniques where fractions of the entire beam are affected by couch attenuation.

necessary. The results showed that (i) there is no measurable effect if the wrong segment of the couch is used in the calculations, (ii) there are significant and of potential clinical impact discrepancies at the level of the target volumes if calculations are performed without couch and delivery is (obviously) performed with couch and (iii) the effect is particularly relevant at low energy (6 MV in this case).

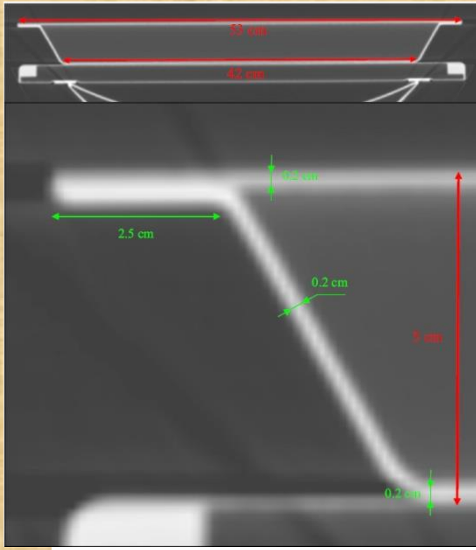
Rapid Arc Treatment Through Couchtop Can also Impact on Dose Distribution

(Gamma Index)

Table 3. Summary of pre-treatment verification measurements (with detectors positioned on the TK couch segment) of plans computed with TK couch and NO couch.

	TK couch	NO couch
GAI (%)	94.9 ± 2.6	92.4 ± 6.1
Range (%)	94.8–100	85.9–100

Vanetti 2009



Dosimetric Effects of Couch Adequately Calculated if Properly Modeled in Pinnacle V8.0d

Mihaylov Med Phys 2008

TABLE I. Comparison between measured and computed doses, as modified by the *ExacTrac* carbon fiber couch. The measurements and the calculations are performed for five posterior angles for both available photon energies. A field size of 10×10 cm^2 was used for the results presented in the table. Each portal was irradiated multiple times with 100 MU. The reported measured doses are averages from the multiple measurements. The results in the parentheses in the last two columns represent the standard deviation of the measured average dose.

Energy (MV)	Beam angle (°)	Delivered MU	Calculated dose (cGy)	Measured dose (cGy) [Uncertainty (cGy)]	Difference with respect to measurement (%) [Uncertainty (%)]
6	0	100	96.00	95.84 (±1.4)	0.17 (1.5)
6	30	100	94.40	94.65 (±1.3)	0.26 (1.4)
6	50	100	89.70	88.79 (±1.2)	1.02 (1.4)
6	75	100	66.00	64.95 (±1.1)	1.62 (1.7)
6	83	100	58.40	59.39 (±1.1)	1.67 (1.9)
18	0	100	106.40	105.80 (±1.2)	0.57 (1.1)
18	30	100	105.40	105.95 (±1.1)	0.52 (1.0)
18	50	100	102.00	102.17 (1.1)	0.17 (1.1)
18	75	100	85.60	84.93 (±1.0)	0.79 (1.2)
18	83	100	79.20	80.41 (±1.3)	1.50 (1.6)

Measured % <u>attenuation</u>

3.2
3.2
5.6
8.6
5.0
0.1
0.6
2.6
5.0
2.9

Up to 8% attenuation without modeling in TPS

Dosimetric Effects of Couch Adequately Calculated by Xio

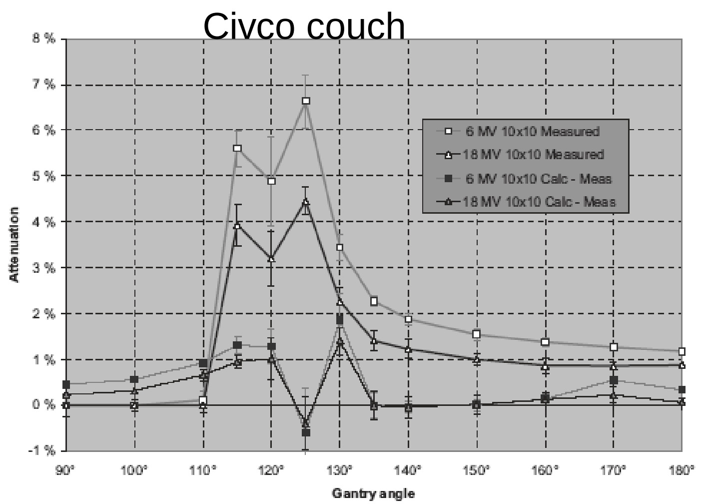


FIG. 4. Percentage attenuation of the Siemens 6 and 18 MV beams by the CIVCO couch as a function of gantry angle for a 10×10 cm^2 field. Also shown is the difference between the measured attenuation and that calculated by XiO.

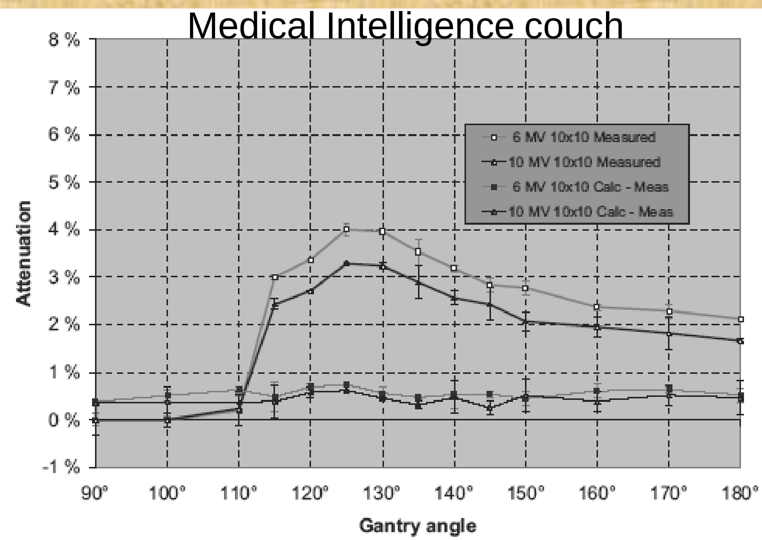


FIG. 5. Percentage attenuation of the Elekta 6 and 10 MV beams by the MI couch as a function of gantry angle for a 10×10 cm^2 field. Also shown is the difference between the measured attenuation and that calculated by XiO.

TABLE I. Result summary.

			Surface dose (% of max)			Physical	Radiological	
Energy (MV)	Machine	Couch	Measured (%)	Calculated (%)	Difference (%)	Thickness (mm)	Thickness (mm)	Shift (mm)
6	Elekta	None	17	40	23	⋯	⋯	⋯
		MI	89	86	−3	50.0	6.3	6.5
6	Siemens	None	17	53	36	⋯	⋯	⋯
		CIVCO	77	73	−4	13.0	4.2	4.3
10	Elekta	None	13	34	21	⋯	⋯	⋯
		Mi	75	75	0	50.0	6.3	6.5
18	Siemens	None	10	31	21	⋯	⋯	⋯
		CIVCO	49	42	−7	13.0	4.2	4.4

Gerig *Med Phys* 2010

Addition of Couch Structure into CT Dataset

- Best method is to use TPS supplied couch model that correctly matches your couch top
- Use image editing software to overwrite the CT couch pixel data with the CT-scanned treatment couch- not practical for most
- Use image-fusion (Scanned treatment couch to planning CT) to bring in a Dicom RT structure set representing the treatment couch, need to define HU values-can be done
- Manually draw in the Treatment couch and assign HU values to its parts. –can be done

Validate Your Couch Model

- Make measurements of attenuation for a range of posterior beam angles which you can also calculate in the TPS.
- Tweak HUs for couch sections to optimize measured vs. calculated dose agreement

Strategies to Avoid External Devices

(If you can't calc it, avoid it)

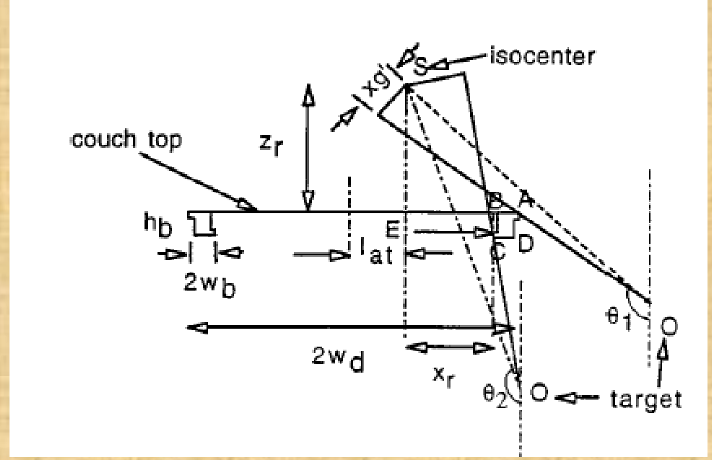
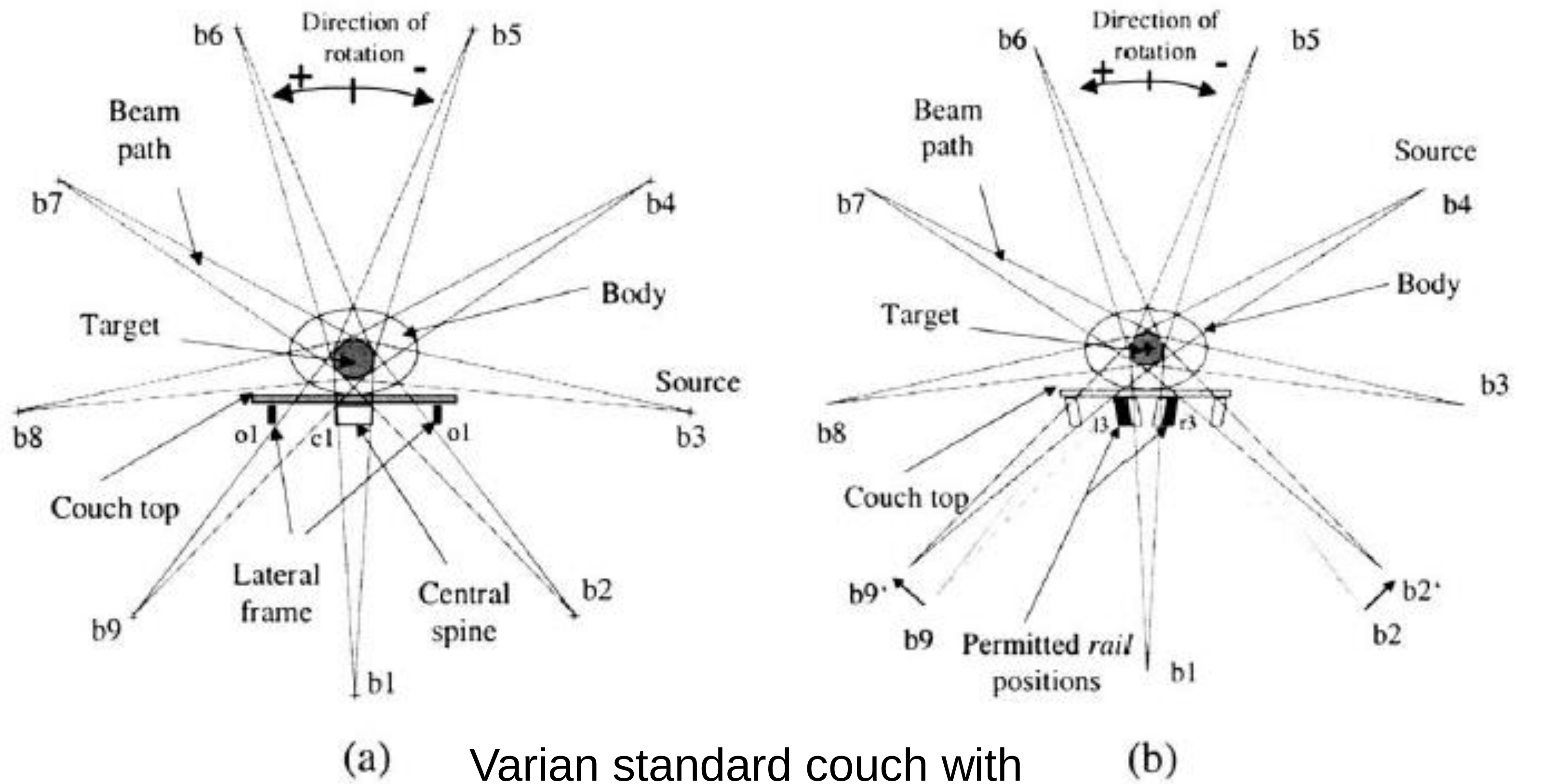


TABLE II. A comparison of model generated and measured range of gantry angles for which part of the beam passes through the couch support assembly for variety of situations. Angles and dimensions are represented in degrees and cm, respectively.

Couch height z_r	Couch lat. l_{at}	Couch rot. ϕ	Coll. rot. κ	Jaws (X_1, X_2, Y_1, Y_2)	Gantry range (θ_1, θ_2) model	Gantry range (θ_1, θ_2) meas.
−10	0	0	0	(10,10,10,10)	(264.2, 214.8)	(264.0, 214.2)
−10	0	0	45	(10,10,10,10)	(95.8, 151.3)	(96.3, 151.0)
−10	10	0	0	(10,10,10,10)	(264.1, 192.7)	(264.0, 191.9)
−15	0	0	0	(10,10,10,10)	(254.3, 210.4)	(254.0, 210.0)
−10	0	0	0	(5,5,5,5)	(257.1, 221.7)	(256.4, 220.9)
−10	0	0	45	(5,10,5,10)	(264.3, 213.9)	(263.7, 213.6)
−10	−10	25	0	(10,10,10,10)	(95.8, 173.9)	(96.0, 173.9)
−10	−10	0	0	(10,10,10,10)	(95.9, 167.3)	(95.6, 167.1)
−10	5	10	0	(10,10,10,10)	(264.2, 202.5)	(263.7, 201.8)
−10	5	0	0	(10,10,10,10)	(264.2, 204.9)	(263.6, 203.9)
−10	0	10	20	(10,0,10,−5)	(261.1, 225.8)	(260.8, 225.4)
−10	0	0	20	(10,0,10,−5)	(260.9, 223.8)	(260.3, 223.4)

Muthuswamy *Med Phys* 1999

Accommodation of couch constraints for coplanar intensity modulated radiation therapy



Varian standard couch with central spine or movable rails

Meyer, Radiotherapy and Oncology 2001

Rules for Couch Rail Avoidance

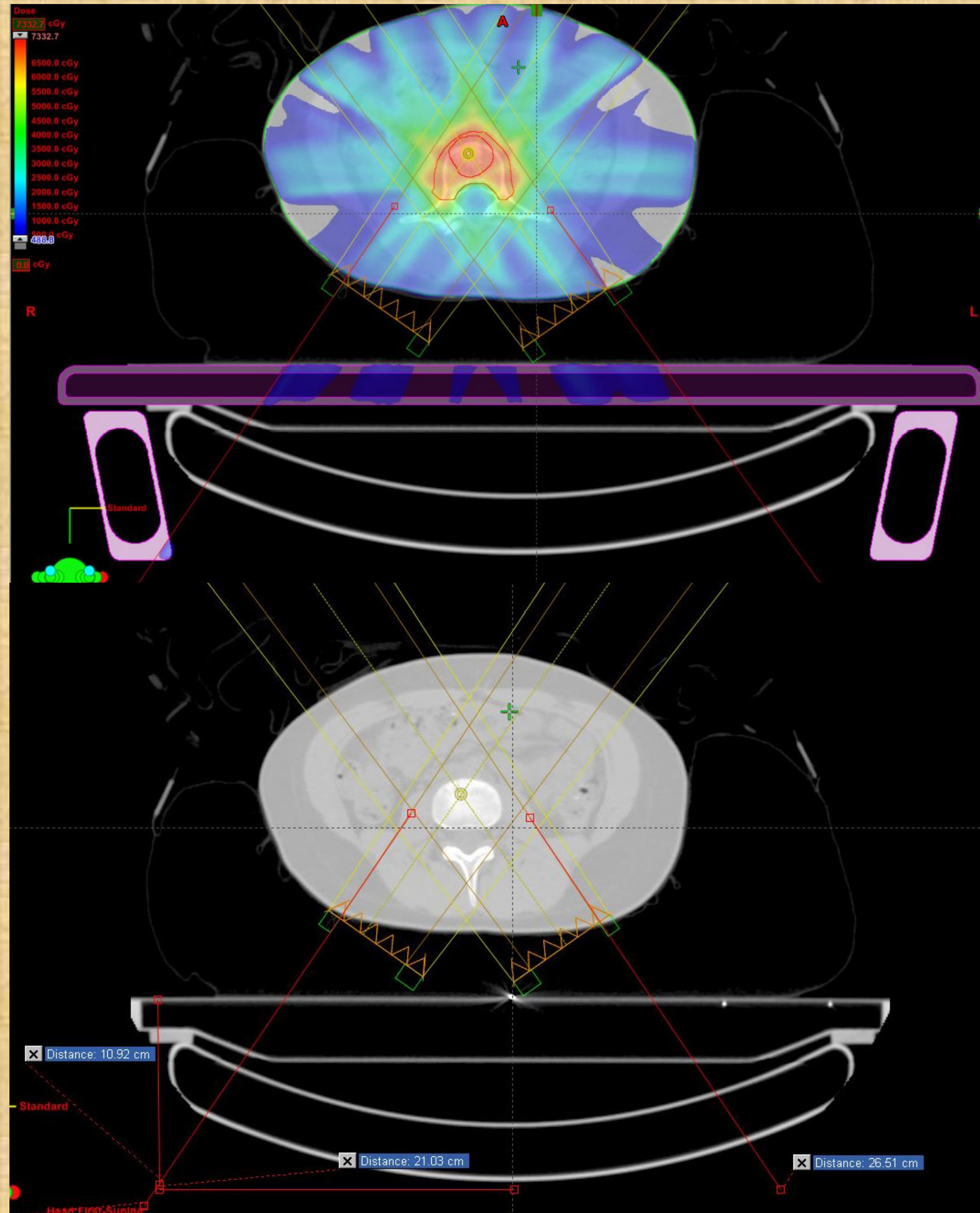
2.3.2. Optimization procedure for the variable standard couch

1. Determine the intersection between the initial beam paths and the *rail* position, i.e. positions L0–L18 and R0–R18 and store the information.
2. Determine which *rail* positions are *permissible* on the left and on the right.
   2.1. If a *permissible rail* position can be found on the left and/or right side, the optimization on the left and/or right side is terminated.
   2.2. If no *permissible rail* position is found on the left and/or right side, the smallest area of intersection between all the possible *rail* positions and all the beams is searched (information already stored in 1 and one beam on the left and/or one beam on the right is/are selected. Note the area of intersection is an indication of which *rail* position enables minimum beam rotation. If more than one beam intersects with a given *rail* position, this position is counted as a worse solution than if only one beam intersects with only one *rail* position, even if the area of intersection is smaller. This is to avoid having to rotate multiple beams to enable a certain *rail* position on one side.
   2.3. The direction of rotation of the beam(s) (positive or negative), determined in 2.2, is determined geometrically.
   2.4. The beam(s) determined in 2.2 is/are rotated in the direction(s) found in 2.3 in steps of 1° until intersection-free delivery is possible. The new beam angles and the *permissible rail* positions are returned.

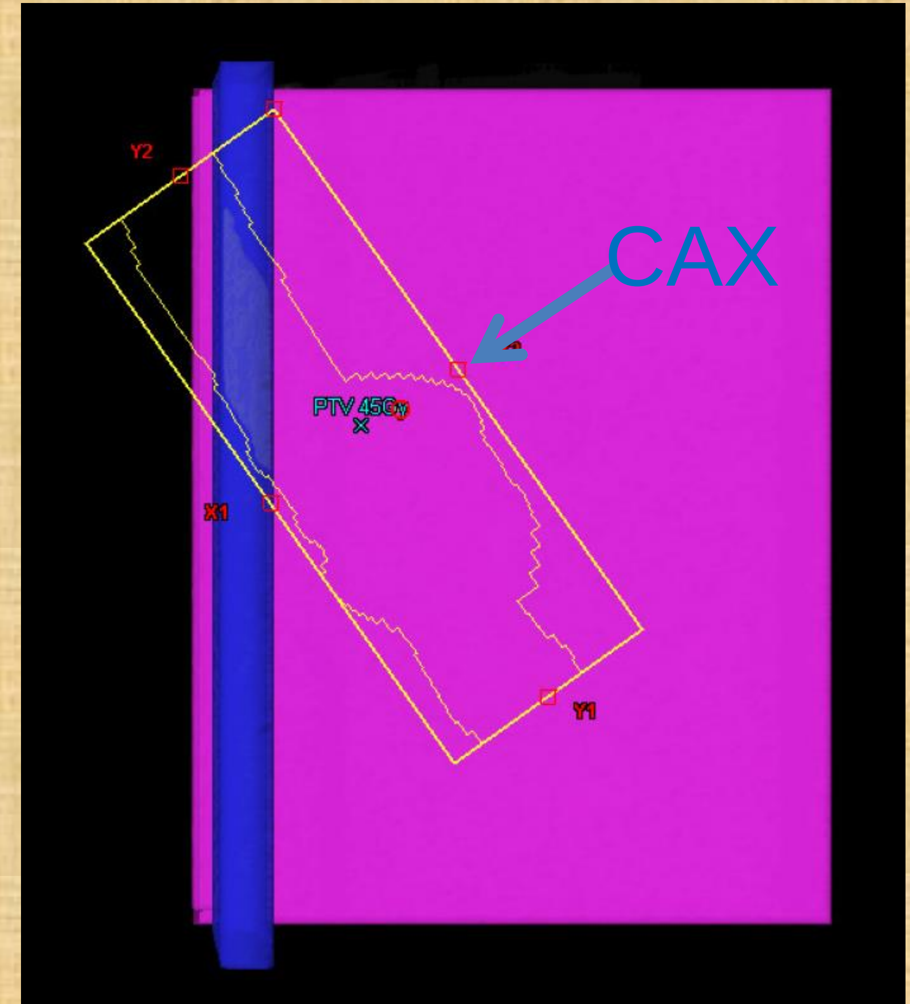
Meyer, R&O 2001

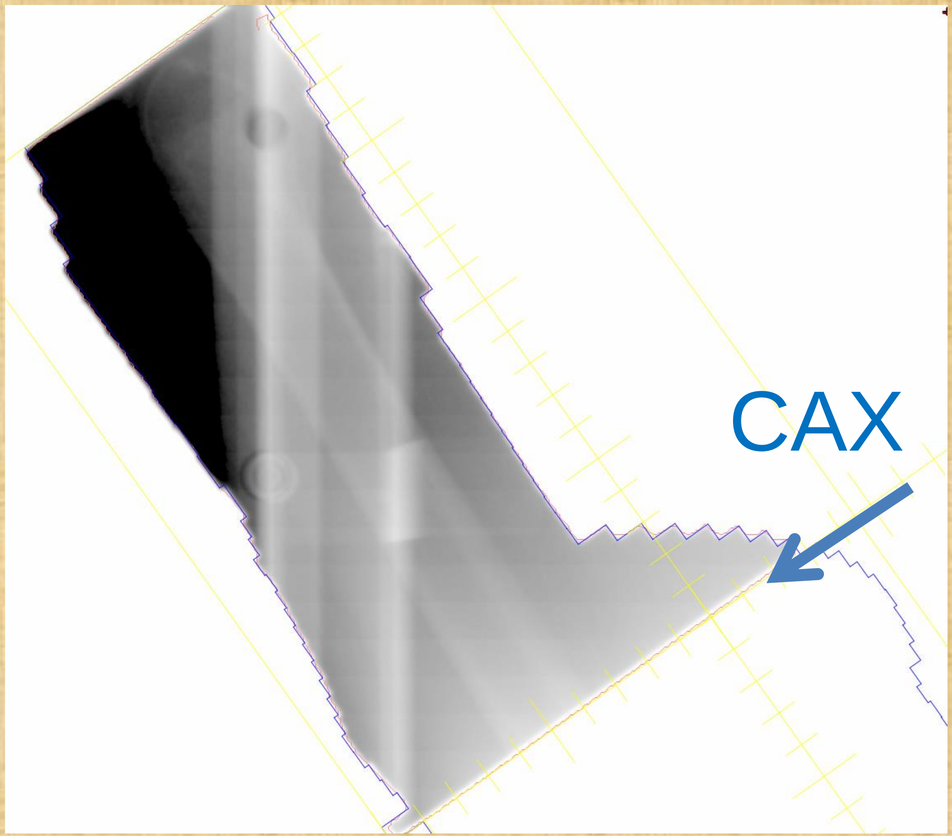
When 7-9 eq. spaced beams were desired, found that about 70% of the time, beam angles had to be changed to avoid passing through couch rails/supports

Do-it-Yourself Couch Rail Entry

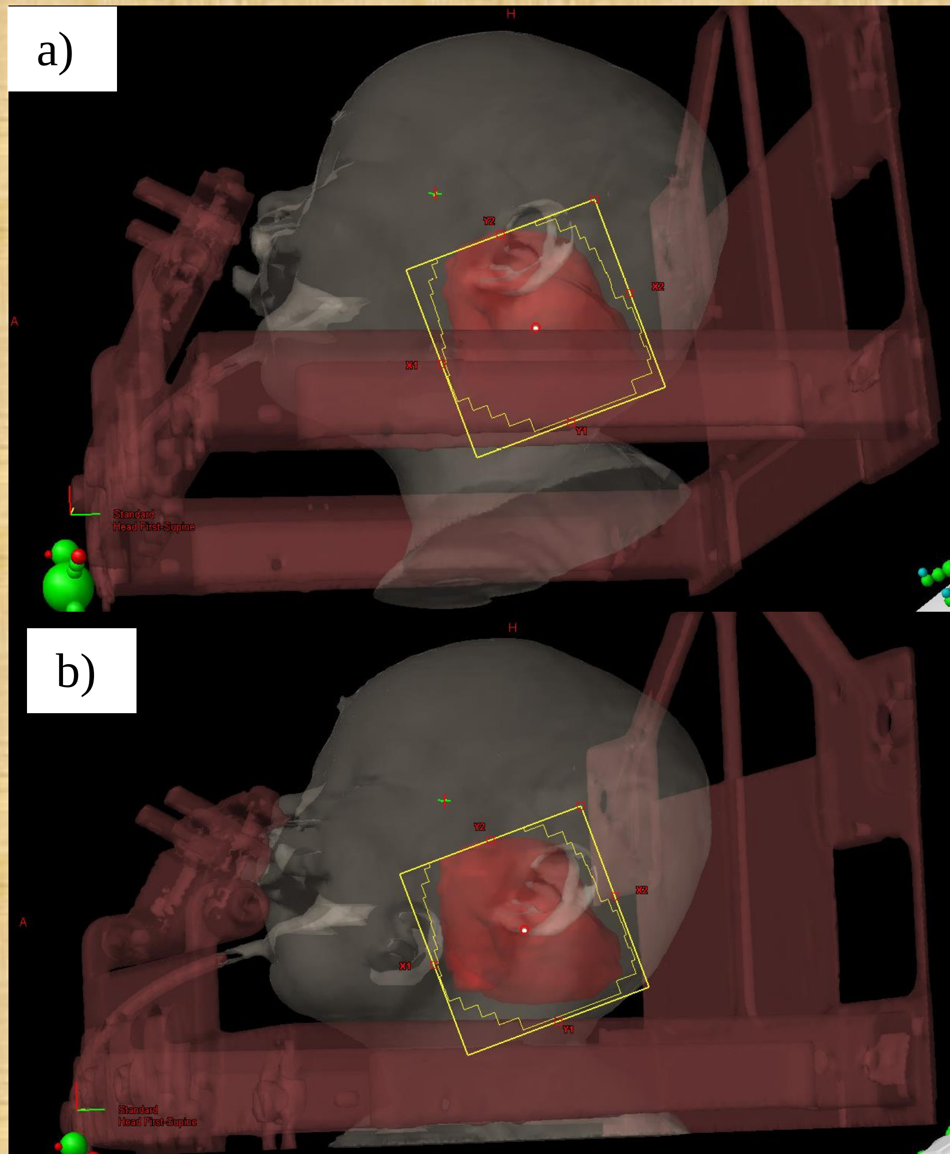


Sometimes You just Can't Avoid It
Frog-Leg Over Rail, APPA





Beam's-Eye-View Immobilization Structure Avoidance



User Recommendations (preliminary)

- Understand the physical dimensions of your couchtop, where are the solid sections, what are the dimensions? CT the couchtop before installation, at least take PVs of it throughout the treatment region. If possible, use same couch at CTSIM as Treatment.
- Determine the capabilities of your planning system, can it accurately calculate the dose through structures external to the "Body".
- Be prepared to validate by measurement the TPS calcs of external devices once this function is available.
- All immobilization devices used for treatment should be in the CT dataset within the FOV.
- Determine if your strategy is modelling, avoidance, or compensation.

Vendor Recommendations (Preliminary)

- TPS vendors: An accurate model of couchtops should able to be automatically inserted at the time of planning so the TPS can calculate the dose accounting for the external device
- Couchtop vendors: We will be recommending specific attenuation and surface dose measurement methods and reporting requirements. Recommend a Dicom RT structure set file or other geometric model of the couch be provided to TPS vendors/users.