It's Grays to Me: Understanding Radiation Data

Hiram A. Gay, MD
Department of Radiation Oncology
Washington University in Saint Louis

Alliance Fall Group Meeting, 11/6/2015

Presentation Objectives

- Understand the importance of radiation protocol compliance
- Understand the basic radiation oncology workflow
- Gain insights where to find radiation oncology data requested by Alliance through a sample case

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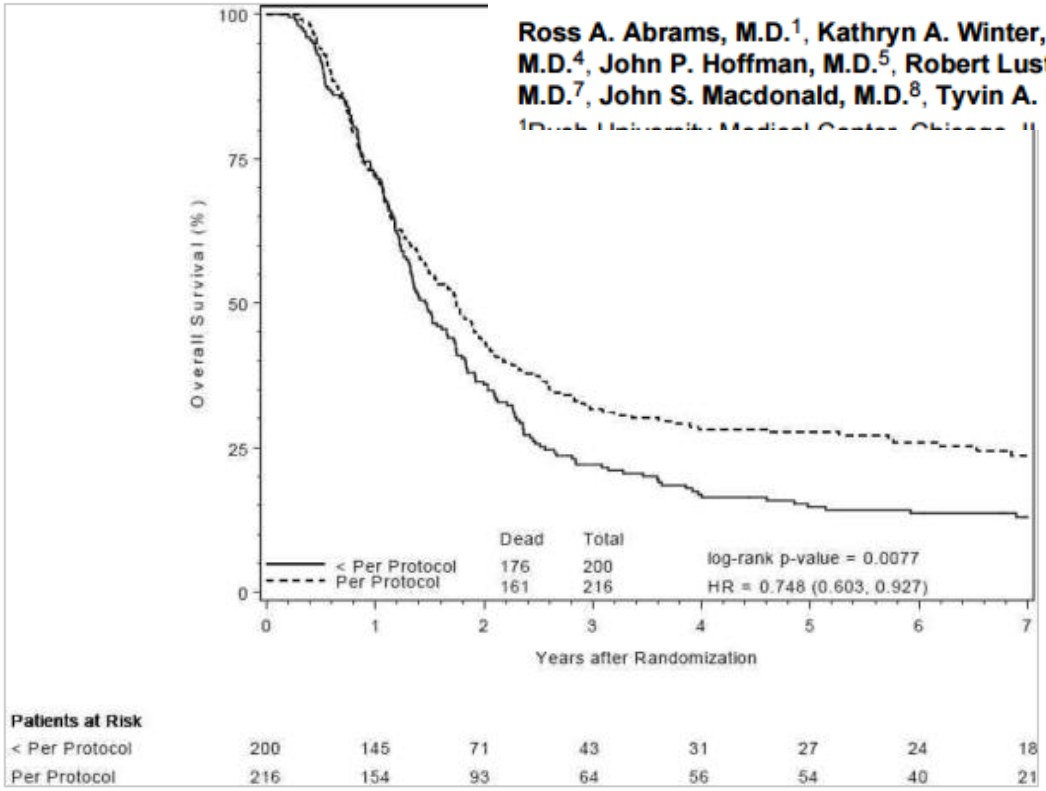
Compliant

Failure to Adhere to Protocol Specified Radiation Therapy Guidelines Was Associated With Decreased Survival in RTOG 9704 - A Phase III Trial of Adjuvant Chemotherapy and Chemoradiotherapy for Patients with Resected Adenocarcinoma of the Pancreas

Ross A. Abrams, M.D.[1], Kathryn A. Winter, M.S.[2], William F. Regine, M.D.[3], Howard Safran, M.D.[4], John P. Hoffman, M.D.[5], Robert Lustig, M.D.[2], Andre A. Konski, M.D.[6], Al B. Benson, M.D.[7], John S. Macdonald, M.D.[8], Tyvin A. Rich, M.D.[9], and Christopher G. Willett, M.D.[10]

[1]Rush University Medical Center, Chicago, IL



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NON-COMPLIANCE Kills Lives

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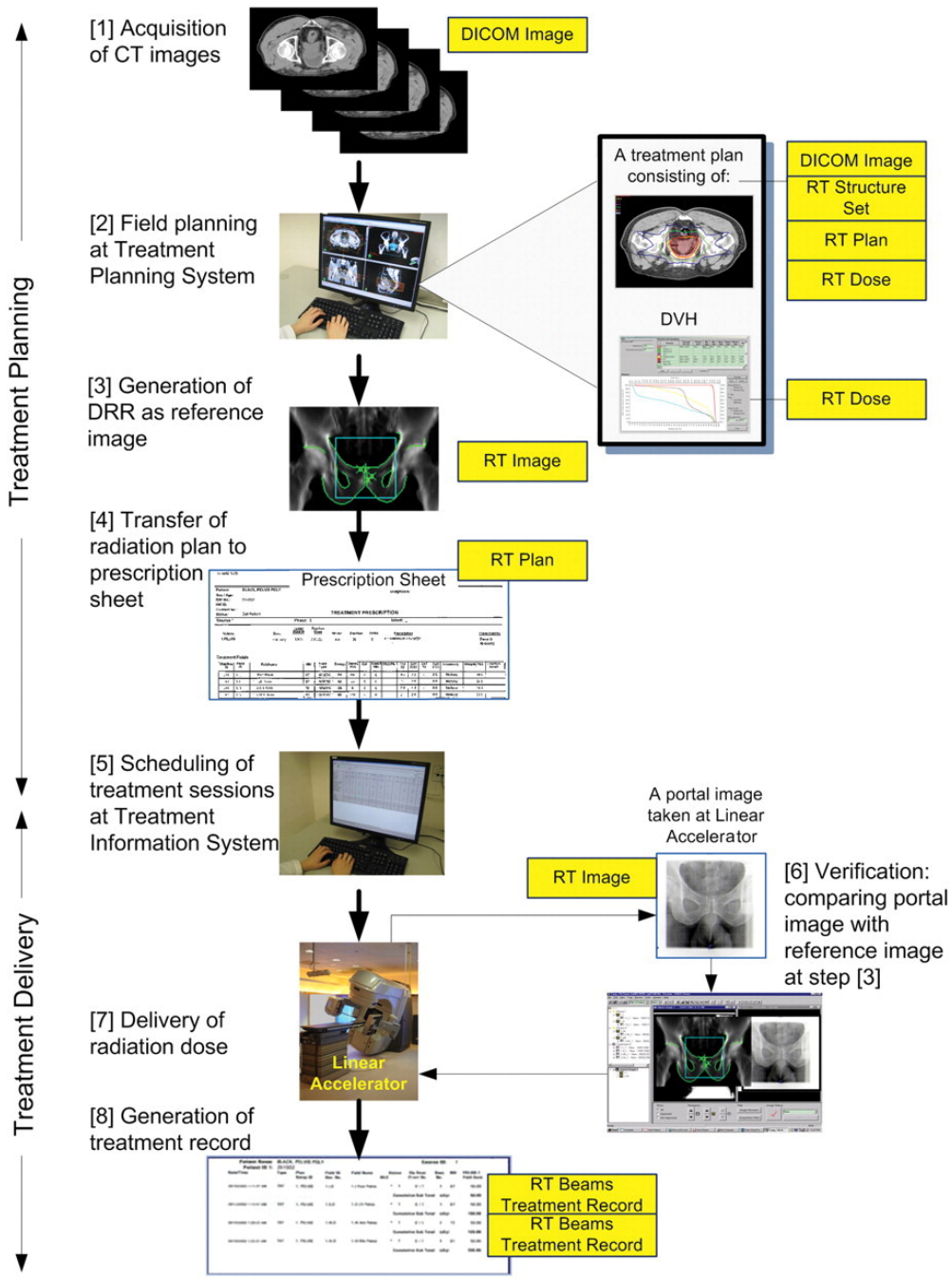
Radiation Oncology Workflow



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ALLIANCE CALGB-30610

Checklist for Submission of Radiation Oncology Quality Assurance Materials

Patient Initials: T,SK Registration #: 136823 RT Start Date: October 28, 2014

Sender's Name: Jason Atkinson Phone #: 314-362-3203

Email: jlatkins@dom.wustl.edu

Radiation Oncologist: Cliff Robinson Email: crobinson@radonc.wustl.edu

Please *enclose a copy of this Checklist* together with the RT materials you submit. All materials must be labeled with the protocol and assigned registration number.

Digital treatment plan, screenshots of other RT data and diagnostic imaging may be submitted via sFTP or on CD. For data sent via sFTP, a notification email should be sent to sFTP@qarc.org with the **protocol # and registration # in the subject line.** Please refer to IROC Rhode Island website for instructions on sending digital data (www.QARC.org).

Data not sent via sFTP may be sent via email to datasubmission@qarc.org with the **protocol # and registration # in the subject line.** Data may also be sent via courier to the address below.

Rapid Review materials must be submitted within the first week of the start of radiotherapy:

DATE SUBMITTED	
3/2/15	Copy of baseline diagnostic CT or PET scan (include reports)
3/2/15	Copy of Treatment Planning CT scan (DicomRT or RTOG format)
3/2/15	Prescription sheet
3/2/15 tx plan	Treatment planning system summary report that includes the MU calcs, beam parameters, calculation algorithm, and volume of interest dose statistics
3/2/15 tx plan	Color Isodose Distributions in axial, sagittal and coronal planes (composite plan) (Only required if Digital RT plan not submitted)
3/2/15 tx plan	Dose volume histograms of PTV, CTV, GTV, Lungs, Heart, Esophagus and Spinal Cord. If IMRT is used, a DVH of unspecified tissue. These will be included with the digital RT plan.
3/2/15	Portal films (or hard copy of real time portal images) of each treatment field
3/2/15 tx plan	DRRs (digitally reconstructed radiographs) of each treatment field
3/2/15 tx plan	Orthogonal Anterior/Posterior and Lateral Films if not part of portals
3/2/15	For thoracic IMRT, motion management description required http://www.qarc.org/forms/IROC_MotionManagementForm.pdf
3/2/15	RT-1 or IMRT Dosimetry Form www.qarc.org/forms/IROC_RT-1DosimetrySummaryForm.pdf

Final Review materials must be submitted within 1 week of the completion of radiation:

3/2/15	Completed RT Daily Treatment Chart, including prescription, daily and cumulative doses
3/2/15	RT-2 Total Dose Record www.qarc.org/forms/IROC_RT2RadiotherapyTotalDoseRecord.pdf
n/a	All revised data if modifications made subsequent to initial data submission

Please contact study CRA by email (alliance@qarc.org) or phone: **(401) 753-7600** for clarification as necessary. Thank you for your ongoing co-operation.

Version date: 12/02/2014

IROC Rhode Island (QARC), Building B, Suite 201, 640 George Washington Highway, Lincoln, RI 02865-4207

ALLIANCE FOR CLINICAL TRIALS IN ONCOLOGY

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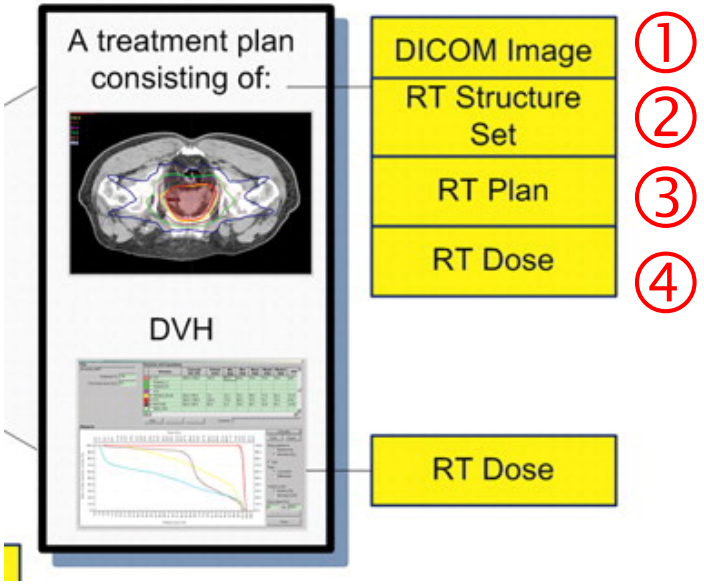
Copy of Treatment Planning CT scan (Dicom-RT or RTOG format)

- Digital Imaging and Communications in Medicine (DICOM) standard is used for the transmission of medical images
  - Radiation therapy is image intensive
    - first specialty incorporated into the DICOM standard after radiology
    - four DICOM-RT objects



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Example illustrated with:

- Mosaiq, record and verify system
- Pinnacle, treatment planning software
- WashU MD orders

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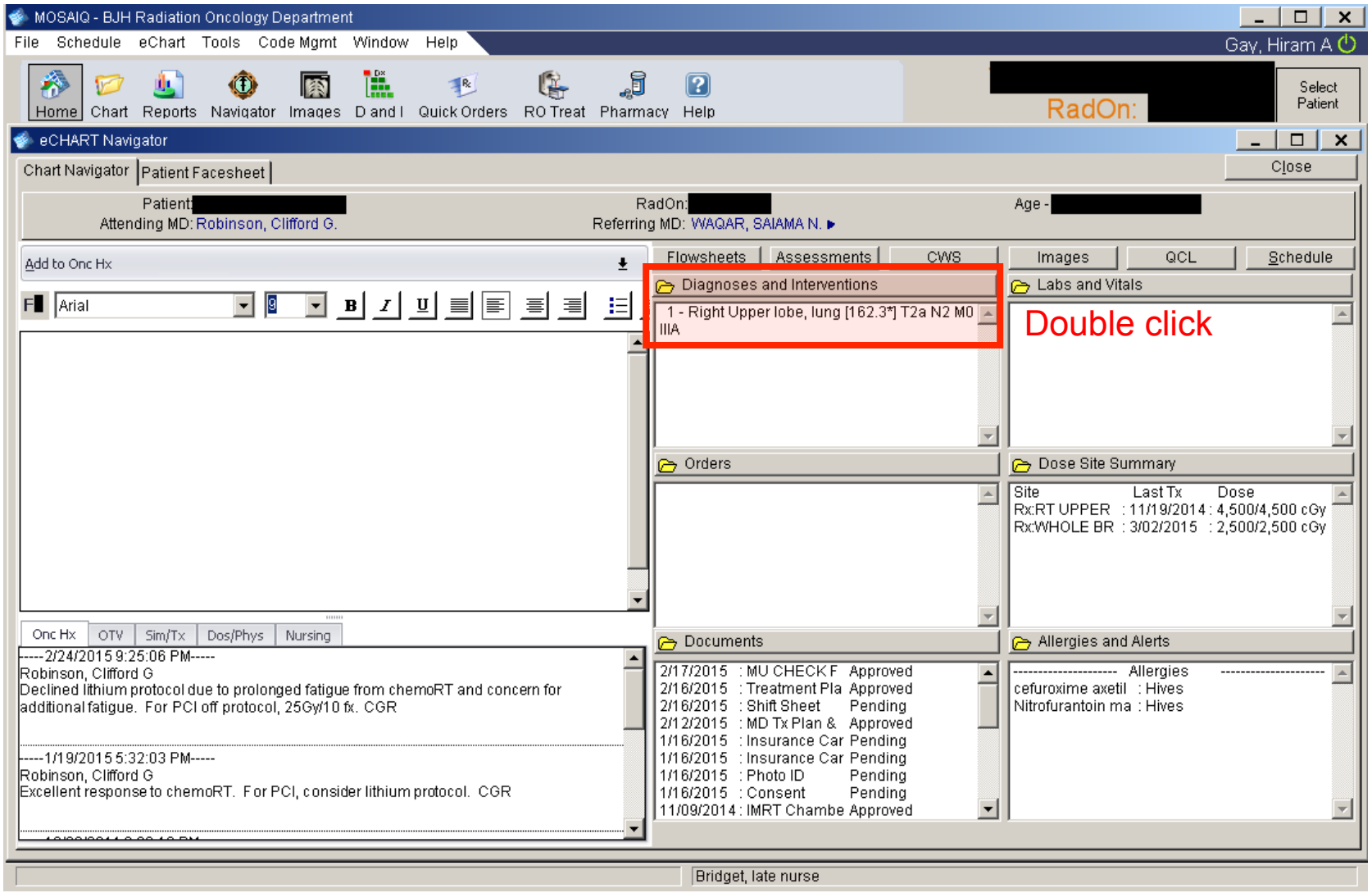
Prescription sheet



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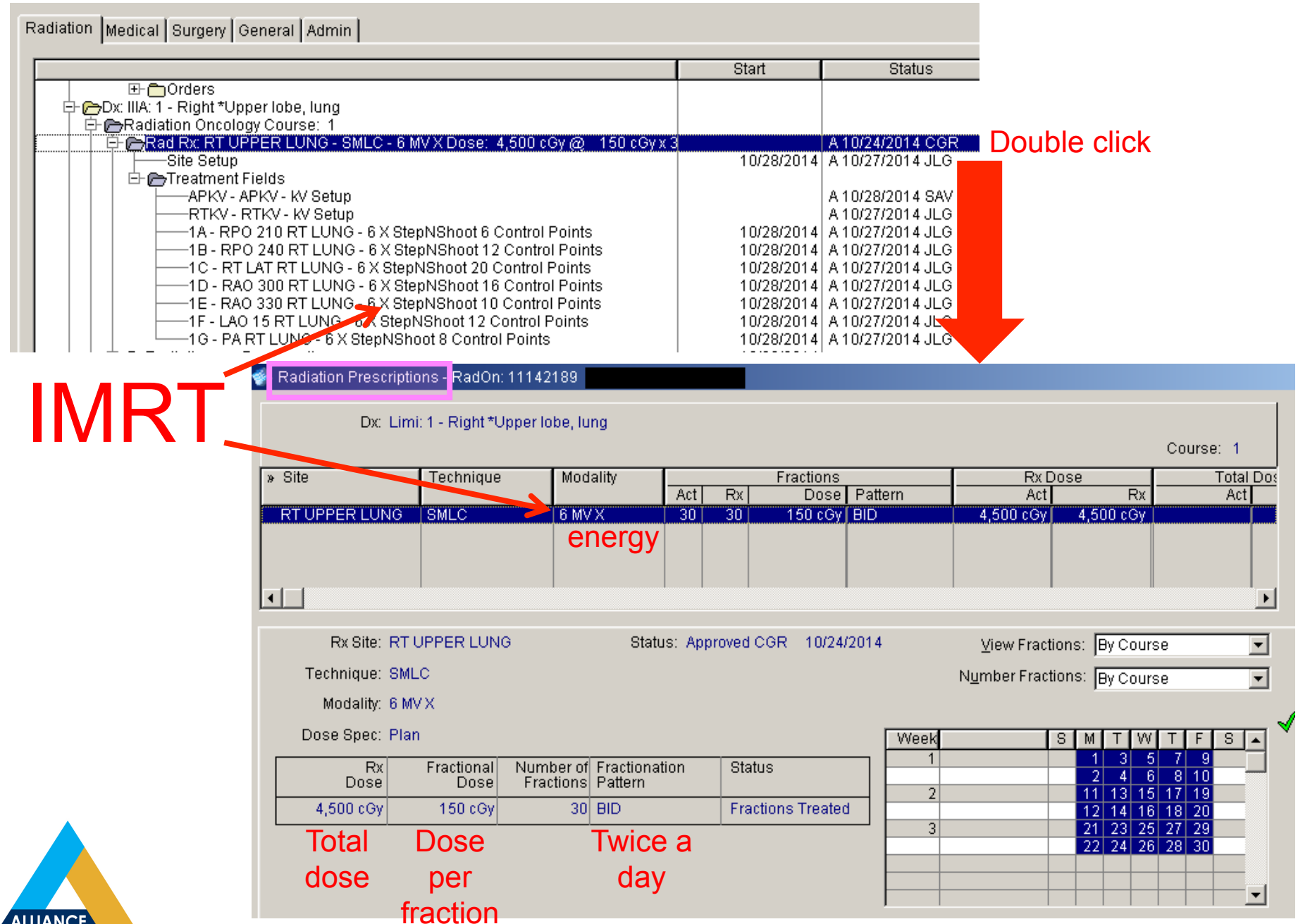

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Treatment planning system summary report that includes the MU calcs, beam parameters, calculation algorithm, and volume of interest dose statistics

Plan Summary Sheet

CALGB 30610
Pt# 136823
T,SK

Beam Setup

Beam	Machine	Energy	Modality	Prescription	Isocenter	SSD (cm) Start / Avg	MU Per Fraction
1A RPO 210 RT ...	TR6_VARIX	6MV	Photons	RT LUNG	PREVIE...	88.34 / 88.34	**33**
1B RPO 240 RT ...	TR6_VARIX	6MV	Photons	RT LUNG	PREVIE...	83.51 / 83.51	**40**
1C RT LAT RT L...	TR6_VARIX	6MV	Photons	RT LUNG	PREVIE...	77.36 / 77.36	**78**
1D RAO 300 RT ...	TR6_VARIX	6MV	Photons	RT LUNG	PREVIE...	77.23 / 77.23	**54**
1E RAO 330 RT ...	TR6_VARIX	6MV	Photons	RT LUNG	PREVIE...	83.96 / 83.96	**58**
1F LAO 15 RT L...	TR6_VARIX	6MV	Photons	RT LUNG	PREVIE...	86.39 / 86.39	**49**
1G PA RT LUNG	TR6_VARIX	6MV	Photons	RT LUNG	PREVIE...	89.94 / 89.94	**41**
APKV	TR6_VARIX	6MV	Photons	RT LUNG	PREVIE...	86.87 / 86.87	**0**
RTKV	TR6_VARIX	6MV	Photons	RT LUNG	PREVIE...	77.36 / 77.36	**0**

	Collimators (cm) (Control Pt 1)				Gantry						
Beam	X1	X2	Y2	Y1	Start / Stop	Couch	Coll	Block	Wedge	Bolus	Comp
1A RPO 210 RT L...	2.5	6.5	4.0	7.0	210.0/210.0	0.0	0.0	MLC	None	No	No
1B RPO 240 RT L...	5.0	6.0	4.0	7.0	240.0/240.0	0.0	0.0	MLC	None	No	No
1C RT LAT RT LU...	7.5	4.0	4.0	7.0	270.0/270.0	0.0	0.0	MLC	None	No	No
1D RAO 300 RT L...	8.5	3.0	4.0	6.5	300.0/300.0	0.0	0.0	MLC	None	No	No
1E RAO 330 RT L...	7.5	2.5	4.0	6.5	330.0/330.0	0.0	0.0	MLC	None	No	No
1F LAO 15 RT LU...	6.5	1.5	4.0	6.5	15.0 / 15.0	0.0	0.0	MLC	None	No	No
1G PA RT LUNG	1.5	7.0	4.0	6.5	180.0/180.0	0.0	0.0	MLC	None	No	No
APKV	5.0	5.0	5.0	5.0	0.0 / 0.0	0.0	0.0	No	None	No	No
RTKV	5.0	5.0	5.0	5.0	270.0/270.0	0.0	0.0	No	None	No	No

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Treatment planning system summary report that includes the MU calcs, beam parameters, calculation algorithm, and volume of interest dose statistics

	1A RPO 210 RT LUNG	1B RPO 240 RT LUNG	1C RT LAT RT LUNG
Beam Setup			
Machine Name	TR6_VARIX	TR6_VARIX	TR6_VARIX
Machine Version	2011–08–03 17:26:32	2011–08–03 17:26:32	2011–08–03 17:26:32
Energy / Modality	6MV Photons	6MV Photons	6MV Photons
SAD (cm)	100.0	100.0	100.0
Prescription	RT LUNG	RT LUNG	RT LUNG
Isocenter	PREVIEW	PREVIEW	PREVIEW
Beam Geometry			
Couch Angle	0.0	0.0	0.0
Gantry Angle	210.0	240.0	270.0
Collimator Angle	0.0	0.0	0.0
SSD (cm)	88.34	83.51	77.36
SSD With Bolus (cm)	---	---	---
Collimators (cm) (Control Pt 1)			
X1 / X2 (Lower)	2.50 / 6.50 (9.00)	5.00 / 6.00 (11.00)	7.50 / 4.00 (11.50)
Y2 / Y1 (upper)	4.00 / 7.00 (11.00)	4.00 / 7.00 (11.00)	4.00 / 7.00 (11.00)
Modifiers			
Wedge Name	None	None	None
Wedge Orientation	---	---	---
Wedge Angle	None	None	None
Blocked/Tray #/MLC(#CP's)	Yes/MLC (3)	Yes/MLC (6)	Yes/MLC (10)
Bolus	None	None	None
Compensator	None	None	None
Opening Density Matrix	None	None	None
Dose			
Dose Engine	Adaptive Convolve	Adaptive Convolve	Adaptive Convolve
Model	All Field Sizes	All Field Sizes	All Field Sizes
Density Correction	Heterogeneous	Heterogeneous	Heterogeneous
Reference Point	PREVIEW	PREVIEW	PREVIEW
Normalized Dose (ND) at Ref Pt	1.094	0.673	0.276
Collimator Output Factor (OFc)(Last CP)	1.000	1.002	1.003
MLC Transmission Factor (Last CP)	0.018	0.018	0.018
Total Transmission Factor (TTF)	1.000	1.000	1.000
SPD/OAD (cm)	100.00 / 0.00	100.00 / 0.00	100.00 / 0.00
SSD to Ref Pt (cm)	88.34	83.51	77.36
Ref Pt Depth / Eff Depth (cm)	11.66 / 8.27	16.49 / 12.16	22.64 / 19.27
Unblk Equiv Sq (cm / %Blkd)(Last CP)	9.9 / 25.2%	11.0 / 32.7%	11.2 / 38.3%
Meas Ref Point Dose (cGy/MU)	---	---	---
Dose at Ref/Fraction (cGy)	24.2	18.1	14.5
Dose Rate (MU/min)	400	400	400
Number of Fractions	30	30	30
MU/Fraction	**33**	**40**	**78**

MU = monitor units

Adaptive Convolve = Convolution Superposition

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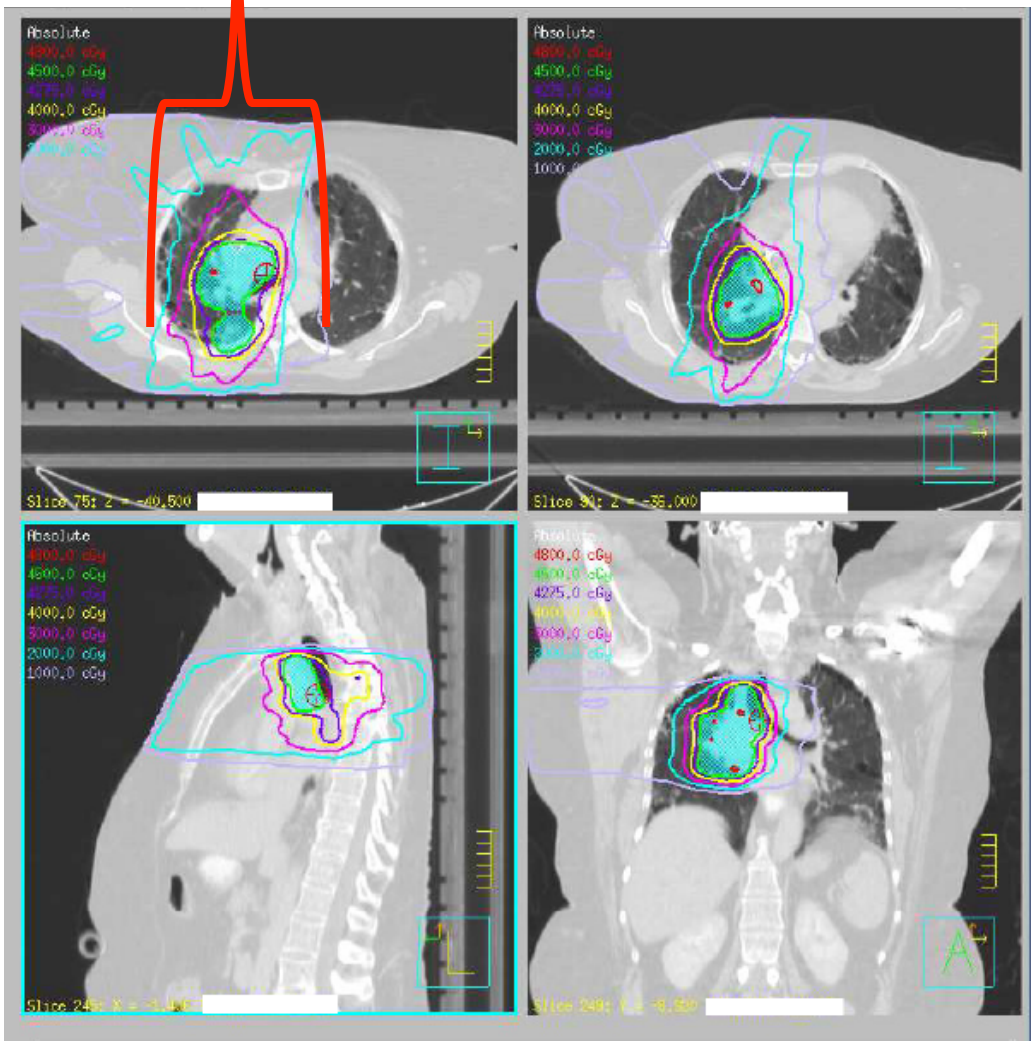
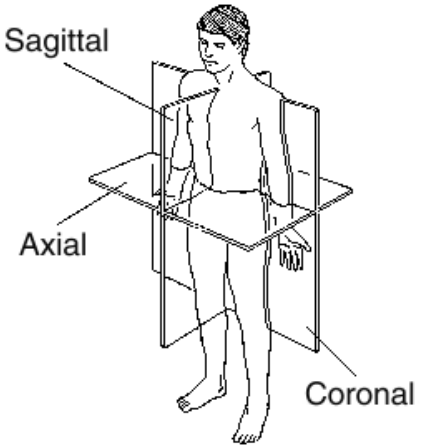
Color Isodose Distributions in axial, sagittal and coronal planes (composite plan) (Only required if Digital RT plan not submitted)

axial



axial



sagittal

coronal

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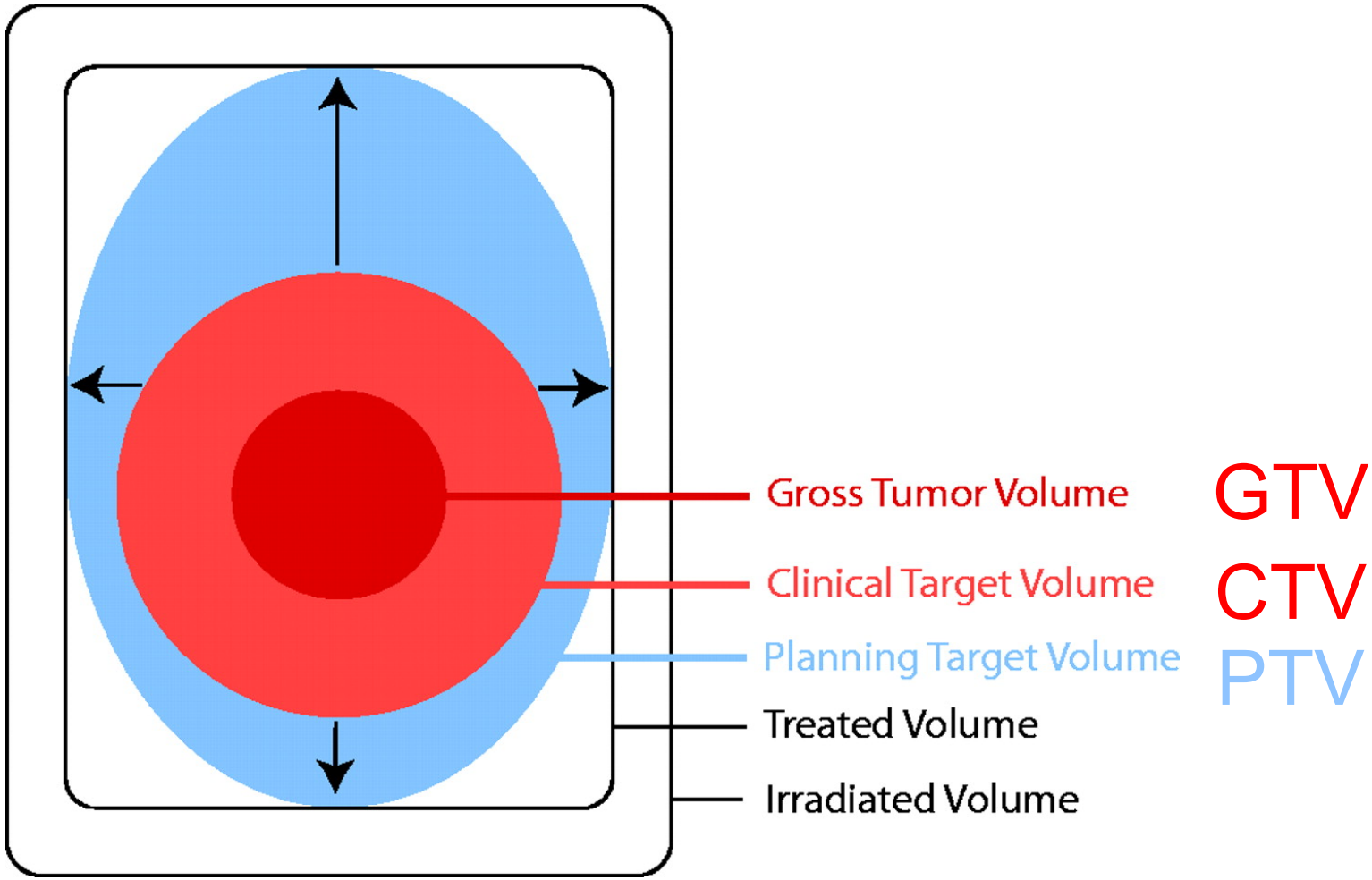
Dose volume histograms (DVH) of PTV, CTV, GTV, Lungs, Heart, Esophagus and Spinal Cord. If IMRT is used, a DVH of unspecified tissue. These will be included with the digital RT plan.



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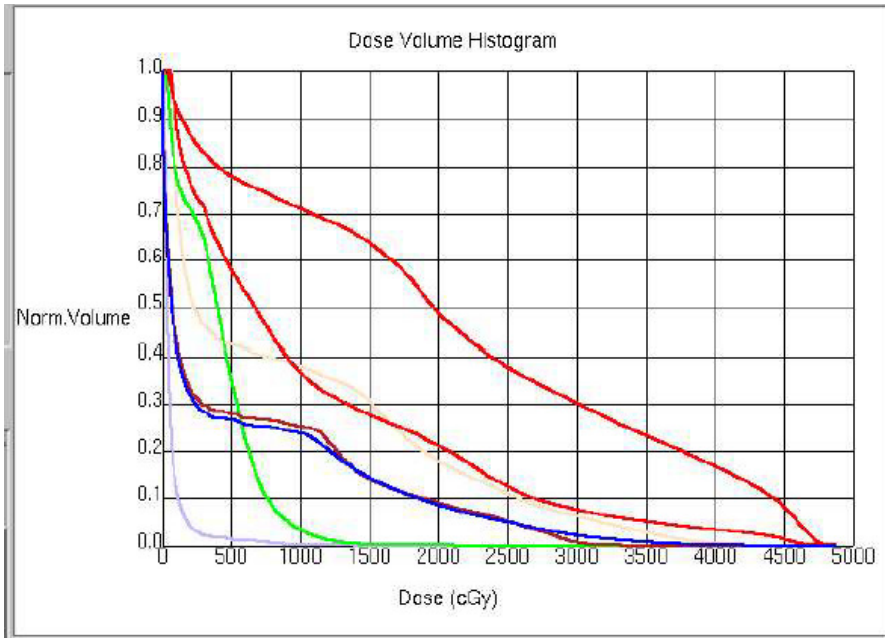
Dose volume histograms (DVH) of PTV, CTV, GTV, Lungs, Heart, Esophagus and Spinal Cord. If IMRT is used, a DVH of unspecified tissue. These will be included with the digital RT plan.



ROI Statistics

Line Type	ROI	Trial	Min.	Max.	Mean	Std. Dev.
	Esophagus	CGR_APPRVD	59.9	4168.5	920.0	1061.7
	Heart	CGR_APPRVD	47.6	4777.8	1084.0	1106.8
	Liver	CGR_APPRVD	1.5	1384.2	61.9	98.3
	Lung_L	CGR_APPRVD	17.6	2114.1	404.9	281.7
	Lung_R	CGR_APPRVD	18.4	4870.6	2110.2	1496.1
	SpinalCord	CGR_APPRVD	0.6	3320.7	522.3	817.6
	SpinalCord_05	CGR_APPRVD	0.3	4201.9	510.2	841.7

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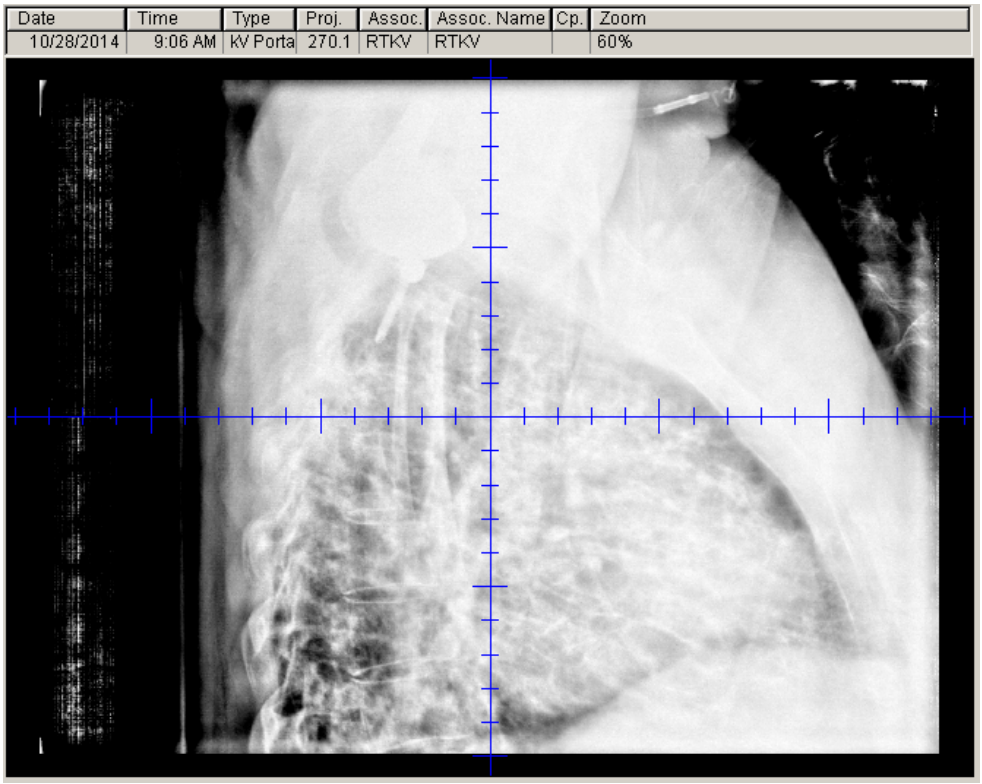
Portal films (or hard copy of real time portal images) of each treatment field



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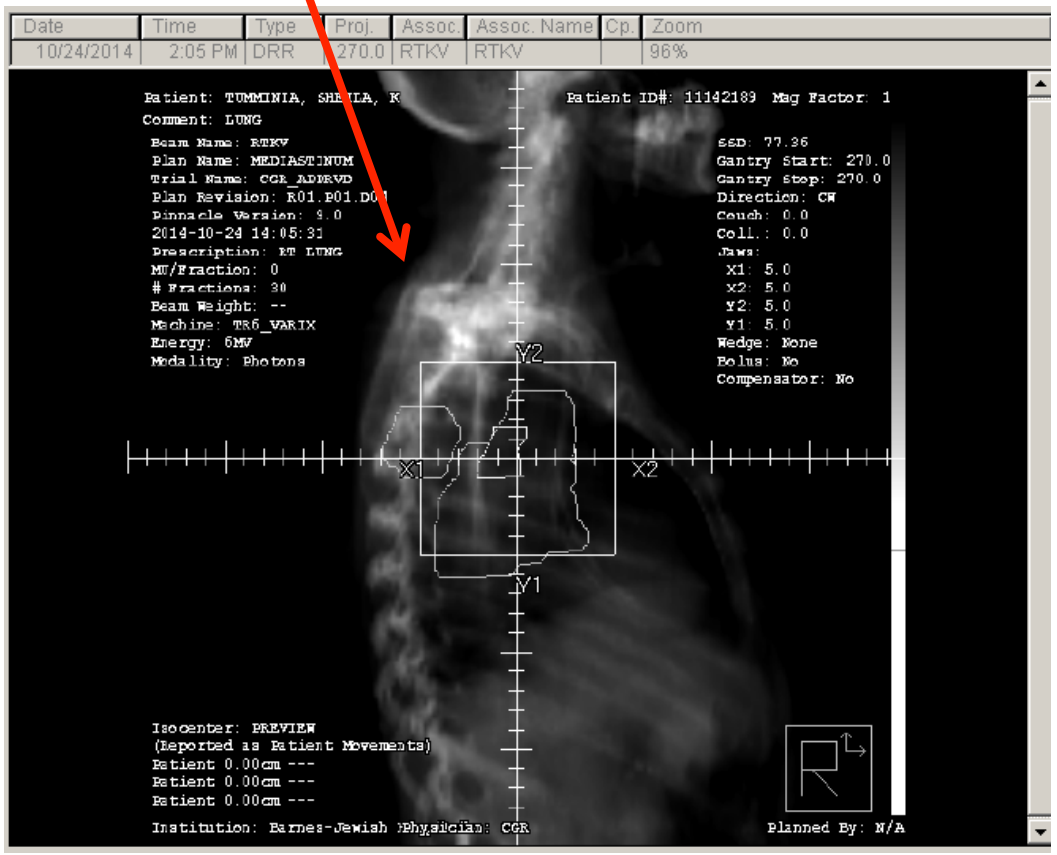
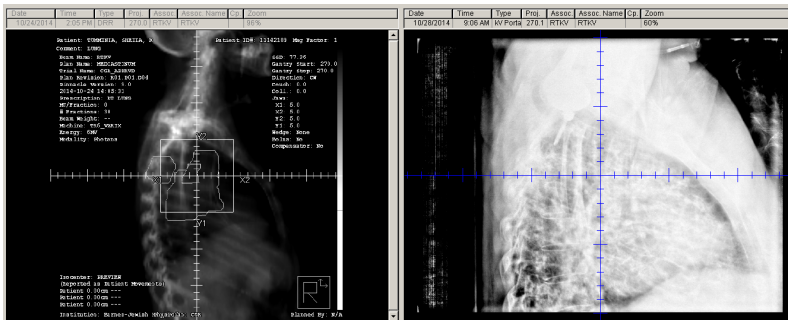
DRRs (digitally reconstructed radiographs) of each treatment field





Orthogonal Anterior/Posterior and Lateral Films if not part of portals

- For IMRT all you get is one Anterior/Posterior (AP) film (or PA), and one either right (RT) or left (LT) lateral film to document the isocenter.
- For 3D conformal treatments you get a the films above to document the isocenter, and films with the shape of each fields (at least 2). Simplest arrangement would be 2 fields: AP/PA

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A word on motion management

- Refers to different techniques to account for tumor motion and ensure we don’t miss hitting the target
- Very important in organs that move, especially the lung and liver that can move a lot during breathing

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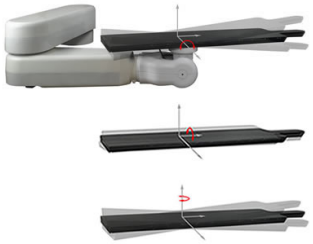
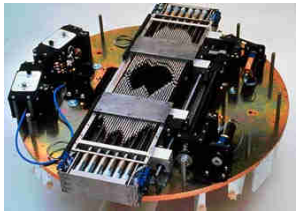
A word on motion management

- Some techniques:
  - Tracking the tumor and moving:

    - The beam (Cyberknife)



    - The patient (robotic couch)
    - MLC (multileaf collimator)



    - Monitoring the breathing cycle
    - Gating (turning on and off the beam when tumor moves the least in respiratory cycle)
    - Active breathing control

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For thoracic IMRT, motion management description required

IROC
IMAGING AND RADIATION ONCOLOGY CORE
Global Leaders in Clinical Trial Quality Assurance

Motion Management Reporting Form

IROC Rhode Island QA Center (QARC)
Building B, Suite 201
640 George Washington Highway
Lincoln, RI 02865-4207
Phone (401) 753-7600
Fax: (401) 753-7601
www.irocri.qarc.org

Coop Group Alliance *Protocol # CALGB30610 *Registration #. 136823
PT initials T,SK Date of birth Aug 25, 1958 Sex M ___ F ✓
Radiotherapy Dept. Barnes Jewish Hospital Radiation Oncologist Cliff Robinson
Physicist/ Dosimetrist V. Rodriguez/ A. Lindsey Phone 314-362-4633

I. Assessment of Lesion Motion due to Respiration

A. How did you assess motion of the lesion with respiration for this patient?
___ fluoroscopy ✓ 4D CT ___ inspiration/expiration fast-CT scan
___ other: Please describe: ___

B. What was used to assess the motion?
✓ lesion itself
___ anatomic correlates: ___ diaphragm ___ chest wall
___ other: Please specify: ___
___ implanted fiducial markers: How many? ___ What size? ___ mm
___ other: Please specify: ___

C. Maximum tumor excursion in any direction prior to motion management: 0.5 cm

WashU MD orders

Simulation	CT
Planning	IMRT (Preport or Start day 10), 4D Bellows

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For thoracic IMRT, motion management description required

II. Method used for managing motion of the lesion with respiration?

- ____ free breathing with increased margins for PTV definition
- ____ forced shallow breathing using abdominal compression
- ____ gating of treatment with breathing cycle
  - ____ active breathing control (ABC)
  - ____ self-held breath-hold with respiratory monitoring (e.g., RPM)
  - ____ gating during free breathing using external monitors or implanted fiducials
  - ✓ other: Please describe: MIP
- ____ tracking motion by
  - ____ moving the beam (e.g. Cyberknife)
  - ____ moving the MLC's
  - ____ moving the patient to follow the target

Commercial system, if applicable ____

III. Definition of Margins

Maximum tumor excursion in any direction following motion management: 0.5 cm

PTV Margins: Ant/Post 0.5 mm Rt/Lt 0.5 mm Sup/Inf 0.5 mm

WashU MD orders

Prescription Information

	Description	Total Dose (cGy)	Daily Dose (cGy)	CTV/ITV to PTV Margin (CM)	Block Margin (cm)
PTV1/Initial Field					
PTV		4500	150 BID	?	

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RT-1 or IMRT Dosimetry Form

Treatment Technique

Check off all that apply: ___ 3D Conformal ___ TomoTherapy ✓ IMRT (SMLC or DMLC)
___ Rotational IMRT ___ Motion Management ___ IGRT
___ Other _____

➢ Note: If Protons are used for treatment, please use the Proton Reporting form instead.

Heterogeneity Calculations: ✓ Yes ___ No Bolus Thickness if used: n/a cm
Treatment Planning System: Pinnacle Patient Position: supine

➢ **Must** Include Treatment Planning System Summary Reports (which includes monitor unit calculations, beam parameters, calculation algorithm and volume of interest dose statistics pages) with data submission.

Protocol Treatment Site	Target Volume Name	Daily Dose (cGy)	Total Number of Fractions	Total Dose (cGy)	Prescription Isodose Surface (e.g. 95%)	Number of Beams	Beam energy (e.g.6X, 6e)
Phase #1	PTV_4500	150	30	4500	96.7%	9	6X
Phase #2							
Phase #3							
Intended Total			30	4500			

Pinnacle³

RTP System 9.0

WashU MD orders

Patient Position:

Patient Position	Supine
Head Position	Neutral
Arm Position	Above Head
Wire	None
Special Treatment Aid Devices	None
Probe	None

Prescriptions

RT LUNG

Prescribe 150 cGy per fraction to 96.7 % of "PTV" mean dose for 30 fractions.
Actual "PTV" mean dose from all prescriptions/beams is 4646.99 cGy.
9 beams are assigned to this prescription.
PRESCRIPTION EXCEEDS MACHINE LIMITATIONS ++

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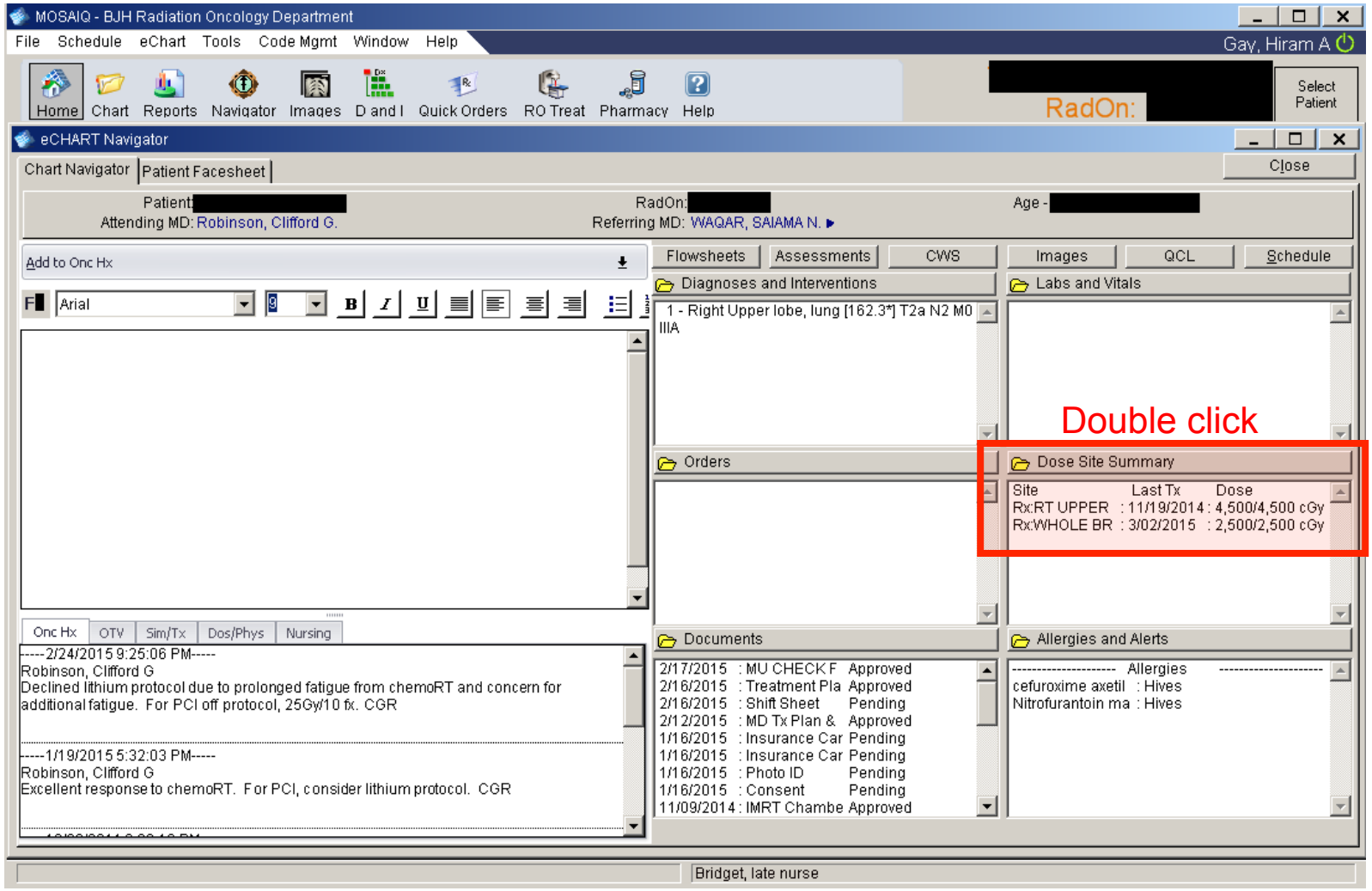
Completed RT Daily Treatment Chart, including prescription, daily and cumulative doses



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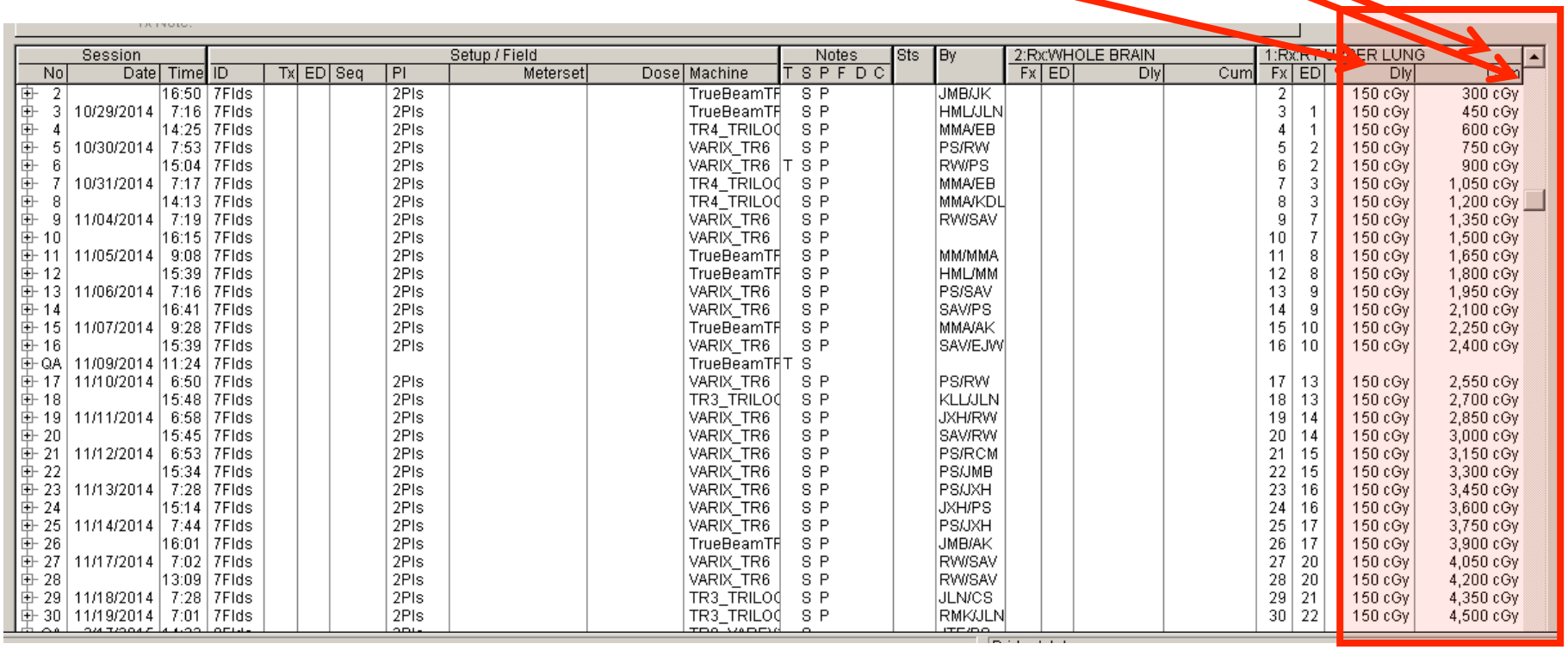

Session			Setup / Field								Notes					Sts	By	2:Rx:WHOLE BRAIN				1:Rx:RT UPPER LUNG			
No	Date	Time	ID	Tx	ED	Seq	PI	Meterset	Dose	Machine	T	S	P	F	D C			Fx	ED	Dly	Cum	Fx	ED	Dly	
2		16:50	7Flds				2Pls			TrueBeamTF		S	P				JMB/JK					2		150 cGy	300 cGy
3	10/29/2014	7:16	7Flds				2Pls			TrueBeamTF		S	P				HML/JLN					3	1	150 cGy	450 cGy
4		14:25	7Flds				2Pls			TR4_TRILOC		S	P				MMA/EB					4	1	150 cGy	600 cGy
5	10/30/2014	7:53	7Flds				2Pls			VARIX_TR6		S	P				PS/RW					5	2	150 cGy	750 cGy
6		15:04	7Flds				2Pls			VARIX_TR6	T	S	P				RW/PS					6	2	150 cGy	900 cGy
7	10/31/2014	7:17	7Flds				2Pls			TR4_TRILOC		S	P				MMA/EB					7	3	150 cGy	1,050 cGy
8		14:13	7Flds				2Pls			TR4_TRILOC		S	P				MMA/KDL					8	3	150 cGy	1,200 cGy
9	11/04/2014	7:19	7Flds				2Pls			VARIX_TR6		S	P				RW/SAV					9	7	150 cGy	1,350 cGy
10		16:15	7Flds				2Pls			VARIX_TR6		S	P									10	7	150 cGy	1,500 cGy
11	11/05/2014	9:08	7Flds				2Pls			TrueBeamTF		S	P				MM/MMA					11	8	150 cGy	1,650 cGy
12		15:39	7Flds				2Pls			TrueBeamTF		S	P				HML/MM					12	8	150 cGy	1,800 cGy
13	11/06/2014	7:16	7Flds				2Pls			VARIX_TR6		S	P				PS/SAV					13	9	150 cGy	1,950 cGy
14		16:41	7Flds				2Pls			VARIX_TR6		S	P				SAV/PS					14	9	150 cGy	2,100 cGy
15	11/07/2014	9:28	7Flds				2Pls			TrueBeamTF		S	P				MMA/AK					15	10	150 cGy	2,250 cGy
16		15:39	7Flds				2Pls			VARIX_TR6		S	P				SAV/EJW					16	10	150 cGy	2,400 cGy
QA	11/09/2014	11:24	7Flds							TrueBeamTF	T	S													
17	11/10/2014	6:50	7Flds				2Pls			VARIX_TR6		S	P				PS/RW					17	13	150 cGy	2,550 cGy
18		15:48	7Flds				2Pls			TR3_TRILOC		S	P				KLL/JLN					18	13	150 cGy	2,700 cGy
19	11/11/2014	6:58	7Flds				2Pls			VARIX_TR6		S	P				JXH/RW					19	14	150 cGy	2,850 cGy
20		15:45	7Flds				2Pls			VARIX_TR6		S	P				SAV/RW					20	14	150 cGy	3,000 cGy
21	11/12/2014	6:53	7Flds				2Pls			VARIX_TR6		S	P				PS/RCM					21	15	150 cGy	3,150 cGy
22		15:34	7Flds				2Pls			VARIX_TR6		S	P				PS/JMB					22	15	150 cGy	3,300 cGy
23	11/13/2014	7:28	7Flds				2Pls			VARIX_TR6		S	P				PS/JXH					23	16	150 cGy	3,450 cGy
24		15:14	7Flds				2Pls			VARIX_TR6		S	P				JXH/PS					24	16	150 cGy	3,600 cGy
25	11/14/2014	7:44	7Flds				2Pls			VARIX_TR6		S	P				PS/JXH					25	17	150 cGy	3,750 cGy
26		16:01	7Flds				2Pls			TrueBeamTF		S	P				JMB/AK					26	17	150 cGy	3,900 cGy
27	11/17/2014	7:02	7Flds				2Pls			VARIX_TR6		S	P				RW/SAV					27	20	150 cGy	4,050 cGy
28		13:09	7Flds				2Pls			VARIX_TR6		S	P				RW/SAV					28	20	150 cGy	4,200 cGy
29	11/18/2014	7:28	7Flds				2Pls			TR3_TRILOC		S	P				JLN/CS					29	21	150 cGy	4,350 cGy
30	11/19/2014	7:01	7Flds				2Pls			TR3_TRILOC		S	P				RMK/JLN					30	22	150 cGy	4,500 cGy

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RT-2 Total Dose Record

List Names Of Target Volumes Corresponding To Those On RT-1 Forms, Record Boost Volumes Separately					
Name of Target Volume (i.e. PTV1, Chest)	PTV4500				
Date of First Treatment to the Target Volume	Oct 28, 2014				
Number of Treatments	30				
Date of Last Treatment	Nov 19, 2014				
Total Dose To Treatment Point (Central Axis)	4500				
Critical Structure	**Max Dose**	**Critical Structure**		**Max Dose**	
A. Spinal Cord	3320.7	**D.** Heart		4777.8	
B. Lung_L	2114.1	**E.** Esophagus		4168.5	
C. Lung_R	4870.6	**F.**			

ROI Statistics

Line Type	ROI	Total	Min.	Max.	Mean	Std. Dev.
	Esophagus	CGR_APPRVD	59.9	4168.5	920.0	1061.7
	Heart	CGR_APPRVD	47.6	4777.8	1084.0	1108.8
	Liver	CGR_APPRVD	1.5	1384.2	61.9	98.3
	Lung_L	CGR_APPRVD	17.6	2114.1	404.9	281.7
	Lung_R	CGR_APPRVD	18.4	4870.6	2110.2	1498.1
	SpinalCord	CGR_APPRVD	0.6	3320.7	522.3	817.6
	SpinalCord_05	CGR_APPRVD	0.3	4201.9	510.2	841.7

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Conclusion

- Radiation therapy (RT) non-compliance kills lives
- The radiation oncology workflow requires and generates a wealth of documentation
- The location of the radiation treatment information that the Alliance requires for a given patient will be unique to the specific clinic, but in general is found in one of more of the following:
  - Treatment planning software (TPS) or documents
  - RT record and verify software:
    - Mosaiq (Elekta)
    - ARIA (Varian)
  - RT paper chart

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