LOYOLA UNIVERSITY HEALTH SYSTEM

Clinical Implementation of SRS/SBRT

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August 3, 2017

AAPM 2017 JUL 30–AUG 3

Disclosures

Speaker:

BrainLAB

Standard Imaging

Research collaboration:

RaySearch

Overview

- Physics Considerations
- SRS Program
- SBRT Program

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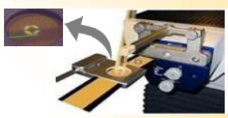
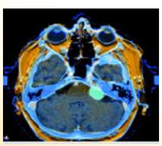
Physics Considerations

- System QA (Image, Plan and Treat)
- Equipment Selection
- Beam Data Measurement
- Data Validation
- End-to-End Test (Process QA)
- Tips and Tricks

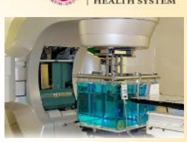
System QA

- Winston Lutz Test
- Process QA
- Image-Fusion Test



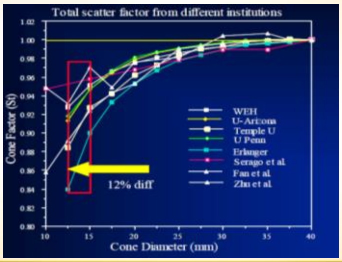


Output/PDD/Profiles



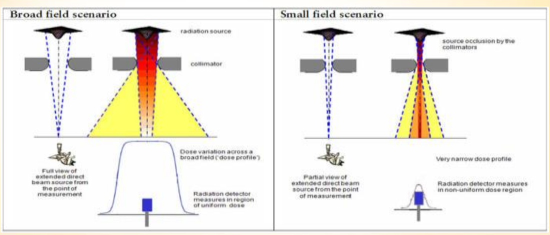
- Beam Output Check: TG-51
- Send for RPC TLDs
- Beam Scans (PDD/Profiles) for MLC & cones
- Scatter factors

Small Field Challenge: Output Factors

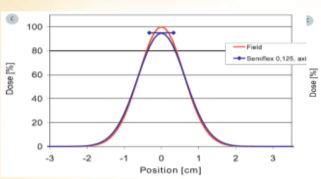


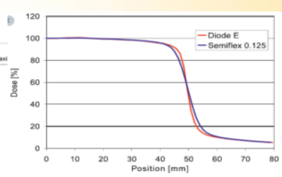
Das *et al.*, 2000.

Large *vs.* Small Fields



Wrong Detector….





- Dose ⟶ Under-estimated
- Penumbra ⟶ Broadened
- FWHM ⟶ Unaffected

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Which Detector to Use?

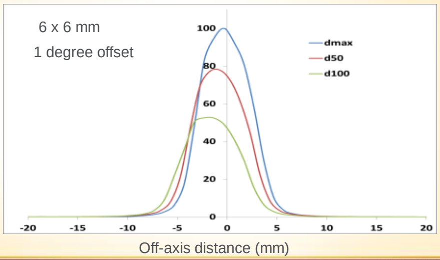
- Ensure detector size < (¼ * Field Size)
- Small ion chamber (<0.1cc): stem effect/leakage.
- Medium ion chamber (0.1 – 1.0 cc): volume averaging
  - CA is under-dosed, penumbra broadened
- Recommend:
  - Unshielded diode for small fields and
  - Ion chamber for large fields

SRS Detectors

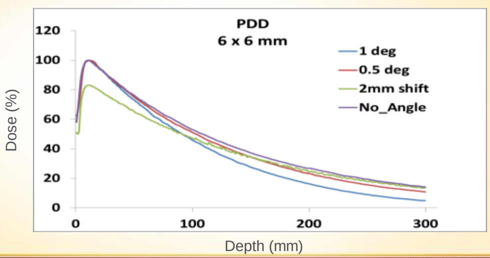
- CC13 (0.13cc active volume)
- A16
- Exradin D1H and D1V
- IBA SFD
- Edge detector
- PTW White diode (60018)

Pitfalls

Beam Misalignment



Beam Misalignment



Beam Data Measurement Tips

- Check water surface (use d_{max} as reference)
- Effective point of measurement
- Align scanning system/ detectors with beam axis. Drive Up!
- Scan small field profile (< 2 cm) to verify detector centering & depth correction if needed
- Repeat with MLC and cones

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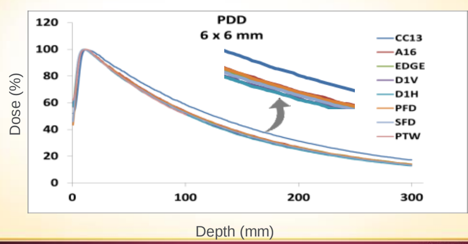
Measurement Tips

- Verify 10x10 cm PDD/profiles
- Compare in-house or from a comparable SRS machine
- Output (scatter) factors with at-least two diode detectors + small volume ion chamber
- Perform cross calibration before each measurement
- Daisy chain at ~4x4 cm: Perform measurements with large chamber for known MU and then deliver same MU to the small detector. Use charge ratio of output for large detector to adjust output with small detector.

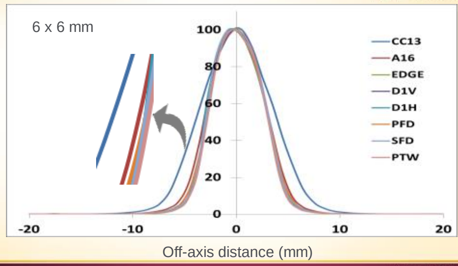
More Tips

- For small fields, No ref detector
- Stealth detector (IBA)
- Slow speed, 20+ pts/meas
- Eliminate noise!
- Watch for Penumbra asymmetry
- Check leakage and subtract from Outpu necessary

Detector Compare

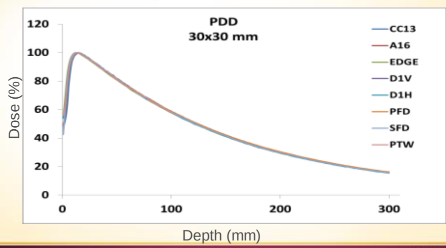


Detector Compare

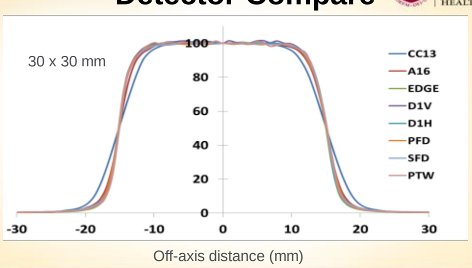


Detector Compare

30 x 30 mm PDD



Detector Compare



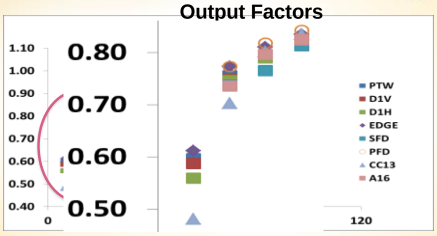
Detector Compare

Penumbra Measurements

F.S. (mm)	→	100 x 100	30 x30	12x 12	6x6
Detector	*Vendor*				
CC13	IBA	5.2	4.9	4.7	3.8
A16	Std Imaging	3.8	3.3	3.1	2.4
Edge	Sun Nuclear	3.2	2.6	2.2	2.1
D1V	Std Imaging	3.0	2.3	2.2	2.1
D1H	Std Imaging	3.0	2.3	2.3	1.9
PFD	IBA	3.5	2.5	2.5	2.3
SFD	IBA	3.1	2.4	2.3	2.0
TN 60018	PTW	3	2.2	2.3	2.1

Detector Compare

Output Factors



Field size (mm)

Output factors of Conical Cones

		6X FFF						
Cone size (mm)		4	5	7.5	10	12.5	15	17.5
Representative OF from Varian		0.603	0.664	0.755	0.795	0.824	0.845	0.852
% diff of measured vs. representative OF	Edge	0.8	1.2	0.1	0.8	0.5	0.5	1.0
	SFD	0.3	-1.3	-3.0	-2.2	-1.9	-1.5	-0.5
	Photon diode	-7.1	-2.6	-1.0	0.2	0.2	0.1	0.9
	CC01	-36.0	-24.3	-9.5	-4.8	-2.9	-1.7	-0.1
	Pinpoint	-43.6	-32.1	-14.3	-7.0	-4.0	-2.6	-0.7

N. Wen,
Henry Ford

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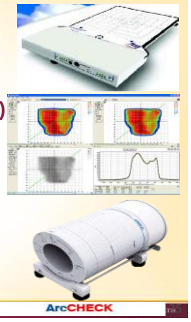
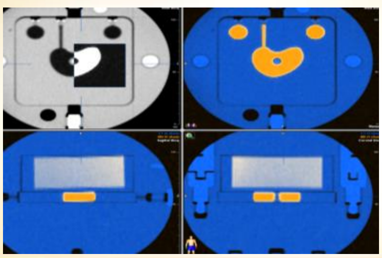
TPS Validation

- Independent MU to Dose Calc
- TG-119 (Planar Array/ ion-chamber/film)
- MU *vs.* Measurement for MLC and Cone plans
- Hetero Correction *vs.* Field size
- Verify Select Fields Dose/MU
- RPC/RTOG credentialing



Fusion QA: CT/MR



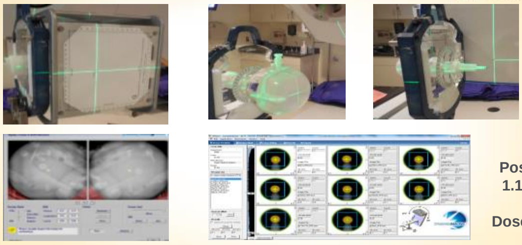
CT/CT :
0.48 ± 0.07 mm

CT/MR :
1.09 ± 0.65 mm

Process QA: Hidden Target Test

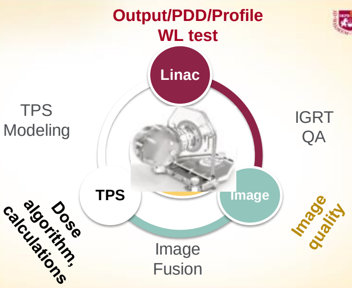
Scan, Plan, Treat, and Verify!

HTT for SRS/SBRT



Position: 1.14 mm

Dose: < 2%



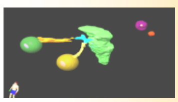
Summary

- Select appropriate set of detectors for small fields
- Ensure positioning and alignment with respect to central axis
- Redundancy of measurements
- Cross check with standard data
- RTP commissioning/verification: for typical treatment fields
- System QA: Imaging/TPS/Linac

SRS Treatment Planning

SRS Rx Dose

- Target Volume, Type, and Location
- SRS Rx dose (RTOG 95-08) max tolerable *vs.* GTV diameter:
  - < 2cm: 24 Gy
  - 2.1 - 3cm: 18 Gy
  - 3.1 - 4cm: 15Gy
- Mets/AVM typically treated with SRS
- Malignant lesions with SRT



SRS Treatment Planning

- Follow RTOG guidelines (www.rtog.org)
- Use DVHs to get
  - target Rx Dose or D_{min}
- Volume of healthy tissue irradiated
  - Conformality index
- Target dose homogeneity (max/min target dose)
  - homogeneity index
- *SRS dose homogeneity is relaxed in favor of dose Conformality*

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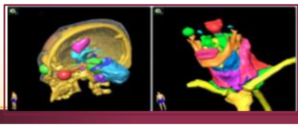
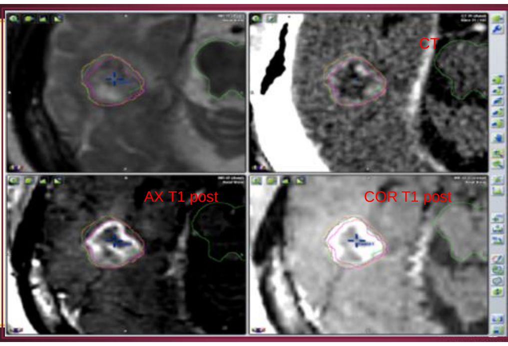
SRS Treatment Planning

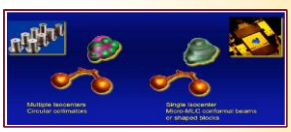
- Draw separate GTVs on CT & MR
  - PTV = GTV (SRS)
  - PTV = GTV + 2mm (SRT)
- Use composite GTV (CT + MR) for planning
- OARs (auto segmentation but verify)

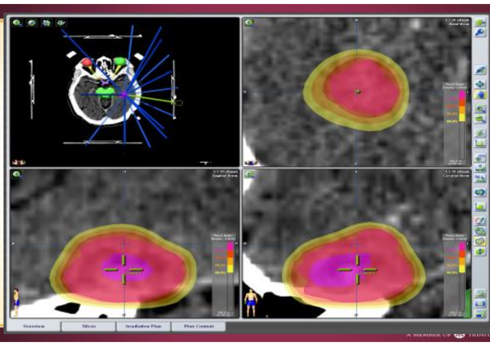




SRS Treatment Planning

- Target size,
- location,
- proximity to OARs
- dose fractionation.
- 3-4 VMAT Arcs
- Can also use conformal fixed fields or circular arcs





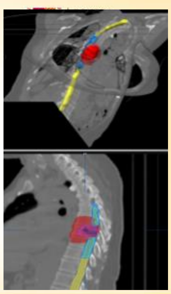
Dose constraints

Structure	Dose (Gy)	Endpoint
Optic chiasm	10	Neuritis
Cochlea	12	Hearing loss
Brainstem	15	Cranial neuropathy
Cord	14	Myelitis

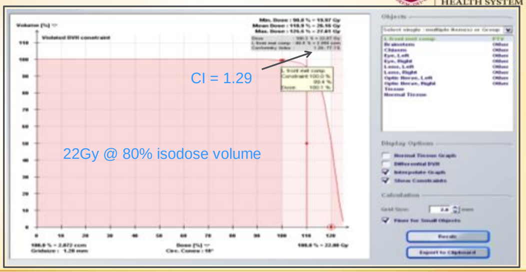
Optic, auditory< trigeminal <motor CN

SRS Plan Evaluation

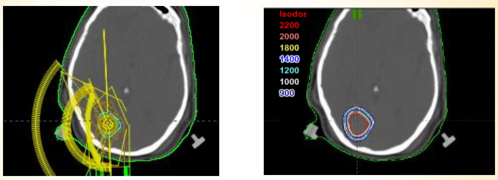
- Draw “Irradiated_OARs” for long structures such as cord, brain stem for accuracy.
- Examine DVHs, Rx Isodose coverage, and OAR sparing
- Conformality index (V100/PTV)
- Homogeneity index (D5/D95)



Case 1: Brain Met DVH

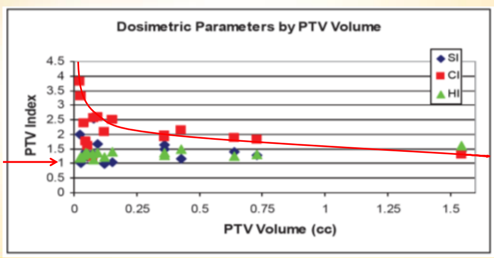


Case 2: Rt Occipital Met



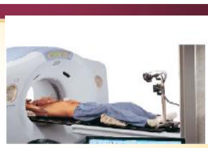
4 VMAT arcs, 4 table angles, 18Gy, single fraction

Conformality Index *vs.* Target size



SBRT Planning

4DCT Scanning



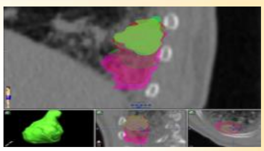
- Free breathing (FB) scan
  - 3x3mm slices
- 4D scan with Varian's RPM
  - ROI: (±5 cm around PTV)
  - 2-3 mm slice width.
- Create MIP (maximum intensity projection) data set.
- Transfer FB images & 4D sets (0%, 50%, MIP & Ave. Int. projection) to TPS

Image Fusion

SBRT OARs

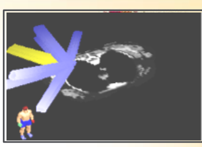
- Rt + Lt lung (pulmonary window)
- Heart, Trachea, Carina
- Esophagus_irrad. (± 3cm sup/inf around PTV)
- Spinal cord_irrad. (± 3cm sup/inf around PTV)
- Liver, kidneys, Small bowel, Pancreas
- **Do not include GTV/PTV in lung definition*

SBRT Targets



- GTV on FB, 0%, 50% CT sets; ITV on MIP
- PTV = ITV + 3 - 5mm
- Create D2cm = PTV + 2cm (high dose spillage)

SBRT Dose Rx.



Loyola:

- For lung patients:

  10 - 12Gy/fx x 5 fractions = 50-60Gy
  BED ~ 100-150 Gy
  M-W-F treatments

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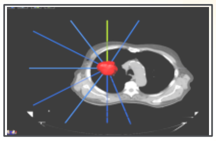
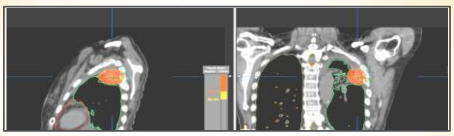
SBRT Treatment Planning



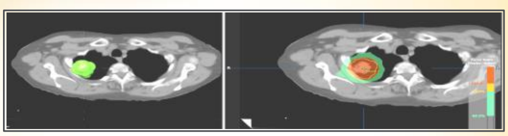
- 6 – 10 MV X-rays,
- VMAT: 3 – 4 VMAT non-coplanar arcs or
- 3DCRT: 8 – 12 non-coplanar, non-opposing fields.

SBRT Plan Evaluation



- Target Coverage: 95% of PTV and 100% of GTV
- Hot spot must be less than ~10-15% & within PTV.
- Target Dose Homogeneity : < 15-20%
- Dose spillage: V50/PTV (see RTOG table)

SBRT Plan Evaluation



- Dose Conformality: V100/PTV = 1.2 - 1.5 (higher values for smaller targets)
- Tighten up PTV - MLC margin or adjust beam parameters to achieve better Conformality index (CI).
- Ensure small calc. grid (1mm) for small structures.

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SBRT Plan Evaluation

Table 1: Conformality of Prescribed Dose for Calculations Based on Deposition of Photon Beam Energy in Heterogeneous Tissue

PTV Volume (cc)	Ratio of Prescription Isodose Volume to the PTV Volume		Ratio of 50% Prescription Isodose Volume to the PTV Volume, $R_{50\%}$		Maximum Dose (in % of dose prescribed) @ 2 cm from PTV in Any Direction, D_{2cm} (Gy)		Percent of Lung Receiving 20 Gy Total or More, V_{20} (%)	
	Deviation		Deviation		Deviation		Deviation	
	None	Minor	None	Minor	None	Minor	None	Minor
1.8	<1.2	<1.5	<5.9	<7.5	<50.0	<57.0	<10	<15
3.8	<1.2	.<1.5	<5.5	<6.5	<50.0	<57.0	<10	<15
7.4	<1.2	<1.5	<5.1	<6.0	<50.0	<58.0	<10	<15
13.2	<1.2	<1.5	<4.7	<5.8	<50.0	<58.0	<10	<15
22.0	<1.2	<1.5	<4.5	<5.5	<54.0	<63.0	<10	<15
34.0	<1.2	<1.5	<4.3	<5.3	<58.0	<68.0	<10	<15
50.0	<1.2	<1.5	<4.0	<5.0	<62.0	<77.0	<10	<15
70.0	<1.2	<1.5	<3.5	<4.8	<66.0	<86.0	<10	<15
95.0	<1.2	<1.5	<3.3	<4.4	<70.0	<89.0	<10	<15
126.0	<1.2	<1.5	<3.1	<4.0	<73.0	>91.0	<10	<15
163.0	<1.2	<1.5	<2.9	<3.7	<77.0	>94.0	<10	<15

From: RTOG 0813

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OAR Dose Constraints

Serial Tissue	Volume (mL)	Volume Max (Gy)	Max Point Dose (Gy)	Endpoint (≥Grade 3)
FIVE-FRACTION TREATMENT				
Optic pathway	<0.2	20 (4 Gy/fx)	25 (5 Gy/fx)	Neuritis
Cochlea			27.5 (5.5 Gy/fx)	Hearing loss
Brainstem	<1	26 (5.2 Gy/fx)	31 (6.2 Gy/fx)	Cranial neuropathy
Spinal cord	<0.25	22.5 (4.5 Gy/fx)	30 (6 Gy/fx)	Myelitis
	<1.2	13.5 (2.7 Gy/fx)		
Cauda equina	<5	30 (6 Gy/fx)	34 (6.4 Gy/fx)	Neuritis
Sacral plexus	<3	30 (6 Gy/fx)	32 (6.4 Gy/fx)	Neuropathy
Esophagus*	<5	27.5 (5.5 Gy/fx)	35 (7 Gy/fx)	Stenosis/fistula
Ipsilateral brachial plexus	<3	30 (6 Gy/fx)	32 (6.4 Gy/fx)	Neuropathy
Heart/pericardium	<15	32 (6.4 Gy/fx)	38 (7.6 Gy/fx)	Pericarditis
Great vessels	<10	47 (9.4 Gy/fx)	53 (10.6 Gy/fx)	Aneurysm
Trachea and ipsilateral bronchus*	<4	18 (3.6 Gy/fx)	38 (7.6 Gy/fx)	Stenosis/fistula
Skin	<10	30 (6 Gy/fx)	32 (6.4 Gy/fx)	Ulceration
Stomach	<10	28 (5.6 Gy/fx)	32 (6.4 Gy/fx)	Ulceration/fistula
Duodenum*	<5	18 (3.6 Gy/fx)	32 (6.4 Gy/fx)	Ulceration
Jejunum/ileum*	<5	19.5 (3.9 Gy/fx)	35 (7 Gy/fx)	enteritis/obstruction
Colon*	<20	25 (5 Gy/fx)	38 (7.6 Gy/fx)	colitis/fistula
Rectum*	<20	25 (5 Gy/fx)	38 (7.6 Gy/fx)	proctitis/fistula
Bladder wall	<15	18.3 (3.65 Gy/fx)	38 (7.6 Gy/fx)	cystitis/fistula
Penile bulb	<3	30 (6 Gy/fx)	50 (10 Gy/fx)	Impotence
Femoral heads (right and left)	<10	30 (6 Gy/fx)		Necrosis
Renal hilum/vascular trunk	<2/3 volume	23 (4.6 Gy/fx)		Malignant hypertension

Parallel Tissue	Critical Volume (mL)	Critical Volume Dose Max (Gy)	Endpoint (≥Grade 3)
Lung (right and left)	1,500	12.5 (2.5 Gy/fx)	Basic lung function
Lung (right and left)	1000	13.5 (2.7 Gy/fx)	Pneumonitis
Liver	700	21 (4.2 Gy/fx)	Basic liver function
Renal cortex (right and left)	200	17.5 (3.5 Gy/fx)	Basic renal function

*Avoid circumferential irradiation.

From: Timmerman, R.D., Seminars in Radiation Oncology 18(4), 215 (October 2008).

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Dose Calculation Algorithms in Lung SBRT

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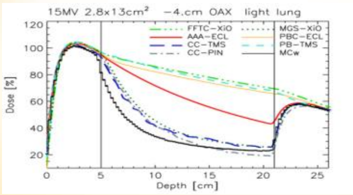
Depth dose, 15 MV, 4 cm off-axis, "light lung", Several algorithms

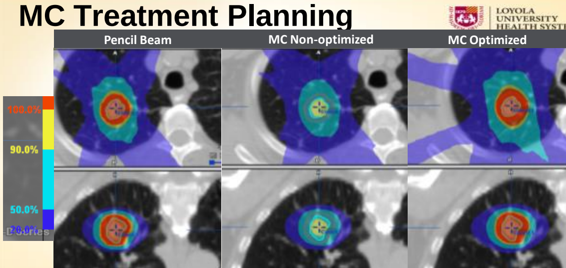


Problems with algorithms that do not model electron transport.

Electronic equilibrium? No problem.

Better agreement between Pinnacle CC and Monte Carlo than between Eclipse AAA and Monte Carlo.

MC Treatment Planning

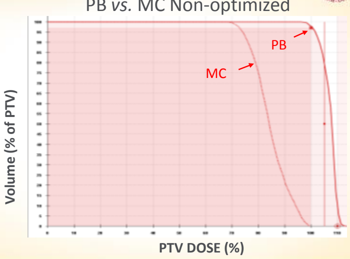


RUL T1aN0 NSCLC, 10.7cm³ PTV

50Gy in 5 fractions, 9 conformal, non-coplanar 6MV beams

56

PB *vs.* MC Non-optimized



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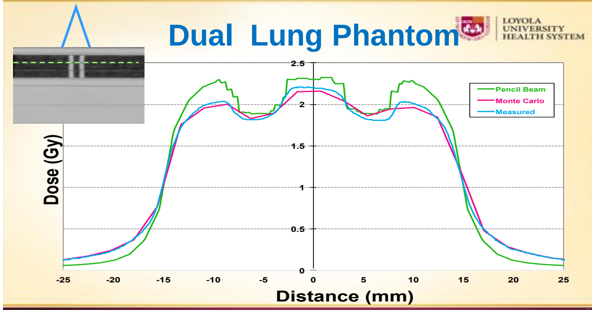
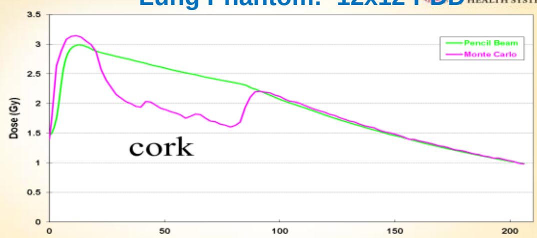
UNIVERSITY
HEALTH SYSTEM

Dual Lung Phantom

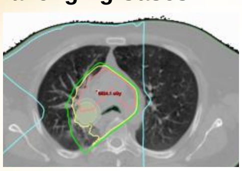


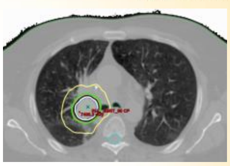
Lung Phantom: 12x12 PDD



Significant differences b/w MC and PB in the cork region

Challenging Cases - 1

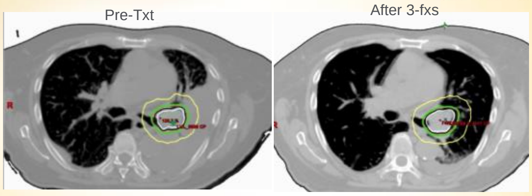




Patient had 3D treatment for lung target 2 years ago and recurred.
Prev Cord dose = 49 Gy, deliver minimum dose to cord
Beam arranged to not enter thru cord, exit only
Cord as OAR in optimization

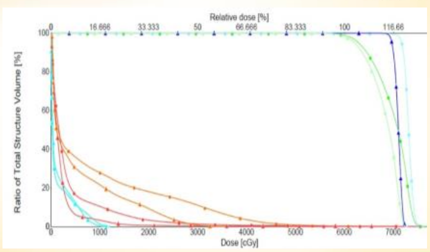
Challenging Case - 2

Pre-Txt | After 3-fxs



A patient with left upper lobe lesion (17 x 22 mm). Significant left lung obstruction. Opened up after three fx. Replanning required. Significant (up to 10%) change in dose to PTV.

Challenging Case - 2



Summary

- Ensure **adequate resources** are available:
  - **Imaging**,
  - **Txt Planning** and
  - **Delivery**
- **Acceptance Testing/Commissioning**
- **Robust System QA (End to End Test)**
- **IMRT/Arc Check QA**

Summary

- Checklists + Independent MU calc
- Follow RTOG Guidelines
- Establish site specific protocols consistent with departmental resources
- Automate Planning and Evaluation methods for efficient and consistent planning
- Follow AAPM/ASTRO/RTOG guidelines

Thank you!

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