

# Automated Planning Techniques

#### The Dosimetrist's Perspective

Robin Marsh CMD & Janell Dow CMD, RT(T)





#### Research Funding

-NIH

-Varian Medical Systems





# On your smart Phone or Tablet Go to: kahoot.it Enter Game PIN: 359954



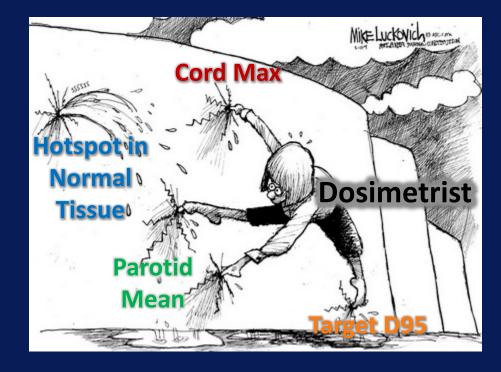
### **Typical Inverse Planning Workflow**

Physician prescribes treatment goals

Dosimetrist Designs Plan Setup and Translates Goals into Cost Function

Dosimetrist Reviews Optimization Result vs. Treatment Goals

- Add Ring Structure
- Add "Hotspot" Structure
- Tweak Cost Function
- etc....





#### Tools to Improve Plan Quality and Efficiency

- Priority based (in-house systems) and multicriteria optimization techniques (RayStation)
- Automated planning techniques that mimic dosimetrist interaction with planning system (Pinnacle)
- Knowledge-Based Planning (In-house systems and Eclipse Rapidplan)

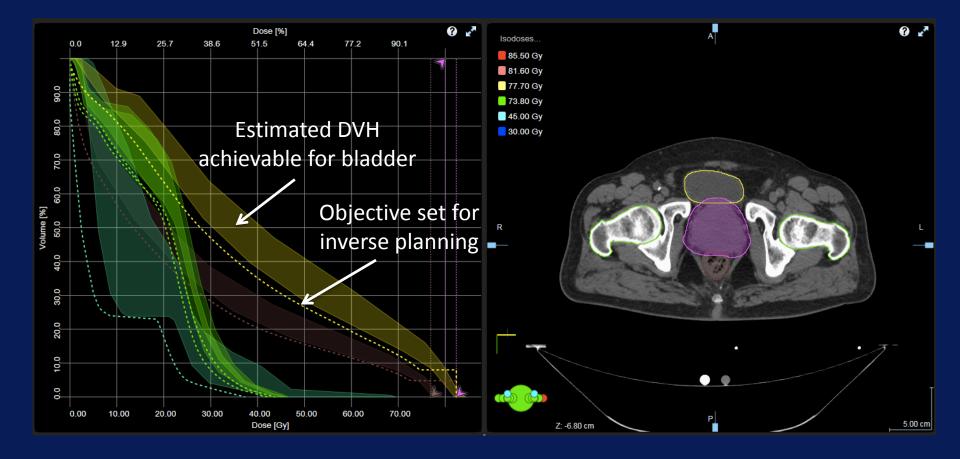


#### What is Knowledge-Based Planning?

- Software tool that utilizes knowledge gained from prior cases when planning current cases
- Source of knowledge
  - prior dose distributions
  - prior DVH metrics and features
  - Physician-prescribed metrics
- Commercially available TPS offer some pre-loaded models as well as the ability to create your own institution specific model (Eclipse Rapidplan)

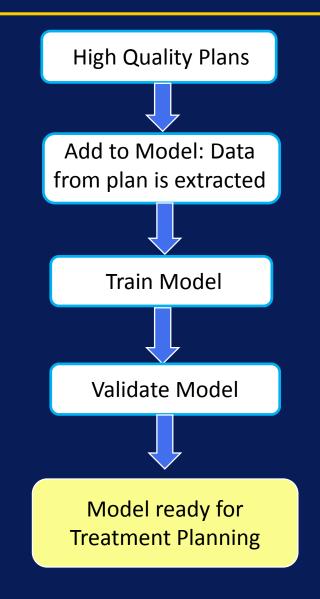


#### Knowledge Based DVH Estimation





### Creating a Knowledge Based Model for Treatment Planning





#### **Quality Matters!**





#### **KBP: Creating a model**

- Developing a model requires a minimum number of cases
- All plans must be high quality i.e. meeting OAR dose limits and PTV coverage goals etc.
- Use same naming convention for targets and OARs

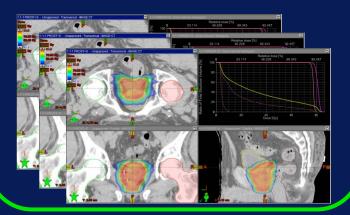


DV

#### **Case Preparation**



#### Contouring & Plan QA



#### **Model Definition**

H Estimation Model Prope	rties					×								
Model ID	Model ID PROS & PBED_UM-#1													
Model Description	P+SV: 77.7 Gy P Only: 75.85 Gy													
Anato	Anator	nic	escription Site s to Include i	n		Remove Remove								
	Model	Model												
	FEMUR		32843 (FMA) 32842 (FMA)	Edit	×									
	PENILE_BULB		19614 (FMA)	Edit	x									
	PTV	V	PTV_High (99VMS_STRUCTCODE) PTV_Intermediate (99VMS_STRUCTCODE) PTV_Low (99VMS_STRUCTCODE)	Edit	x									
	RECTUM		14544 (FMA)	Edit	х									
				ОК		Cancel								



#### Data Extraction

Add Plan C1 / T7 VMATJF_HR to DVH Esti	nation Model - \$spine	sb\$76_1, Thoracic (\$spinesb	76_1)			
Sort Order Model ID		-				?
DVH Estimation Model SPI	NE SBRT UM - MOD	EL A O	her Thurs	sday, March 0	5, 2015 2:51:35 PM	
Model Version 13.5.15						
Anatomical Region Other						
Trained Yes						
Published No						
		05, 2015 2:51:35 PM UPPER LUMBAR SPINE S	оот			
	EXPERT PLANS	OFFER LOWBAR SPINE 3				
30 Gy IN	3 Fx					
Clinical						
Plan Prescription 30.0	00 Gy					
Plan Structure ID (Codes)	Туре	Model Structure ID (Codes		<b>^</b>	Unmatched Model Structures	
CORD_HR ()	AVOIDANCE	CORD (7647)			PTV, PTV_EVAL, PHARYNX, LARYNX KIDNEY_TOTAL, KIDNEY	ς,
CORD_MRT1 ()	AVOIDANCE					
CORD_MRT2 ()	AVOIDANCE					
CORD_PRV2_HR ()	AVOIDANCE	CORD_PRV2 (PRV)				
CTV_VB ()	сту	CORD (7647)				
Dose 18[Gy] ()	CONTROL	CORD_PRV2 (PRV)				
		ESOPHAGUS (7131)				
Dose 29.5 ctrl (Dose)	CONTROL	TRACHEA (7394)				
Dose 29.5 val (Dose)	CONTROL	PHARYNX (46688)		=		
		LARYNX (55097)				
		KIDNEY_TOTAL (26481			OK Cancel	



#### Data Extraction



- PTV
- Cord
- Cord PRV
- Esophagus

#### Patient Structures

- 🧈 Cord
  - Cord+2mm
  - Esoph
  - PTV1



#	Patient ID/Course ID/Plan ID	Plan Prescr	iption		Structure Matching	Include	Extracted	In Mod		
1	\$pros002/C1/1.1-1 PROST+S	79.200	Gy		Target: 1/1 Other: 4/5	1	Yes	13.5.15		
2	\$pros003/C1/1.1-1 PROSTAT	75.850	Gy	-	Target: 1/1 Other: 4/5	<b>V</b>	Yes	13.5.15		
3	\$pros004/C1/1.1-1 IMRT PR	70.200	Gy		Target: 1/1 Other: 5/5	<b>V</b>	Yes	13.5.15		
4	\$pros005/C1/1.1-1 PROST B	70.200	Gy		Target: 1/1 Other: 4/5	<b>V</b>	Yes	13.5.15		Train
5	\$pros006/C1/1.1-1 PROSTAT	75.850	Gy	//.5555	Target: 1/1 Other: 4/5	<b>V</b>	Yes	13.5.15		
6	\$pros007/C1/1.1-1 PROSTAT	75.850	Gy		Target: 1/1 Other: 4/5	V	Yes	13.5.15	5.0	x
8	\$pros009/C1/1.1-1 IMRT PR	77.700	Gy		Target: 1/1 Other: 5/5	<b>V</b>	Yes	13.5.15	3.7	х
9	\$pros010/C1/1.1-1 PROST+S	77.700	Gy	544	Target: 1/1 Other: 5/5	<b>V</b>	Yes	13.5.15	1.5	х
10	\$pros011/C1/1.1-8 PROST+S	77.700	Gy	1865	Target: 1/1 Other: 5/5	V	Yes	13.5.15	1.5	х
11	\$pros012/C1/1.1-1 PROST+S	77.700	Gy		Target: 1/1 Other: 4/5	V	Yes	13.5.15	1.6	x
13	\$pros014/C1/1.1-3 IMRT PR	77.700	Gy		Target: 1/1 Other: 4/5	<b>V</b>	Yes	13.5.15	3.3	х
14	\$pros015/C1/1.1-1 PROST+S	77.700	Gy	(855)	Target: 1/1 Other: 4/5	V	Yes	13.5.15	3.8	х
15	\$pros016/C1/1.1-1 PROST+S	77.700	Gy		Target: 1/1 Other: 4/5	<b>V</b>	Yes	13.5.15	4.2	х
16	\$pros018/C1/1.1-1 PROST B	70.200	Gy		Target: 1/1 Other: 4/5	<b>V</b>	Yes	13.5.15	17	х
17	\$pros019/C1/1.1-1 PROST+S	77.700	Gy	1222	Target: 1/1 Other: 5/5	<b>V</b>	Yes	13.5.15	35	х
18	\$pros023/C1/1.1-1 PROST+S	77.700	Gy		Target: 1/1 Other: 4/5		Yes	13.5.15	5.2	x

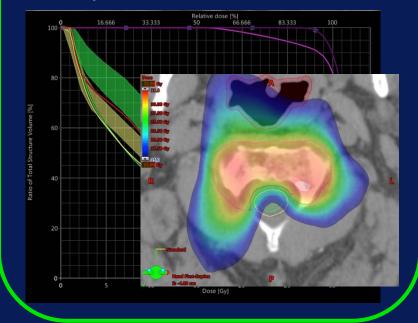


#### Model Verification & Validation

#### Use Tools to Add/Remove Outlier Cases from the Model

0.6	+	RECTUM:	Geometric p	lot				+
	++	Geometric distribution principal component score 1	Geometric distribution principal component score 2 X	OAR volume X	CAR overlap volume percentage to target	OAR out-of-field volume percentage	Larget volume XX X X	
		• ₩ XXX	( )) <b>X</b> X	Ĭ	×		No.	

#### Test how the Model Works Compared to Clinical Plans





How do you know if you have a 'good' model?

- Somewhat subjective...
- Plans should meet all planning objectives for OARs and targets
- Normal tissue DVHs should fall within the estimated regions
- Consistent results



### KBP: Using the model

				Plan Information		?										
Estim	nate DVH Sort Ord	ler ID		<ul> <li>Show Unpublished I</li> </ul>	Nodels											
	Estimation Mod	iel 📃 Liver -	Clinica	al Model	Abdome	en '										
	Model Versio	on 13.6.23														
	natomical Regio Publishe		C Est	timation Statistics				_		_	_	_			_	□
		on Variation of Added seco changed %		odel del ID Liver - Clinical Model												
		Clinical De	Str	ructures						cs for:	CHEST	WALL/RIB				
Targe	t Dose Levels			Plan Structure ID	Model Structure ID	Status										Statistics Legend
	Structure ID	Target		CHESTWALL/RIB	CHESTWALL/RIB		nside threshold values	Ī		т						Max Value
GTV_0	OPT	55		COLON	COLON		nside threshold values									
PTV		55		CORD	CORD		nside threshold values									
PTV_C	NOT.	55		DUODENUM	DUODENUM		nside threshold values									90 Percentile Value
Struct		55		ESOPHAGUS	ESOPHAGUS		nside threshold values									
Struct	Plan Structure	ID (Codes)		HEART	HEART		nside threshold values									Median Value
	GTV (GTVp)			KIDNEY_L	KIDNEY_L	•	Dutside threshold values			Ĵ.						10 Percentile Value
				KIDNEY_R	KIDNEY_R		Dutside threshold values									
	GTV_OPT (G	51 V P)		KIDNEY_TOTAL	KIDNEY_TOTAL		Outside threshold values				rget .					<sup>⊥</sup> Min Value
	GTV1 ()			LIVER	LIVER		nside threshold values		- eg		centage to target		core			imes Inside threshold values
	GTV2 ()			LIVER OPT	LIVER		nside threshold values	_			tage		ents			X Outside threshold values
	HEART ()			LIVER-GTV	LIVER-GTV		nside threshold values	_	e per				uodu			
<b>V</b>	KIDNEY_L ()			STOMACH	STOMACH		nside threshold values	_			ne pe		al con			
	KIDNEY_R ()	)							ield vo		volur	je	incipa			
	KIDNEY_TOT	TAL ()						olume	ut-of-f		verlap	volum	etric pi			
	LIVER ()							OAR vol	OAR out-		AR ov	arget X	jeome			
	LIVER OPT (	)						<u> </u>				J - E				
	LIVER-GTV (	o						_								
	LIVER-PTV (	)					Some statistics	are outside th	e thresh	old va	lues. Do you	want to gene		tes and objectives?	Yes	No
Unmato	PTV () ched Model Stru		PTV BOWE	PTV (PTV High)	55.00 Gy 🔻		7									
					Generate Estimates and	Objective										
	la	Estimate DVH					n <b>m</b> )									



### **KBP: Optimization & 3D Calc**

7 🔛 🔪	Estimate DVH		n Information			?	📐 😃 🤍	R / 1 ·	🔶 칠 🗳	3K			📐 🖑 🤤	, 😻 🔚 💕 🗳	🗢 🏋 🏌
- 1 -	🚽 🔶 🗚 dd g					H									
ד/סו 🕲	ype Vol[cn	1²] Vol [%	5] Dose[Gy]	Actual Dose[Gy]	Priority	gEUD a	0.0	36.4	Dose [% 72.7		0 🛃	Isodoses		A	
GTV_OF	•т •	1.9										60.50 Gy			
Lowe		1.7 98	.0 60.50	59.73	150	x						<mark>55.00 Gy 0</mark>			
PTV		19.2					0.06								
Uppe		0.5 1	.0 71.50	72.30	50	x									
Lowe		19.2 100	.0 25.00	25.69	300	x	80.0				_				
PTV_OF	чт -	19.2					0.0								
Lowe		18.7 99	.0 52.25	45.11	200	х	02								
Lowe		18.2 98	.0 55.00	47.82	200	x	0.00								
	WALL/RIB 6	51.3											63		
Line	6	14.8			75	x	fume [%]					R		X /	
	2:	35.2					%					-		200	
Uppe		0.0 0	.0 28.80	34.71	300	x	40.0							<b>6</b>	1 2
Uppe		2.4 1	.0 28.00	28.74	200	x								Alt -	
Uppe		4.7 2	.0 27.20	27.31	100	x	30.0								
Line	2	32.9			75	x	20.0					P			· <i>ភ</i> - "
		60.5					SC 1								
Uppe		0.0 0	.0 22.50	12.86	300	x	0.01								
Line		59.9			75	x									
	NUM 4	2.1					8								
Uppe		0.0 0	.0 27.00	6.81	300	x	0.00	20.00	40.0 Dose [Gy			Z:	5.60 cm	P	
Uppe		0.4 1	.0 26.00	5.85	200	x		3D Dose Max	75.29 Gy			<b>*</b>		PTV_OPT	
Uppe		0.8 2	.0 25.50	5.33	100	x	3D MAX for <no 3D MEAN for <no< td=""><td></td><td></td><td></td><td></td><td></td><td>Aut</td><td>LIVER-GTV</td><td></td></no<></no 						Aut	LIVER-GTV	
ormal Tissue Obje		11 7			75	T0/Automatic NTO	2D MIN for < no							COLON GTV_OPT	
J Objective								Elapsed Time Monitor Units	25 s 3004 MU					CORD KIDNEY_R	
se Dose Plan						None	200 Leaf Sequen		1/5					CHESTWALL/RIB	
ttings						Normal (2.5 mm)									Oper



#### Motivation

- Decrease planning time = increase in productivity
- Reduce variability in planning
- Potential to increase confidence of novice planners
- Aid in evaluating institution's treatment planning practices - which may result in improved tx planning protocols throughout the Rad Onc Community





# Go back to your phone / tablet.... We would like to learn a little more about you & your department!





Started with an easier body-site....

Prostate

Then moved to more complex sites:

Spine SBRT

Liver SBRT

Head/Neck



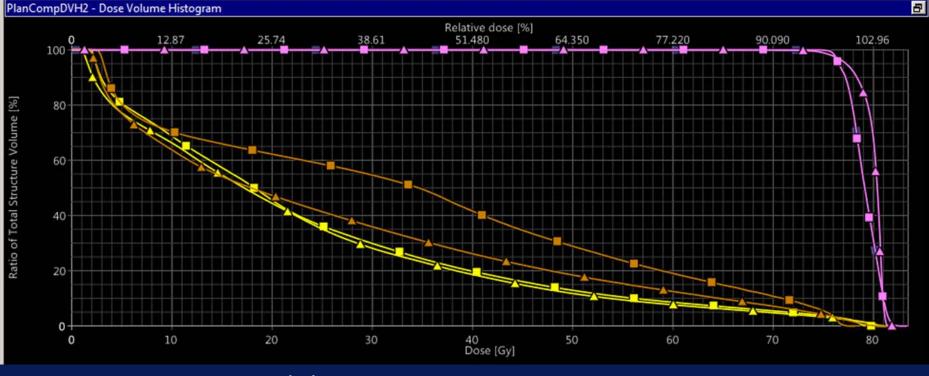
#### Prostate Model at UM

- 60 clinically treated patients
   Prostate and Prostate Bed IMRT plans
   Proscription range: 68 4 70 2 Gy
  - Prescription range: 68.4 79.2 Gy
- Exported from in house TPS, UMPlan, and imported into Eclipse, v13.5
- Structure and plan QA performed; unacceptable geometries and plans were not included in the final 60-plan model



# Initial Model Validation

#### Used only the generated line objectives for normal structures



KBP-generated Plan

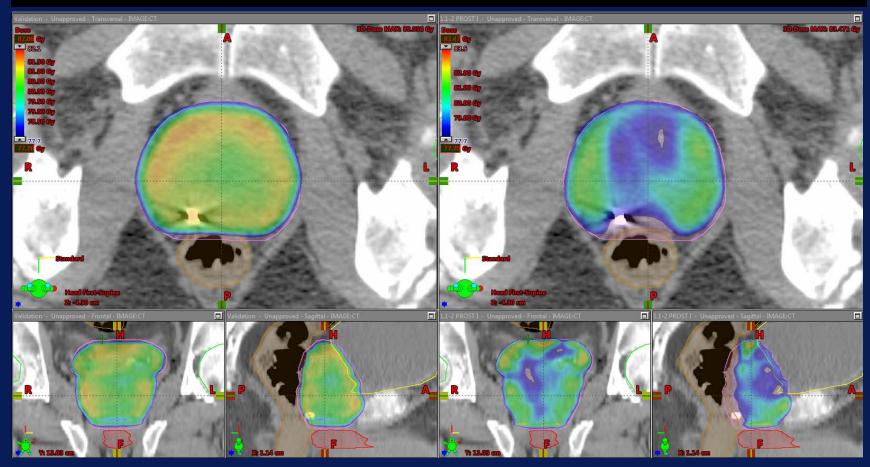
= Clinically- Used Plan



# Initial Model Validation

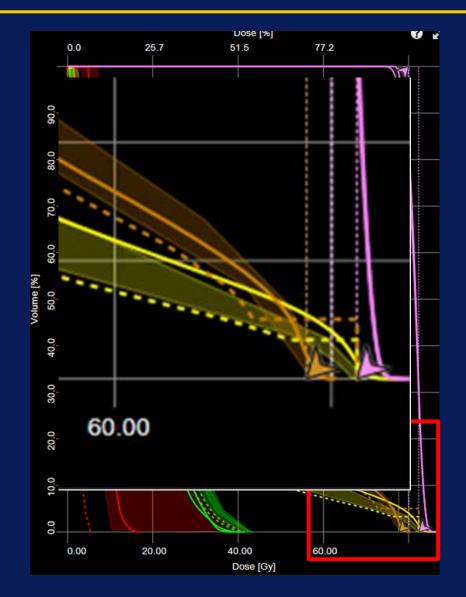
#### Validation Plan

#### Clinically-Used Plan





#### Target Coverage vs. OAR Sparing





# Model Application: Quality Control of Treatment Plans

- How does the plan quality of prostate patients compare across our system of hospitals?
- Ran the model on cases that came from 4 different community clinics
- Generated DVH estimations for OARs defined by the model for each patient
- Optimized a new plan based on the DVHestimations
  - Field parameters were copied from the original plan

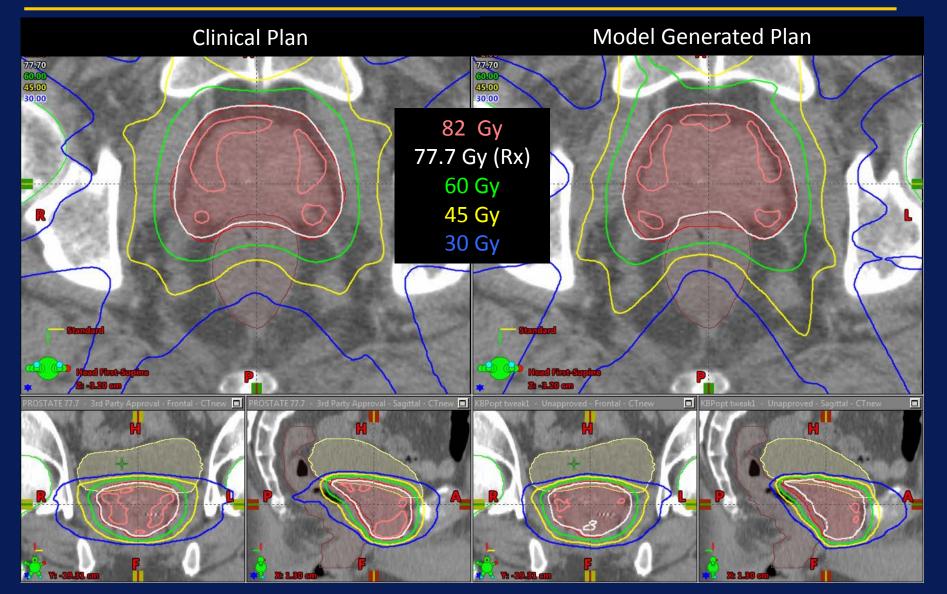


#### Clinic A: DVHs



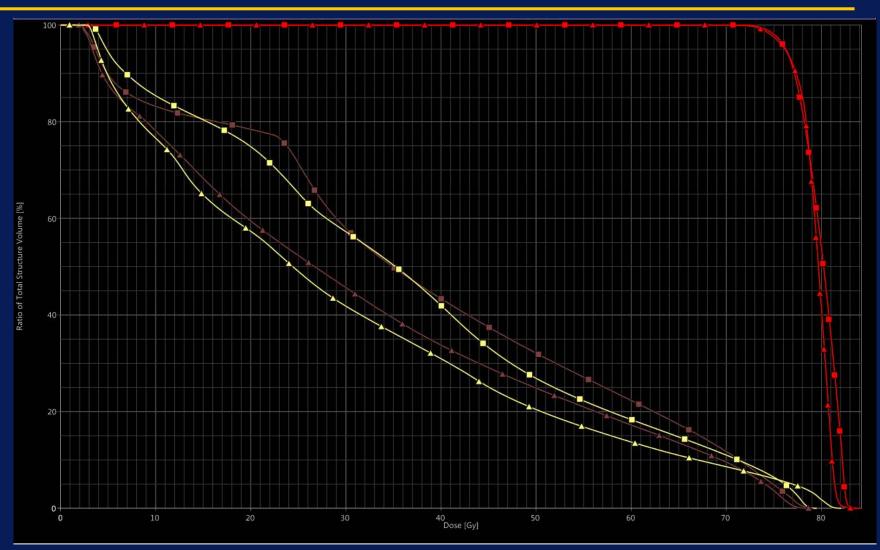


# Clinic A: Plan Quality





#### Clinic B: DVHs

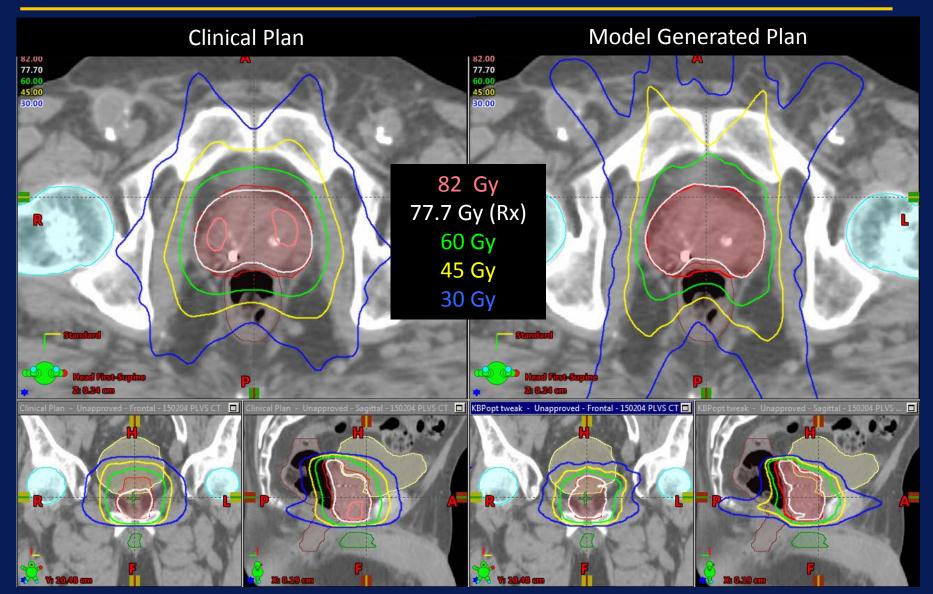


KBP-generated Plan

Clinically- Used Plan



# Clinic B: Plan Quality





#### Clinic C: DVHs



KBP-generated Plan

Clinically- Used Plan



# Clinic C: Plan Quality

Model Generated Plan **Clinical Plan** 68.40 68.40 60.00 45.00 45.00 30.00 72 Gy 68.4 Gy (Rx) 60 Gy 45 Gy 30 Gy 

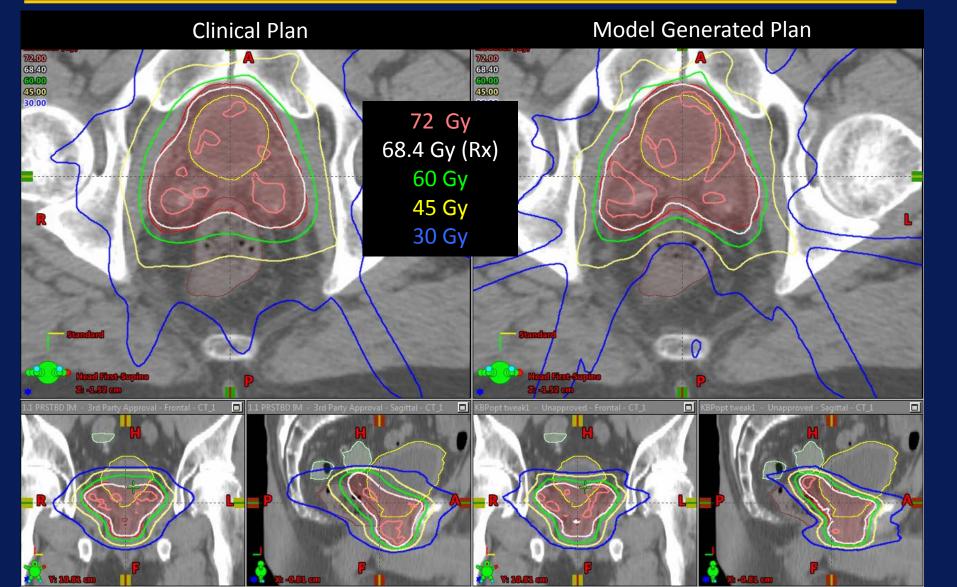


#### Clinic D: DVHs



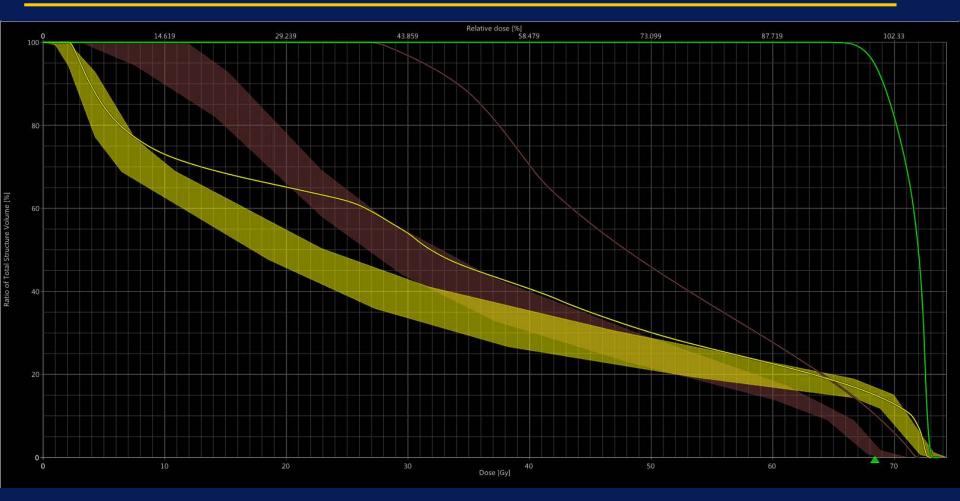


# **Clinic D: Plan Quality**











#### **KBP Prostate: Summary**

- Inverse planning is an iterative process and time consuming
  - Difficult to ensure that all OAR structures, especially those of lower priority, are at an ALARA level
- Across our own system, there is a wide variation in plan quality for a simple site like prostate
- Knowledge-based planning can help improve both the quality and efficiency of the planning process



## Knowledge Based Planning to improve standardization and efficiency in spine SBRT

- Spine SBRT can be urgent and time sensitive used as a technique to treat
- Spine SBRT planning can be iterative and timeconsuming
  - Geometrical variation
  - Importance of OAR sparing (Reduced acceptability of tradeoffs)



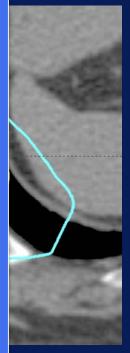
Example Targets from RTOG 0631 (PI S. Ryu)



#### Knowledge Based Planning for Spine SBRT

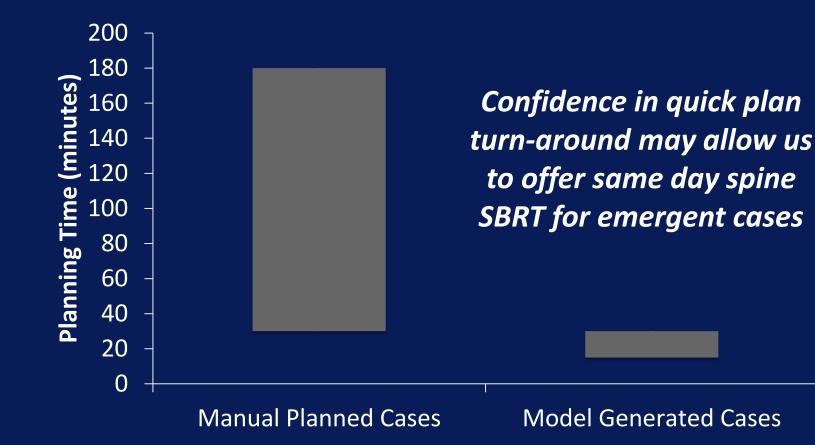
- 6/10 model-generated cases were acceptable with no tweaking
- 4/10 model-generated cases were acceptable after 1 or 2 iterations of tweaking

• Without sacrificing cord and cord\_prv objectives, target coverage improved by approximately 5% in the modelgenerated plans Plan



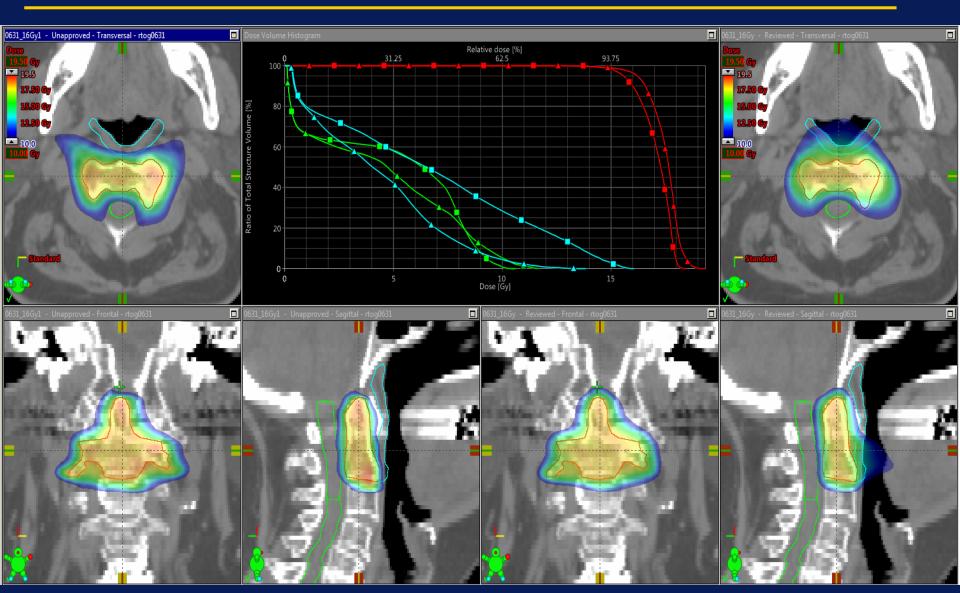


#### **Spine Model Plan Efficiency** Range of Planning Times (Not including Physician Review)



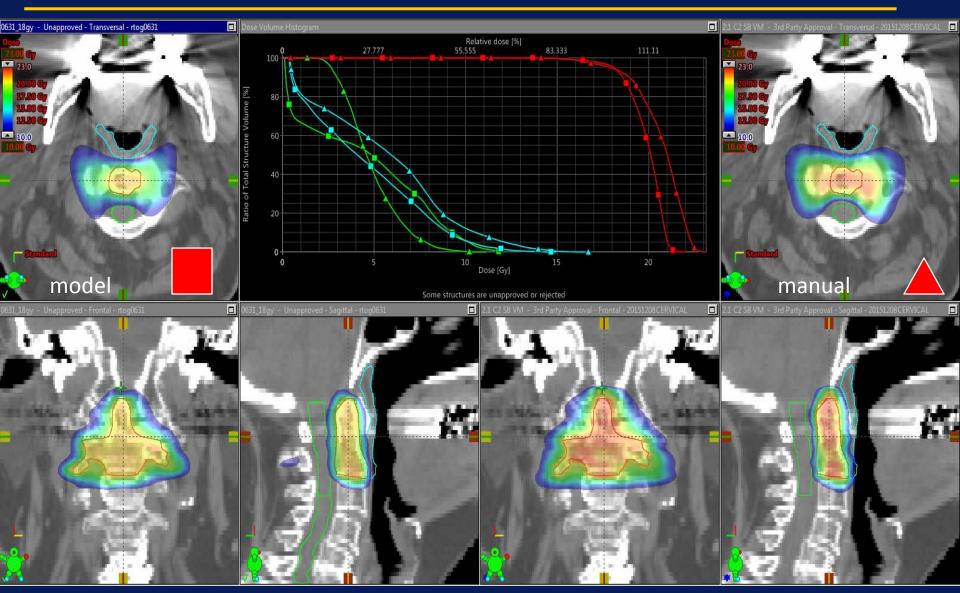


## 20 cases of specific oar's



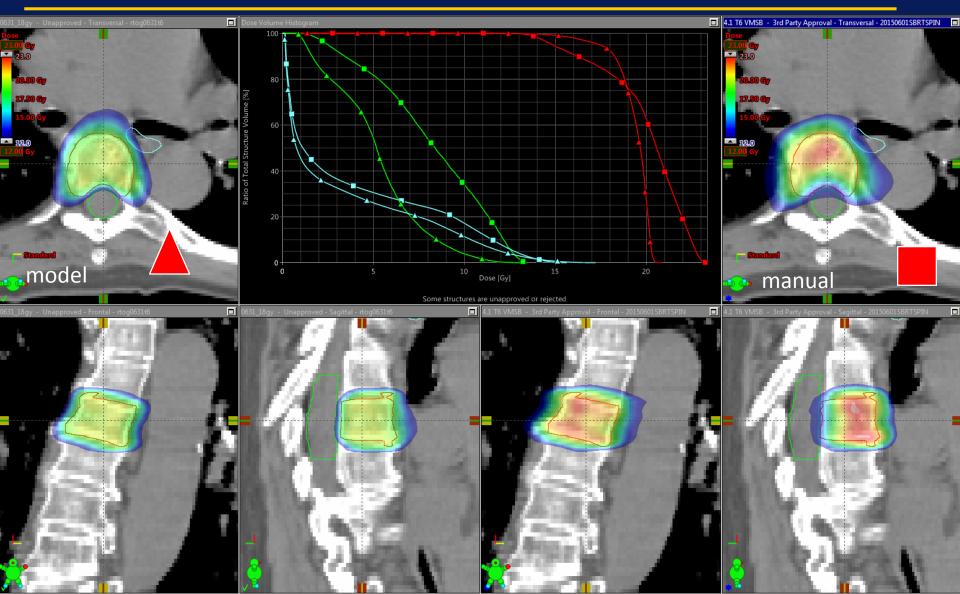


## Model vs Manual C Spine



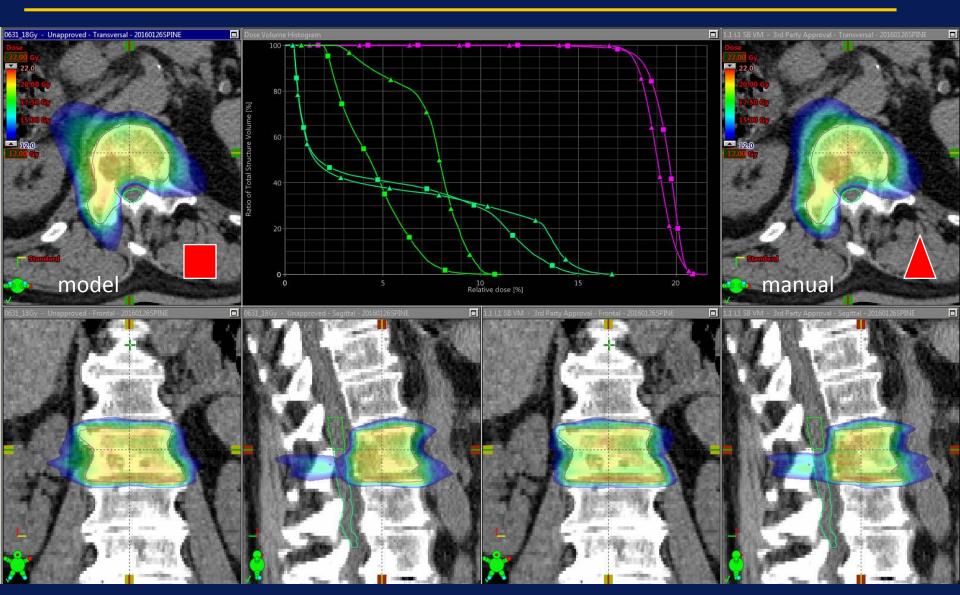


## Model vs Manual T Spine





#### Model vs Manual L Spine





## Planning points of Spine sbrt

- Fractionation (1,3,5 etc.)
- Spine level (Cervical, thoracic, lumbar)
- Quantity of spines for modeling
- Reviewed by another dosimetrist or physics who may on you spine service.





#### Please join us for a few more questions!





- Large liver SBRT service
- Variation in plan quality between dosimetrists as well as physicians
- Things to consider:
  - Non-standard geometry
  - PTV overlap with various structures

We knew we would need a LOT of plans to create a 'good' model



#### **KBP: Liver SBRT**

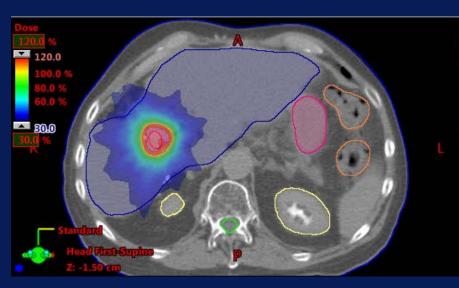
- 60+ plans to create model
- Tested with 20 plans, made tweaks to the model
- Validated the model with 16 new cases
- 13 of 16 met all priority 1 planning objectives with the push of a single button



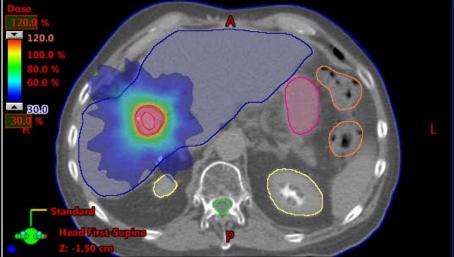
#### **KBP: Liver SBRT**

#### Model Plan – 'Easy Button'

#### Manually optimized plan



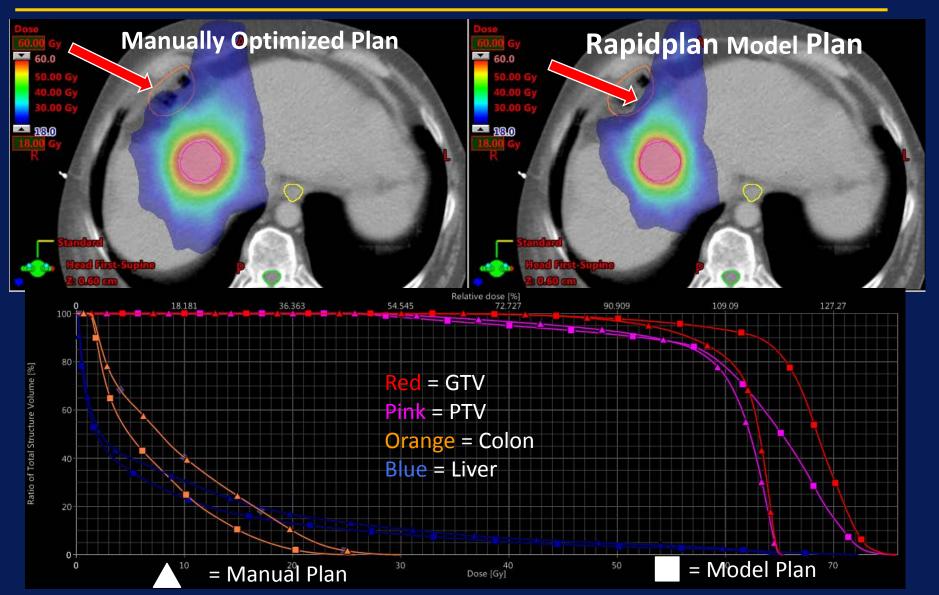
- 1 Iteration
- All OAR constraints met
- Planning time: 9 minutes



- 1 Iteration
- All OAR constraints met
- Planning time: 10 minutes - experienced dosimetrist
   17 minutes - novice dosimetrist



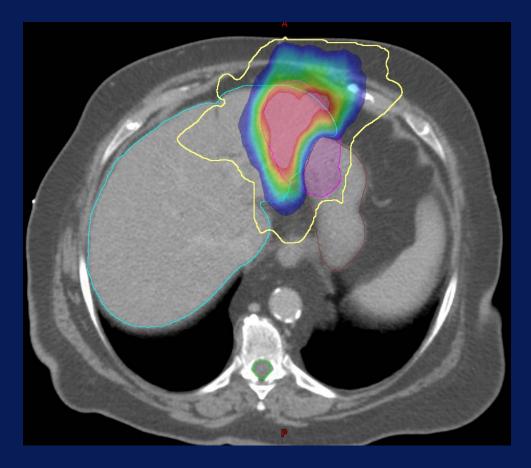
## **KBP: A tool for Novice Planners?**



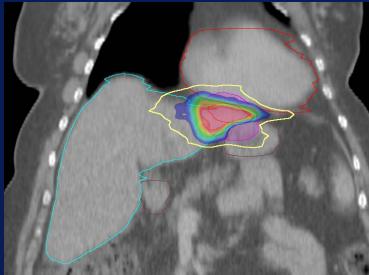


#### **KBP: Liver SBRT**

- PTV overlap w/ multiple OARs
- Model reduced planning time from 1 hour to 20 minutes



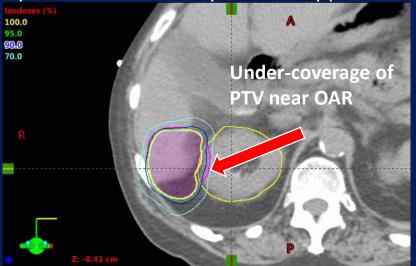






#### **KBP: Liver SBRT**

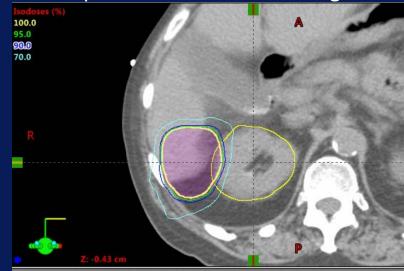
#### Rapid Plan Model 'easy-button' approach



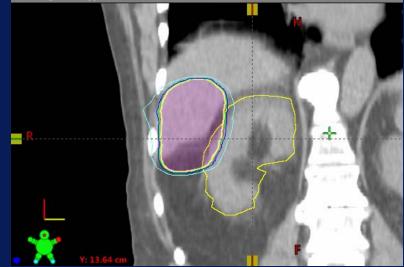
VM VALID - Unapproved - Frontal - 20151103 UT



Rapid Plan model + tweaking



/M VALID\_JD - Unapproved - Frontal - 20151103 UT P



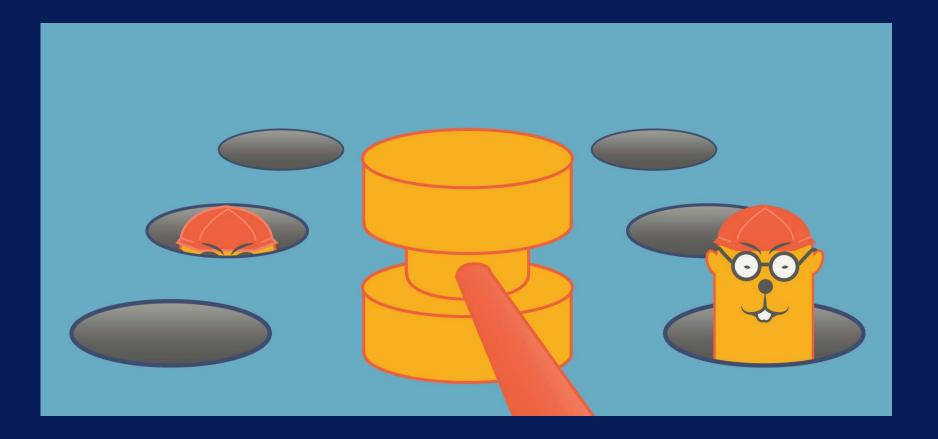


## **Rapidplan for Liver SBRT**

- Great tool for dosimetrist's especially novice users
- Very useful in implementing planning for a new or less common body site
- Impressive performance in areas of PTV/OAR overlap
- Excellent first pass for both simple and complex geometries: some 'tweaking' may be necessary to achieve 'ideal' plan



## Inverse Planning for HN

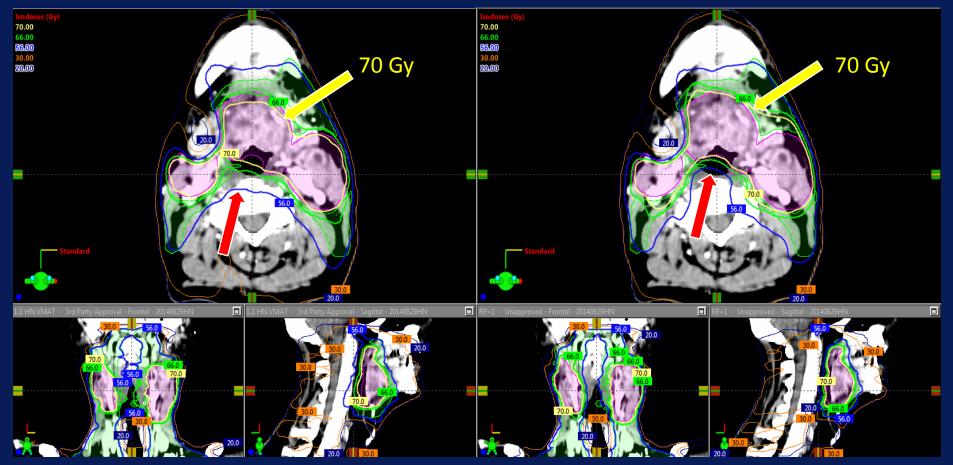




#### KBP: Head and Neck

#### Manually Optimized Plan

#### Rapidplan



Example #1



### KBP: HN Target Coverage

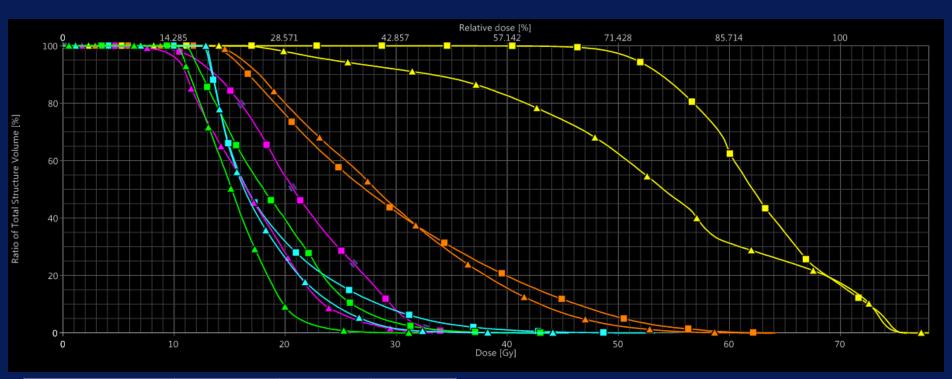


= Manually Optimized Plan

= Rapidplan Optimization



## **KBP: HN OAR sparing**



OAR	Mean: Manual Optimization	Mean: RapidPlan	Difference
Lips	21.3	16.9	4.4
Superior Constrictors	62.5	53.3	9.2
Esophagus	18.9	15.5	3.4
Larynx	19	17.8	1.2
RT Submandibular	29.3	29.5	-0.2

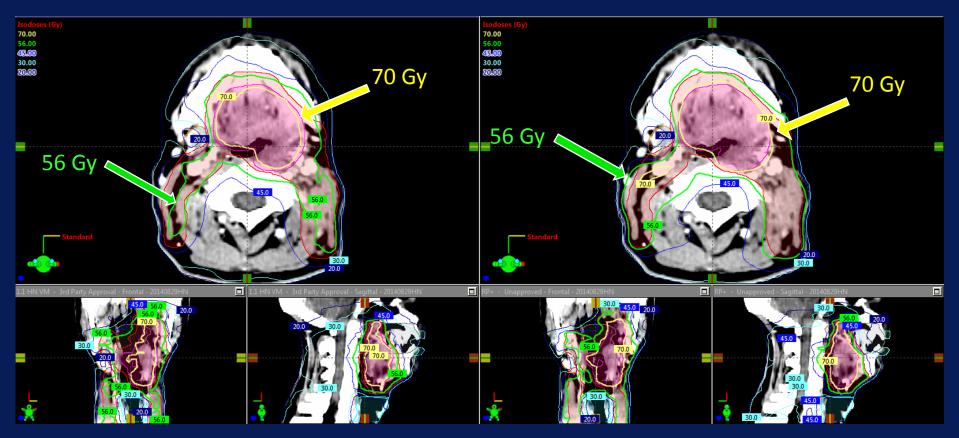
- = Manually Optimized Plan
- ▲ = RapidPlan Optimization



### KBP: Head and Neck

#### Manually Optimized Plan

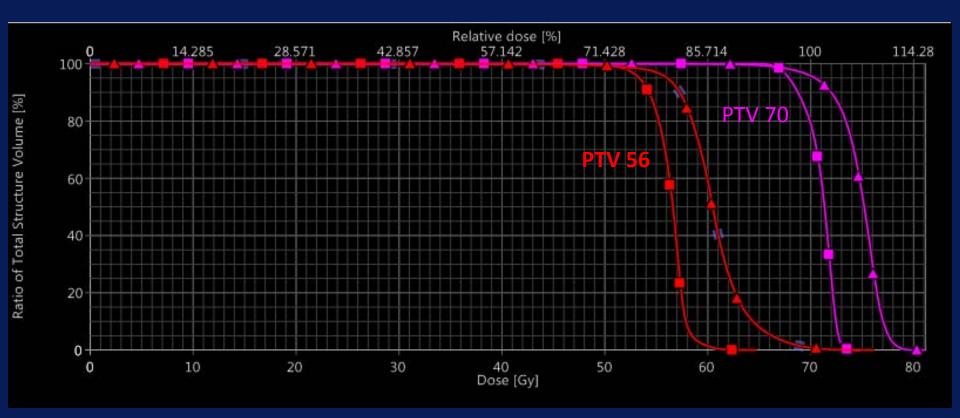
RapidPlan



Example #2



## KBP: HN Target Coverage

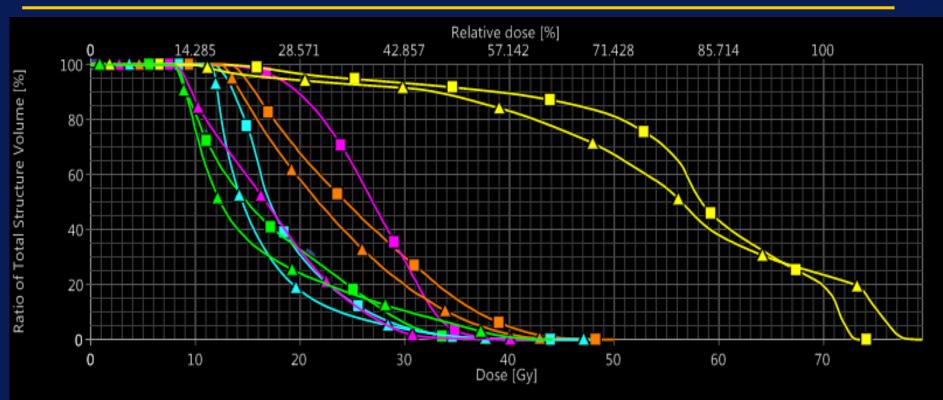


= Manually Optimized Plan

= Rapidplan Optimization



### **KBP: HN OAR Sparing**



OAR	Mean: Manual Optimization	Mean: RapidPlan	Difference
Lips	26.6	17.3	9.3
Superior Constrictors	57.1	54.8	2.3
Esophagus	17	16	1
Larynx	18.8	16.4	2.4
RT submandibular	25.4	23.1	2.3

= Manually Optimized Plan

= RapidPlan Optimization



#### KBP: Head and Neck

- Time Savings
- Excellent start individualization still necessary
- Line Objectives helps reduce dose to OARs





# Please take out your phone / tablet and join us for a few final questions....





- Model building is time consuming Is it worth it?
- Multiple body-sites that are great candidates for KBP
- Variation in plan quality from dosimetrist to dosimetrist – as well as from clinic to clinic



## What do our dosimetrists think about RapidPlan?

#### • Depends on:

- Dosimetrist seniority
- Dosimetrist experience with using Rapidplan
- Dosimetrist engagement in the model creation



## Do we still need dosimetrists? (Yes!)

- Is it possible to create a fully automated plan with a push of a button?
  - Perhaps, but you still need a dosimetrist!
- Limitations include:
  - There are evaluation criteria that can't be put in the objective function (NTCP, conformity, etc...)
  - There may still be improvements that can be gained on top of the default objectives
  - Not every patient is going to be represented by a model
     leaving more time for planners to tackle complex nonstandard cases



#### Acknowledgements

- Martha Matuszak
- Kelly Younge
- Dawn Owen
- Mary Feng
- Dan Hamstra

- Kathryn Masi
- Joseph Foy
- Hunter Gits
- Karen Vineberg
- UMHS community Practices



## Thanks from The Big House !

