Enhancing a Physicist's Role in the Assessment of Treatment Plan Quality

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Disclosures

- This presentation does not represent the opinions of AAPM or any working group.

Learning Objectives

- To define quality in radiotherapy treatment planning
- To understand the role of a physicist in determining quality
- To learn how to evaluate technical features that impact plan quality
- To learn how to evaluate clinical features that impact plan quality
- To understand how automation and data-driven plan quality control tools can be used clinically to support quality

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Definition of quality

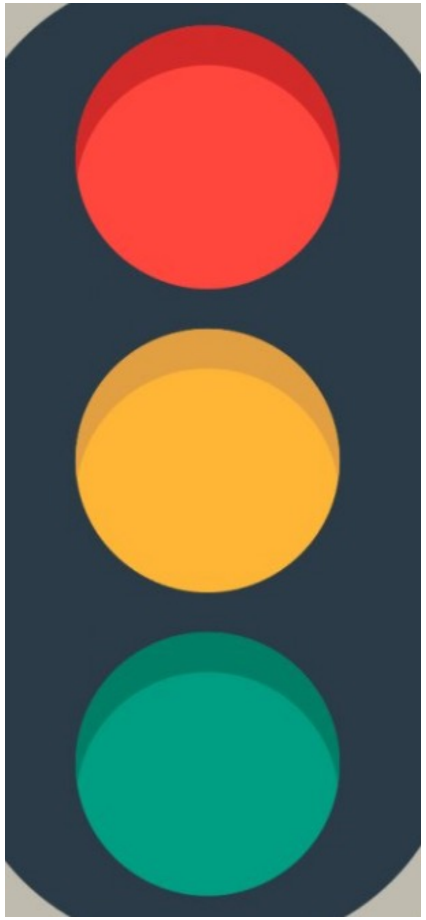
Quality (Merriam Webster):

“How good or bad something is.”

Plan quality (TG-308):

***“**Given a desired therapeutic dose of radiation to a patient, treatment plan quality is the degree to which a dose distribution maximizes tumor control and minimizes normal tissue injury for a given technique.”*

Stoplight approach to plan quality



Unacceptable: Plan is unsafe for treatment

Acceptable: Plan will not harm patient, but could be improved

High Quality: Plan strikes a balance between target coverage, normal tissue sparing, robustness, and clinical practicality

Spectrum of Plan Quality

Spectrum of Plan Quality

Often the majority of plans are ***acceptable*** and the goal as a physicist is to ensure/transition to ***high quality***

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Role of a Physicist in Radiation Oncology

"The first responsibility of the radiation oncology physicist is to the ***patient***--to assure the ***best possible*** treatment given the state of technology and the skills of the other members of the radiation oncology department." – Task Group 38

Create a culture that promotes quality

Multi-disciplinary approach

Review plan quality critically

Use automated/data-driven methods

Potential hurdles to a culture that promotes quality

Potential Hurdles	Environment does not support physics feedback	Remote work/ new hires	Resource constraints	Physicist unsure if quality is adequate
Solutions	Relationship building and added value	Implement clear processes and procedures	Emphasize ILS for systematic improvement	Increase planning exposure for physicists

Technical and Clinical Aspects

According to RO-ILS data, “Treatment” is the most common step for discovery of issues

Patie Simulat → Plan Creation/ Plan Quality Review → ysician eview → Physics Pre-treatment Check → Treatment

Technical Aspects

- Beam Configuration
  - Number of Arcs/Beam
  - Arc/Beam Angle Selection
  - Collimator/Jaw Selection
- Optimization Objectives
- Plan Modulation
- Treatment Devices
- Density Overrides

Clinical Aspects

- Images
- Registrations
- Contours
- Isodose
- DVHs
- Plan Sum Evaluation

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Technical Aspects: Beam Configuration

Patient Simulation → **Plan Creation/ Plan Quality Review** → Physician Review → Physics Pre-treatment Check → Treatment

Technical Aspects

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Number of Arcs/Beams

- Too few:
  - Reduced degrees of freedom necessary for maximum OAR sparing/target coverage
- Too many:
  - Decreased delivery efficiency, slow dose rate (arcs)
- Standardized based on institution, treatment site, complexity

Technical Aspects: Number of Beams/Arcs

Background:

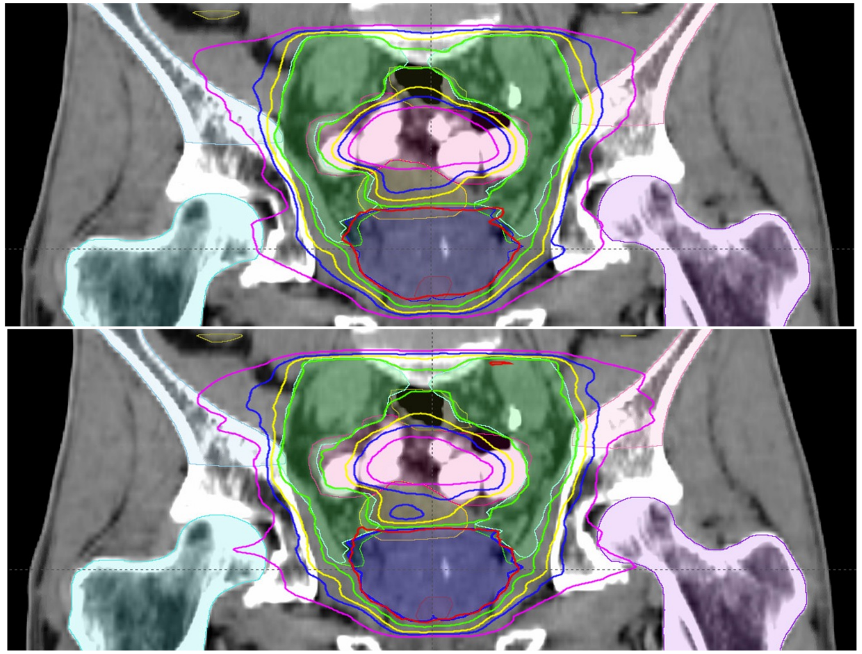
- Prostate + Nodes with SIB

Issue Identified:

- Original plan utilized 4 full arcs
  - Collimator: 10, 45, 315, 90
  - Fraction MU: 724
  - Mean Dose Rate: 113 MU / minute

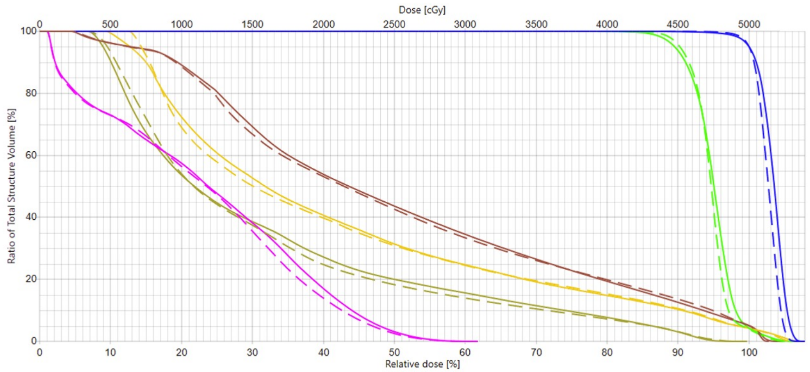
Improvement:

- Replanned using 2 full arcs
  - Collimator: 10, 90 degrees
  - Fraction MU: 590
  - Mean Dose Rate: 260 MU / minute
- Consistent plan quality with more efficient delivery



4-Arc

2-Arc



2-Arc

4-Arc

Technical Aspects: Beam Configuration

Patient Simulation → Plan Creation/ Plan Quality Review → Physician Review → Physics Pre-treatment Check → Treatment

Technical Aspects

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Arc/Beam Angle Selection

- Avoid entrance through poorly immobilized anatomy
- Clearance of patient
  - Both for field path AND between fields/arc
  - Minimize shifting of patient
- Maximize target coverage from multiple angles
- Minimize entry through critical OARs

Technical Aspects: Beam/Arc Angle Selection

Background:

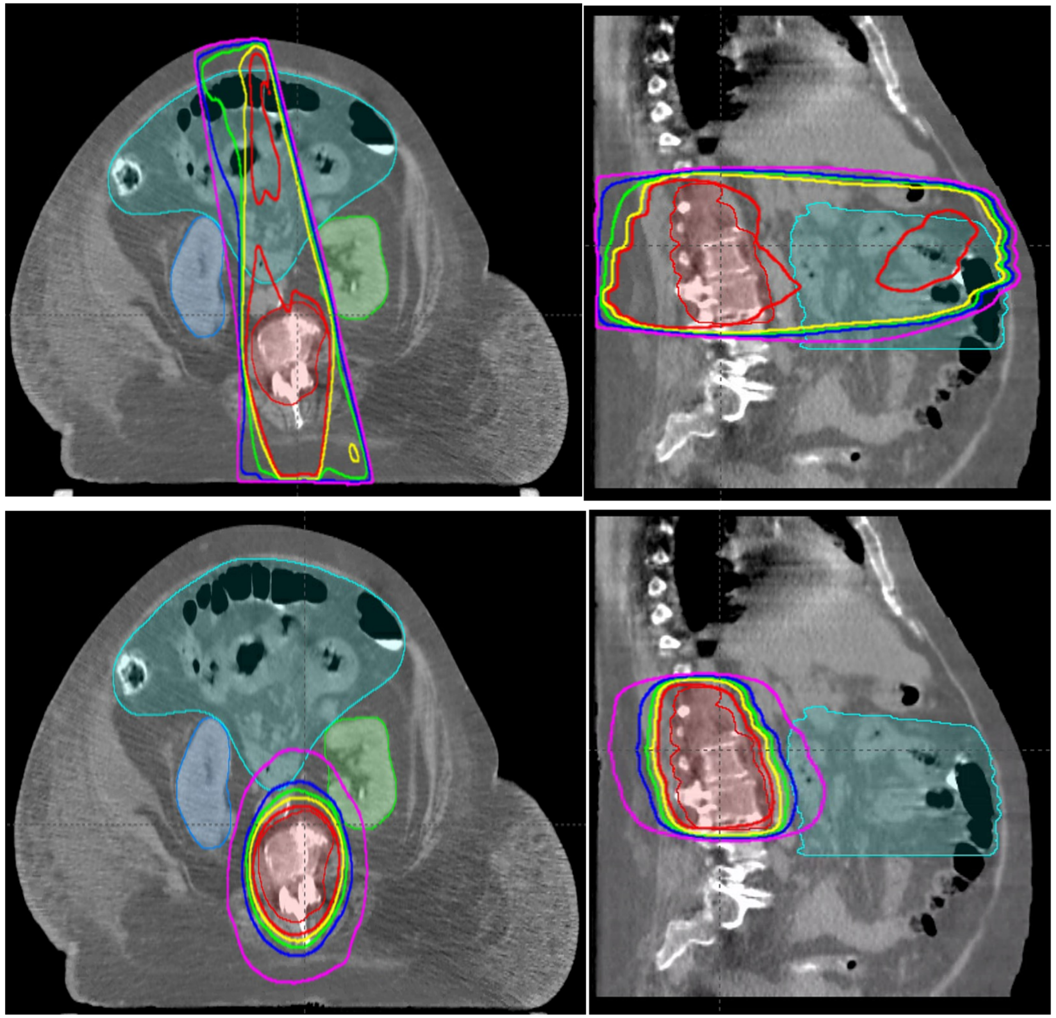
- 3D T/L Spine prescribed 600 cGy x 3 fractions
- Physician specifically requests "AP/PA" plan

Issue Identified:

- Plan violates institutional 3-fx bowel constraints

Improvement:

- Discussed AP/PA rationale with physician
  - ➢ Physician wanted something quick for the patient, hence AP/PA request.
- Suggested / executed replan with single conformal arc
  - ➢ Negligible impact to on-table time for patient
- Bowel D2cc reduced by 35%(1880 cGy → 1240 cGy)
- Bowel mean dose reduced by 43% (700 cGy → 400 cGy)



Technical Aspects: Beam Configuration

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Technical Aspects

- **Beam Configuration**
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Collimator/Jaw Selection

- Collimator Angle:
  - Utilize collimator angles to minimize in-field OARs
  - Varying collimator angles for multiple arcs to increase degrees of freedom
- Jaw Selection for Large Targets
  - Maximize critical OARs with low dose objectives under the jaws
  - Limited jaw size and MLC travel

Technical Aspects: Collimator/Jaw Selection

Background:

- Long Scalp and left upper neck/face treatment
- Treatment on Varian HDMLC linac

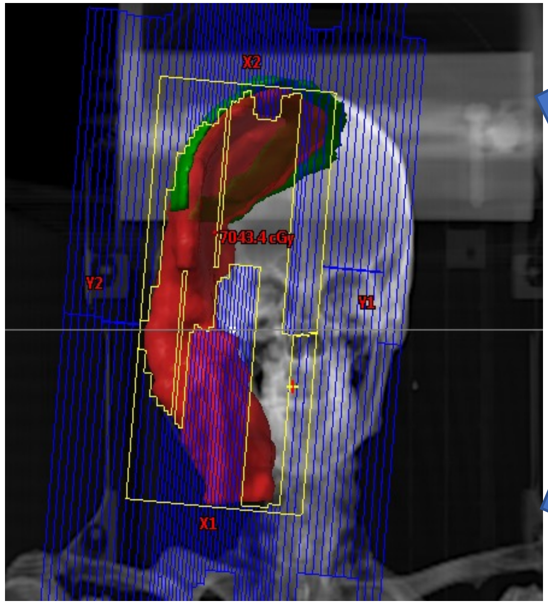
Issue Identified:

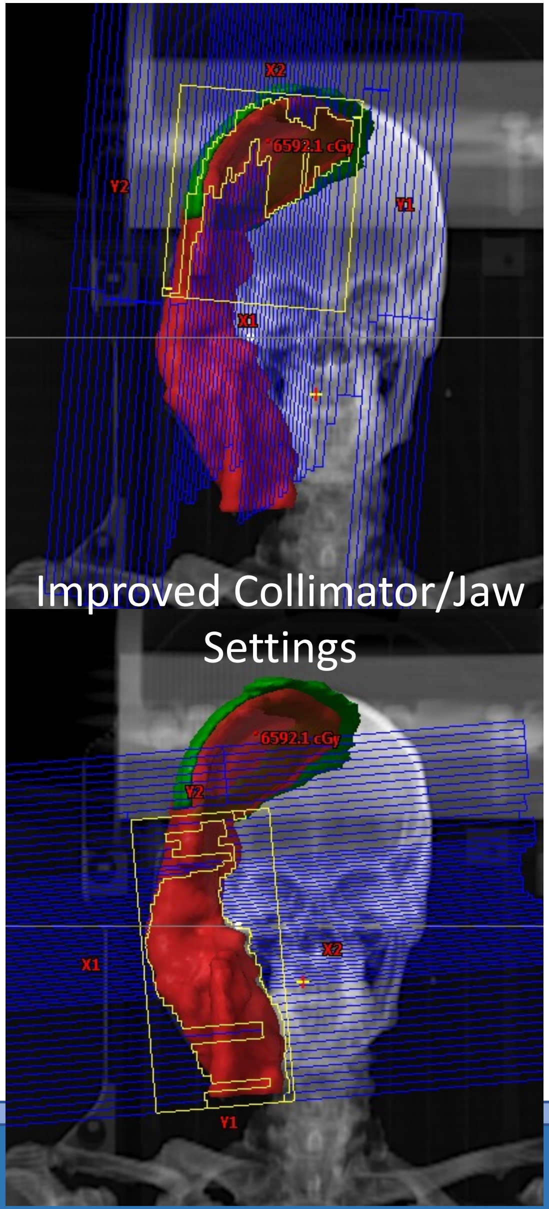
- Field too wide resulting in open MLC shapes due to carriage limitations

Improvement:

- Selected better collimator angles and jaw limitations to reduce MLC travel
- Reduces unnecessary dose to patient

Original Collimator/Jaw Settings





Improved Collimator/Jaw Settings

Technical Aspects: Optimization Objectives

Patient Simulation → Plan Creation/ Plan Quality Review → Physician Review → Physics Pre-treatment Check → Treatment

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Optimization Objectives

- Achievable Objectives
  - Reasonable separation between min and max goals for targets
  - Appropriate sparing of OARs
- Conflicting Objectives
  - OAR/Target objectives not simultaneously achievable
- Omitted OARs/Targets
- Objective weights should follow OAR/Target prioritization

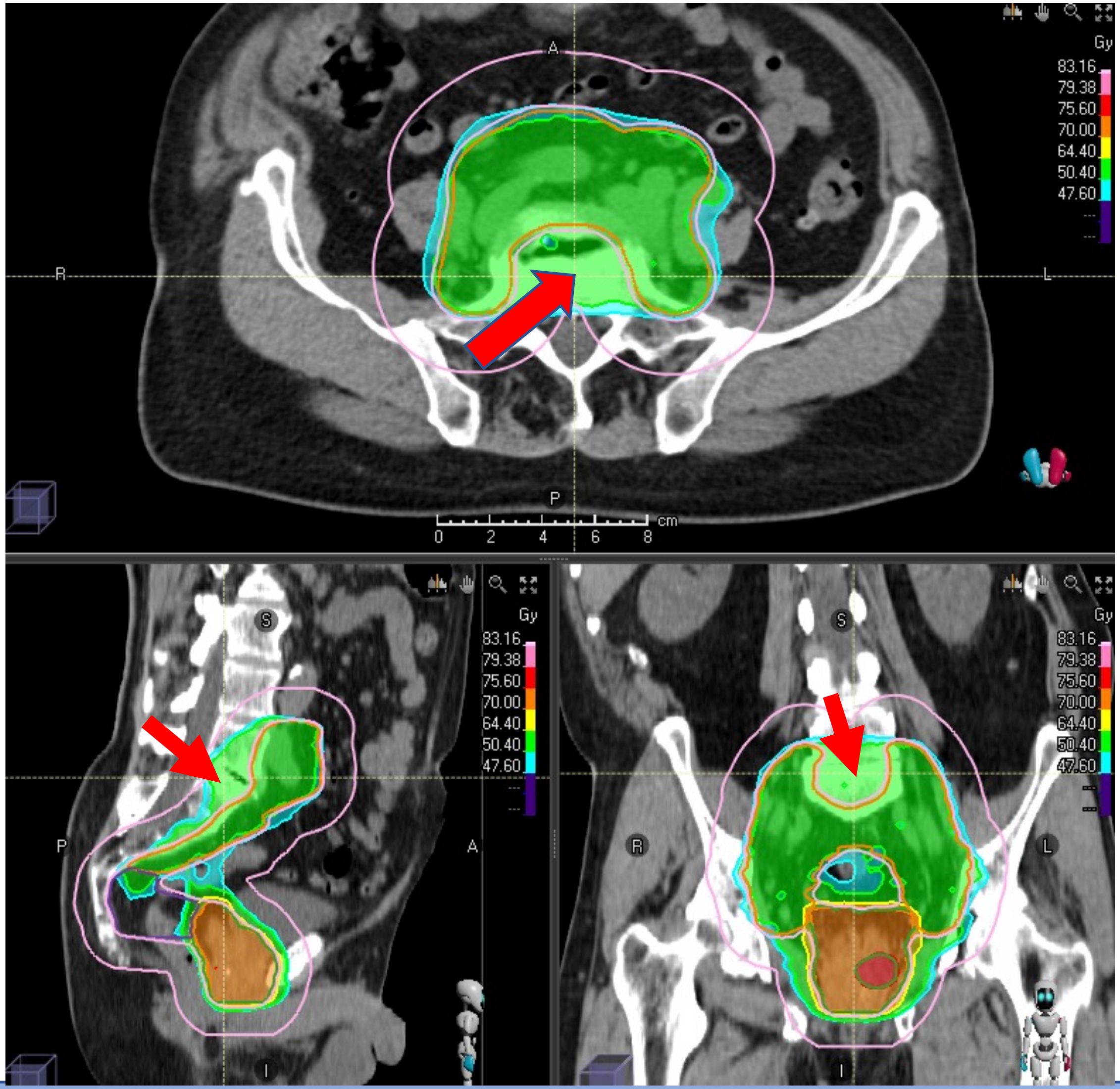
Technical Aspects: Optimization Objectives

Background:

- Complex prostate + nodes SIB case with multiple dose levels
- Single ring structure used to promote conformality

Issue:

- Dose objective selected for ring structure was ineffective for certain PTV dose levels
- Results in poor plan conformity and risk of fracture to vertebral body



Technical Aspects: Optimization Objectives

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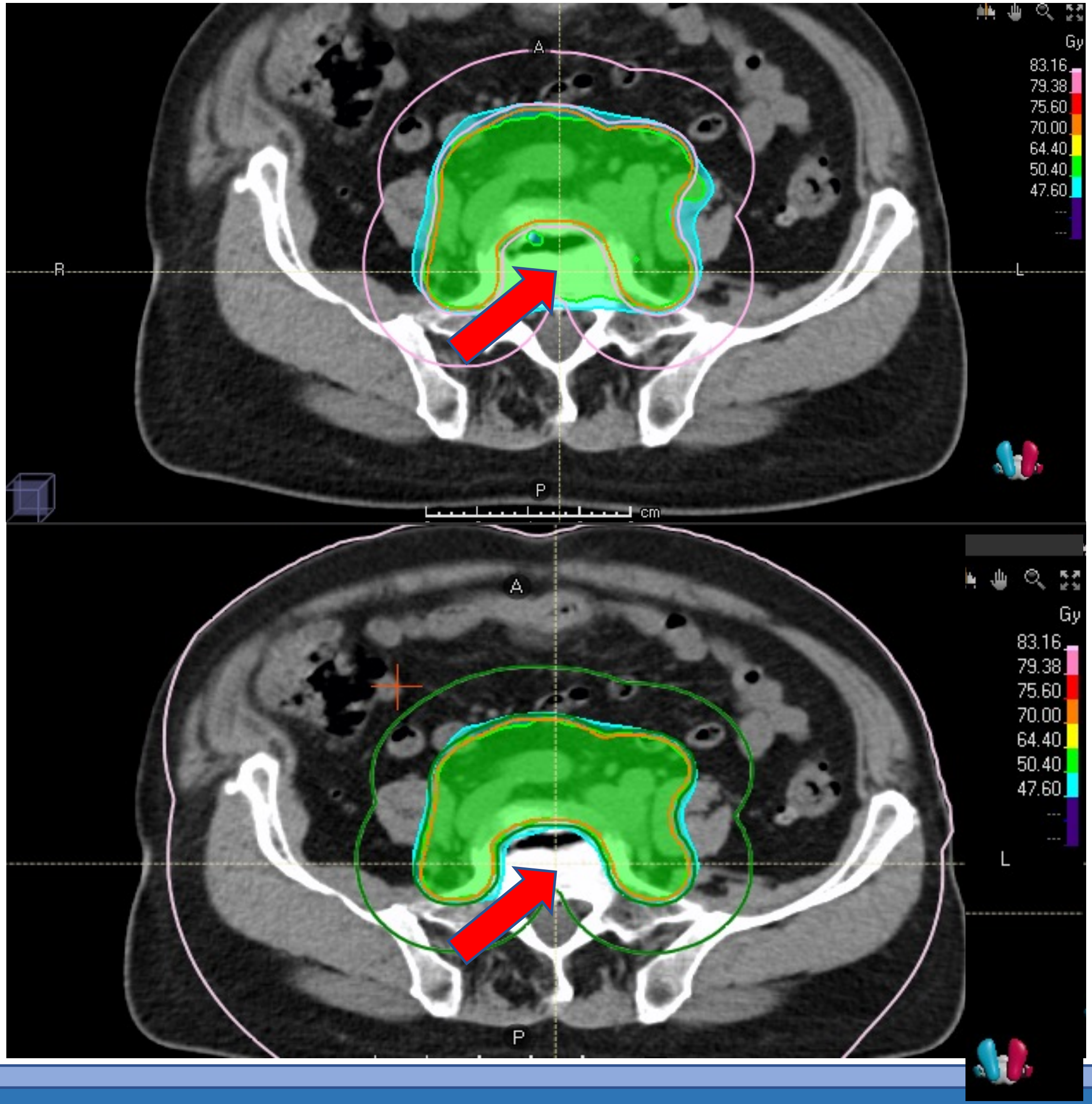
- Complex prostate + nodes SIB case with multiple dose levels
- Single ring structure used to promote conformality

Issue:

- Dose objective selected for ring structure was ineffective for certain PTV dose levels
- Results in poor plan conformity and risk of fracture to vertebral body

Improvement:

- Create separate ring structures and apply appropriate objectives to increate conformity



Technical Aspects: Missing Objectives

Background:

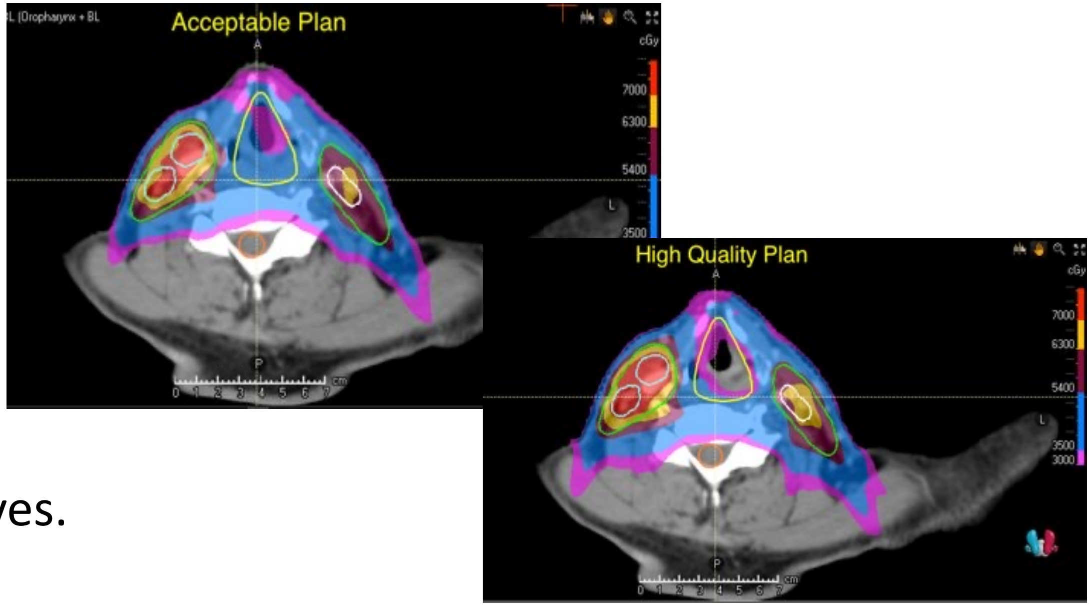
- Oropharynx treatment with 3 prescription dose levels.
- Larynx dose violated the clinical goal but the physician accepted as it was not a top priority. (PTV coverage was prioritized.)

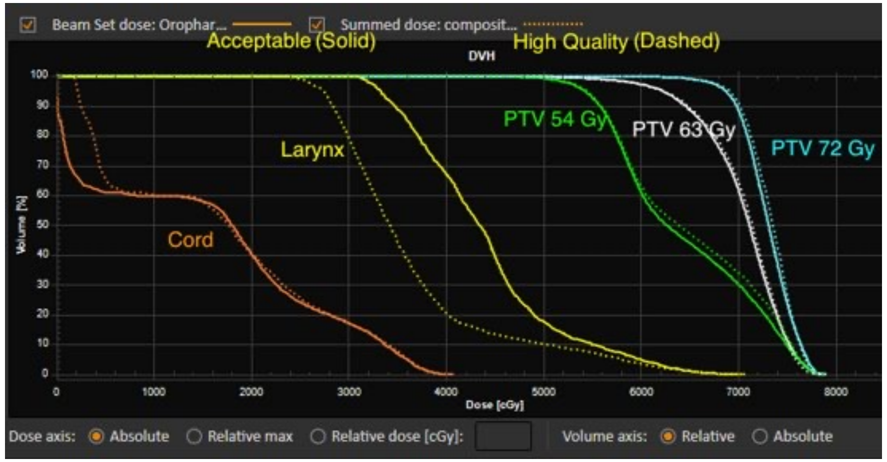
Issue:

- Larynx ROI was not included in the optimization objectives.

Improvement:

- Larynx objective was added in the optimization.
- Larynx dose decreased without compromising PTV coverage and cord dose.
  - ✓ PTV 54 Gy, PTV
  - ✓ Larynx average dose 44 Gy -> 36 Gy.





Technical Aspects: Plan Modulation

Patient Simulation → Plan Creation/ Plan Quality Review → Physician Review → Physics Pre-treatment Check → Treatment

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Plan Modulation

- Heavily modulated plans may exceed accuracy of dose calculation models
  - Resulting QA rates may decrease
  - Best to evaluate/mitigate prior to plan review/approval
- Plan complexity evaluation includes:
  - MU ratios within expected range
  - MLC aperture size/motion in BEV
  - Complexity factors when available

Technical Aspects: Plan Modulation

Definition of modulation factor: MU/fractional dose

Typical modulation factors:

3D: ~1 (without wedge)
FIF: 1-1.5
VMAT: 2-5
SMLC IMRT: 3-7
DMLC IMRT: 5-10
Multi-Met SRS: 3-8 (see figure)

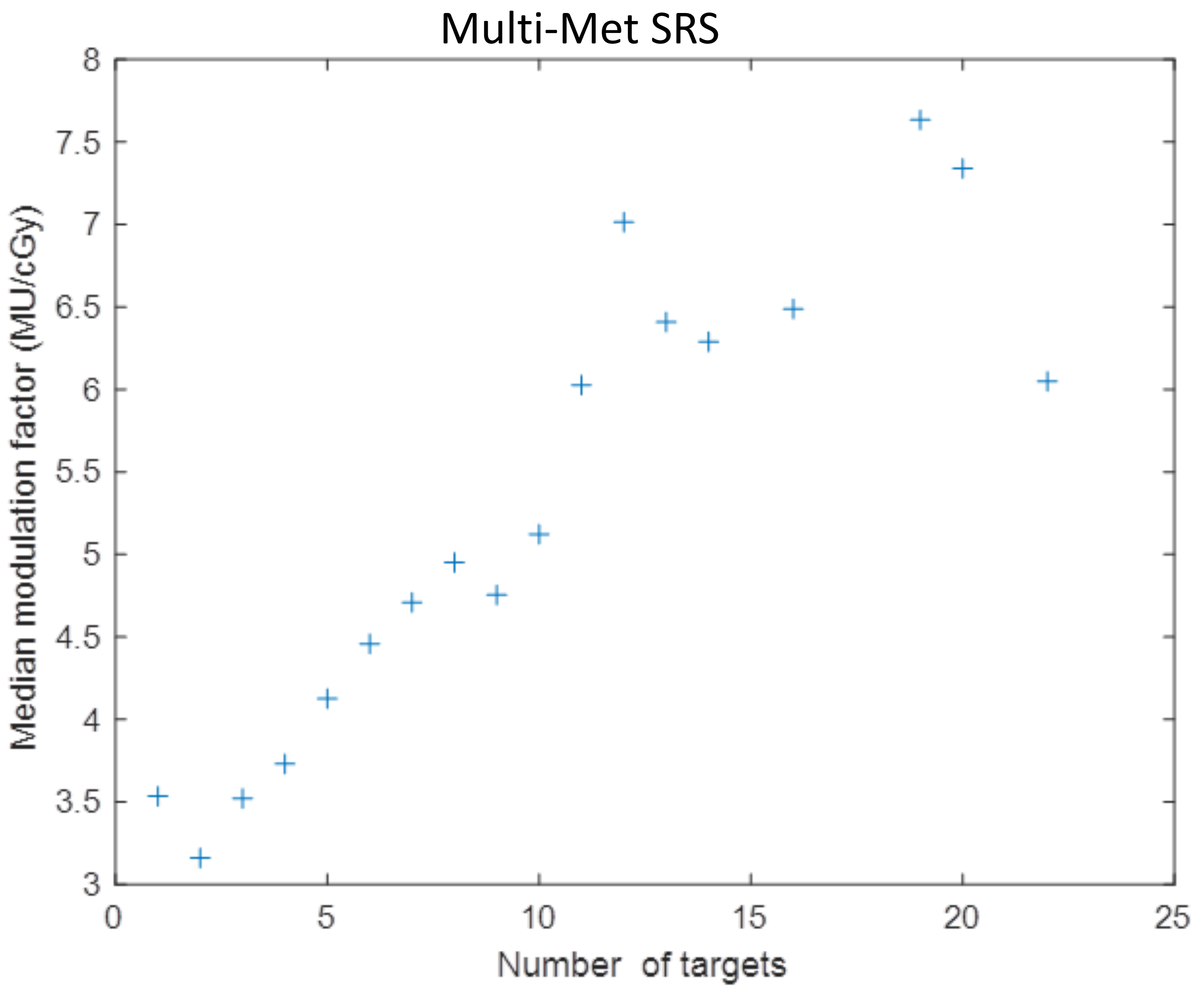


*Figure Courtesy of Richard Popple, PhD

Technical Aspects: Modulation and Delivery Efficiency

Background:

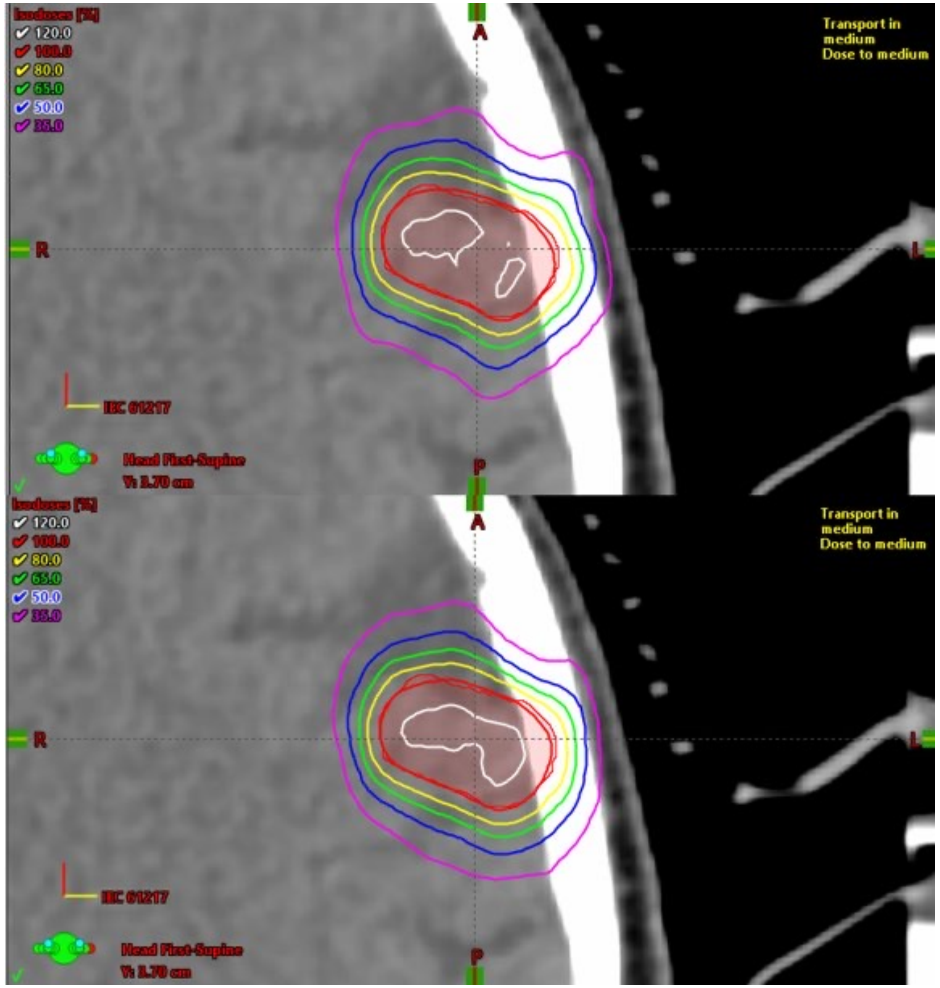
- 2400 cGy / 1 Fx SRS Brain

Issue:

- Planner pushed unconstrained VMAT optimization to an MU factor of 3.6
  - 95% PTV coverage, CI = 1.02, GI = 3.65

Improvement:

- Replanned with strict MU objective + high-strength aperture shape controller → MU factor 2.6
  - 95% PTV coverage, CI = 1.02, GI = 3.70
- Reduction of about 2400 MU or nearly 2 minutes of beam-on time at nominal 1400 MU/min dose rate with no decrease in plan quality



Technical Aspects: Treatment Devices

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Treatment Devices

- Couch model
- Immobilization devices
- Motion management devices (e.g., diaphragm control device)

Technical Aspects: Treatment Devices Inclusion

Background:

- Plan created without couch but treated with couch

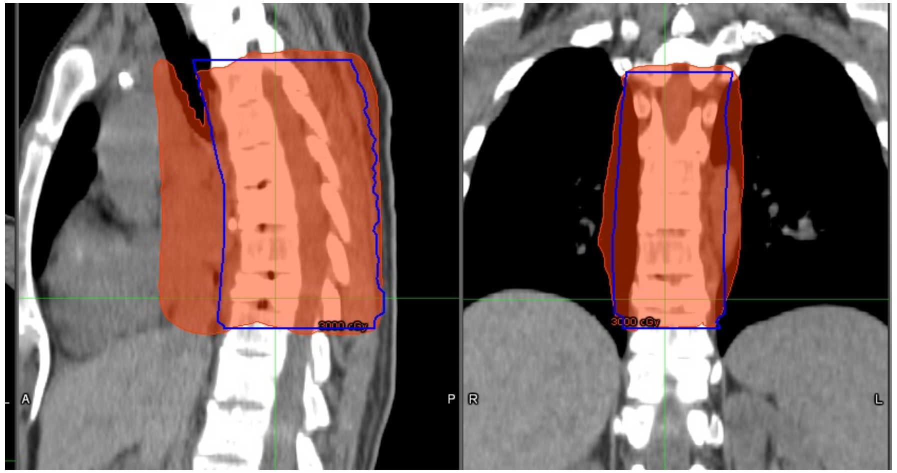
Issue:

- Omission of couch impacts PTV coverage

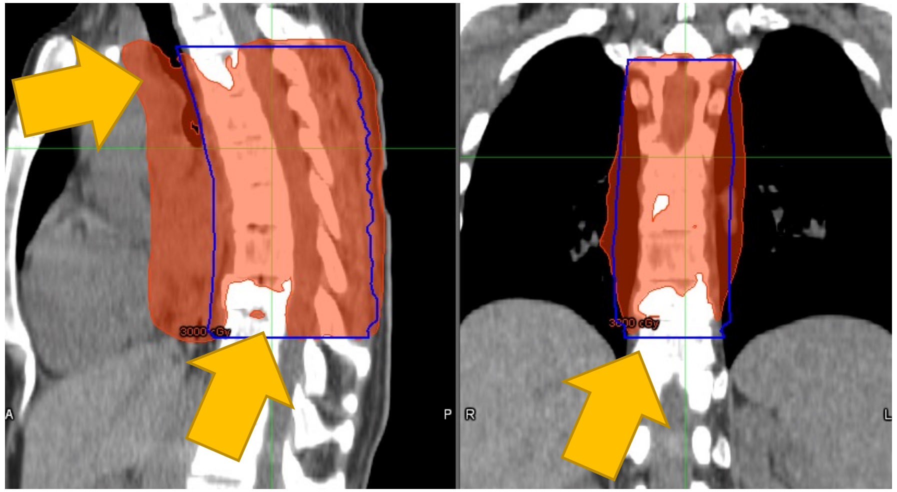
Improvement:

- Inclusion of treatment couch in plan
- More accurate representation of dose to patient

Plan generated without a couch



Plan treated through a couch



Technical Aspects: Density Overrides

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- **Density Overrides**

Density Overrides

- Volumes with density that are not physically present during treatment
- Location, volume, proximity to target all dictate when it is important
- Constrast, hardware, artifacts
- No universal standard

Technical Aspects: Density override

Background:

- Patient had hip replacement hardware.

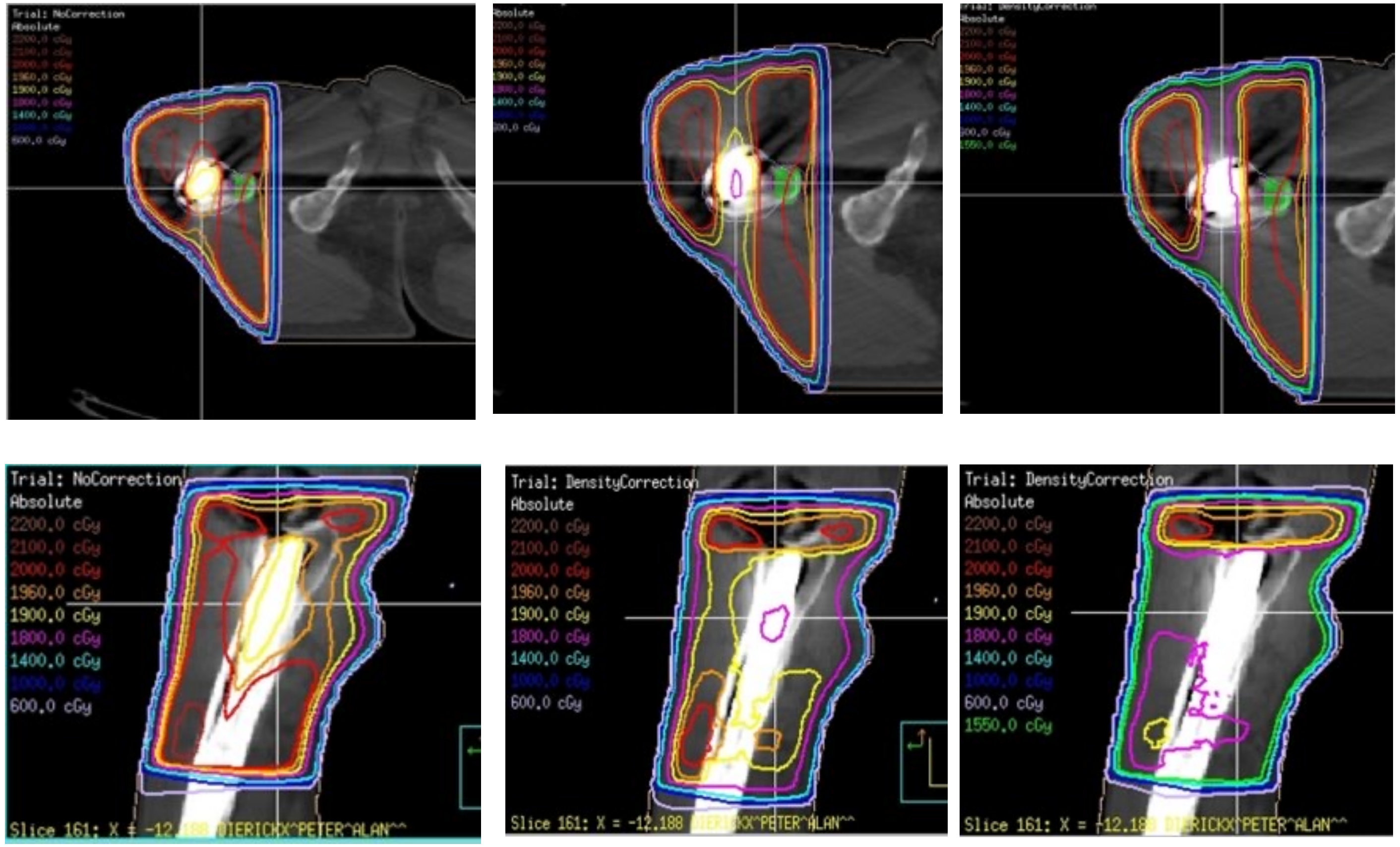
Issue:

- No density was overridden because the materials were unknown.

Improvement:

- According to TG 63, most prosthetic devices are made of steel (8.1 g/cm^3), Co-Cr-Mo (7.9g/cm^3), or titanium (4.3g/cm^3) and the comparison was provided to physicians to make informed clinical decision.

No density override | Density override : 4.2g/cm^3 (Titanium) | Density override: 8.0g/cm^3 (Steel or Co-Cr-Mo)



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Clinical Aspects: Images

Patient Simulation → Plan Creation/ Plan Quality Review → Physician Review → Physics Pre-treatment Check → Treatment

Clinical Aspects

- **Images**
- Registrations
- Contours
- Isodose
- DVHs
- Plan Sum Evaluation

Images

- Proper motion management /immobilization
- Correct planning images
- Quality of the planning images
  - Resolution, contrast
  - Field-of-view, scan length
  - Fiducial location
  - Artifacts

Clinical Aspects: Insufficient CT scan length

Background:

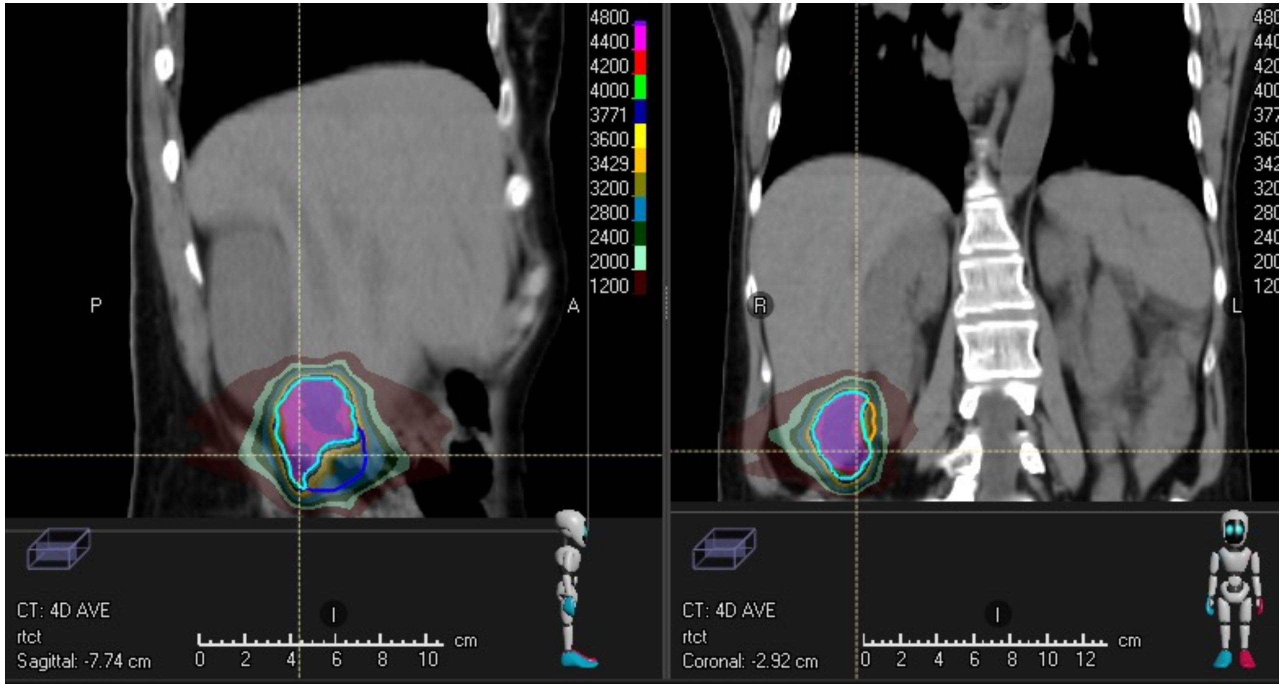
- Liver SBRT treatment

Issue:

- Scanning parameter was entered incorrectly by mistake and a limited CT dataset was acquired.
- PTV is located at the edge of the CT images acquired

Improvement:

- Re-simulation if part of an important parallel organ or PTV is missing in the CT scan
- Extend CT to add missing tissues for dose calculation in full scatter condition



Clinical Aspects: Registrations

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Clinical Aspects

- Images
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Registrations

- Evaluate primary to secondary dataset registrations
  - Rigid and deformable registrations
  - Positioning of patient in secondary dataset may be different
  - Accuracy of registration may be limited to small region
- Communicate any unusual variations to physician.

Clinical Aspects: Registrations

Background:

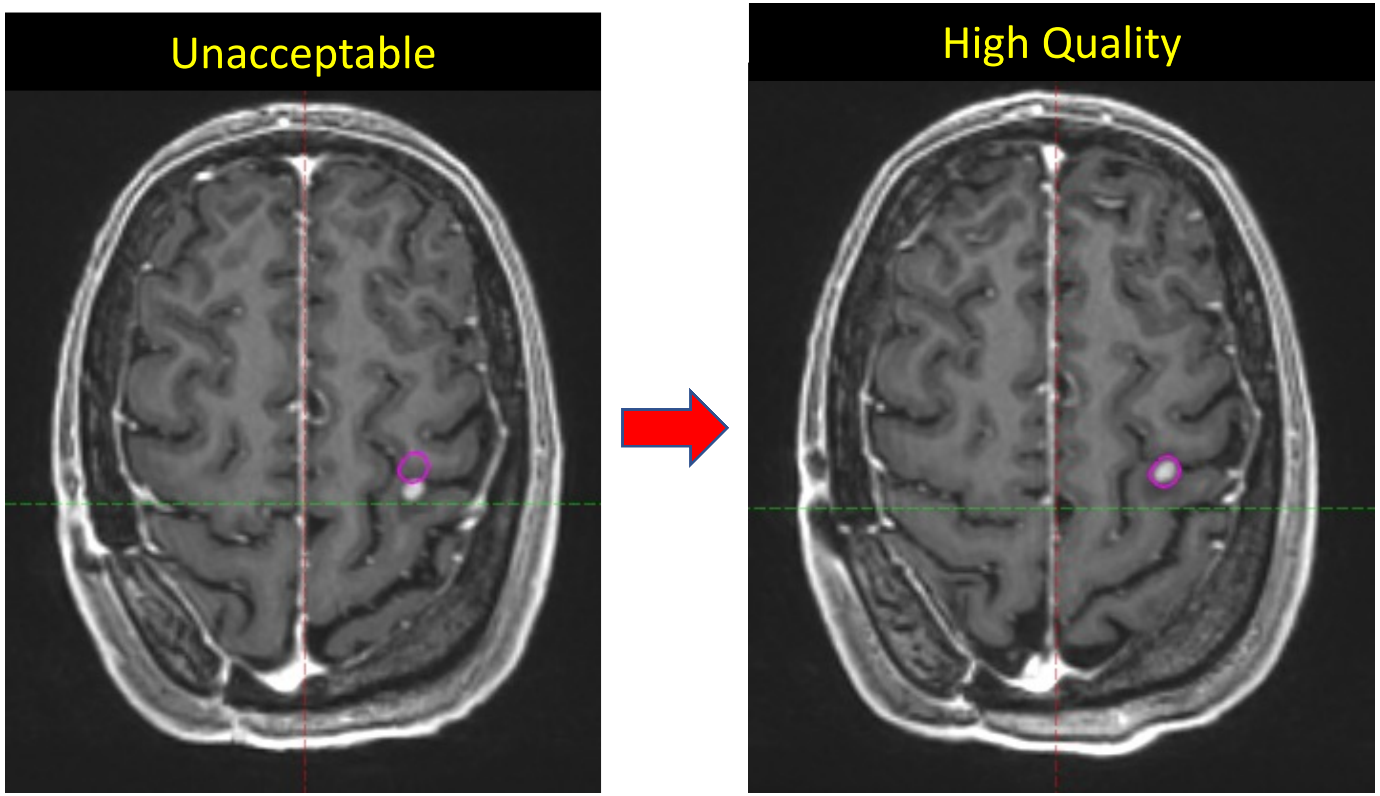
- Brain SRS case contoured using fused MR

Issue:

- MR fusion not accurate
- Results in inaccurate target contours

Improvement:

- Review image registration and target contours prior to planning/approval



AAPM TG-132 recommends that clinics establish a patient-specific QA practice for efficient evaluation of image registrations

Clinical Aspects: Contours

Patient Simulation → Plan Creation/ Plan Quality Review → Physician Review → Physics Pre-treatment Check → Treatment

Clinical Aspects

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Contours

- Accuracy of contours impacts plan trade-offs and quality evaluation
  - Missing contours
  - Missing interpolation
  - Stray pixels
  - Incomplete contours
  - Incorrect labeling of contours

Clinical Aspects: Contours

Table 1.A.i: Photon/electron EBRT high-risk failure modes for initial plan/chart review. Failure modes (FMs) with *RPN*>100 are listed in order of decreasing RPN. For each FM the number of checks is listed, i.e. the number of different checks from Table 1.C.i which might identify this failure mode.

FM#	Process Step	Failure Mode	Cause	# checks	RPN	S	O	D
1	Tx Plan	"Wrong" or inaccurate MD contours	Workflow/Communication Issue, e.g., Attending MD does not review resident contours, MD does not clearly identify dose levels, Incorrect CT dataset, Fusion incorrect or with wrong image set, Target motion not considered, Wrong set of contours imported	7	261.3	7.4	4.9	7.2
2	Pt Assmnt	Miscommunication about prior dose, pacemaker, pregnancy	Information not communicated or available information incorrect	4	214.1	7.4	5.5	5.3
3	Tx Plan	Improper margins for PTV	Structural issues, e.g. policies and procedures inadequate or non-existent, margins not provided	2	198.0	5.5	6.0	6.0
4	Tx Plan	Unintentional re-irradiation of a previously treated area	Technical Issue: Inadequate medical records in hospital data base, Re-creation of prior plan incorrect, Missing previous RT dose structure, No records available (foreign country, distant past, lost)	3	181.2	7.7	3.8	6.2
5	Pt Assmnt	Incorrect or missing pathology	Pathology report incorrect or not read by MD	3	180.3	6.8	3.6	7.3
6	Tx Plan	Dose in plan does not match intended	Wrong Rx provided to planner, e.g. why: MD wrote wrong Rx (typo, e.g. 220x30 vs. 200x33) maybe via email, MD unintentionally writes Rx to max dose, wrong Rx signed off in chart or Rx not signed	7	175.3	6.4	5.8	4.8
7	Tx Plan	"Wrong" or inaccurate dosimetrist contours	Human performance issue by dosimetrist or other, e.g. distraction or interruption, inattention, slip, lack of training, mistakes CTV for PTV, forgets to expand CTV to PTV, full structure not contoured (e.g. partial cord in Tx region)	5	175.2	6.2	5.5	5.2
8	Pt Assmnt	Sub-optimal treatment plan or approach related to communication or coordination with multidisciplinary care	Lack of coordination or miscommunication with e.g. surgeons, med onc, etc.	4	160.2	4.9	4.3	7.6

Strategies for effective physics plan and chart review in radiation therapy: Report of AAPM Task Group 275

Clinical Aspects: Incomplete Contours

Background:

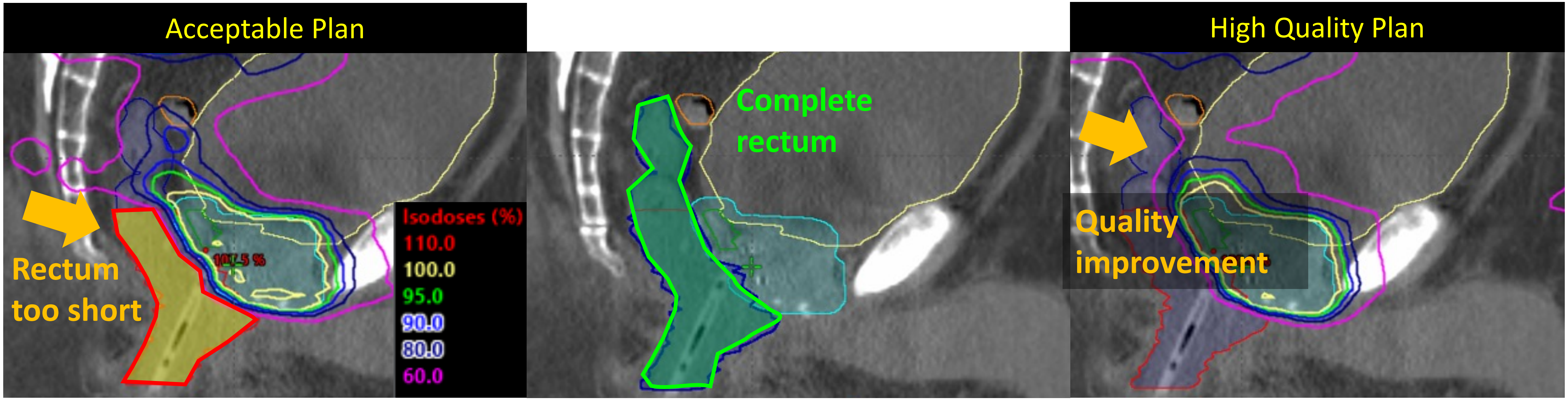
- Prostate + nodal SIB plan with dose leaking to the posterior side

Issue:

- Rectum was not completely contoured in the superior boarder

Improvement:

- Completed the rectum contour to fix the dose leak



Clinical Aspects: Isodose

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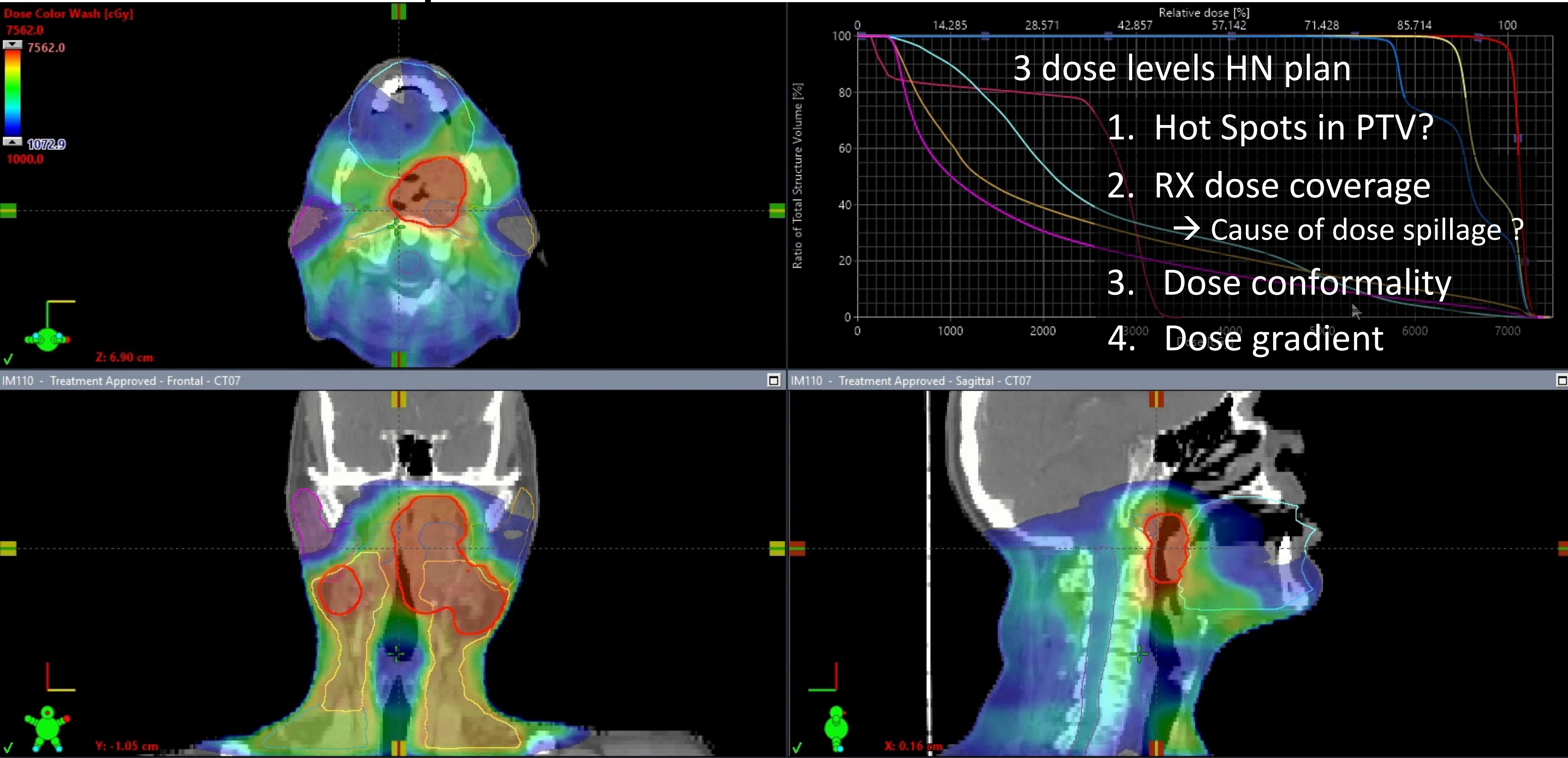
Isodose

- Review low, medium, high dose levels, including dose gradients
- Understand the ‘typical’ dose gradient different modalities/sites of treatments
- Understand the preference of trade-offs in your institution

Clinical Aspects: Isodose



Clinical Aspects: Isodose/Dose Gradient

Background:

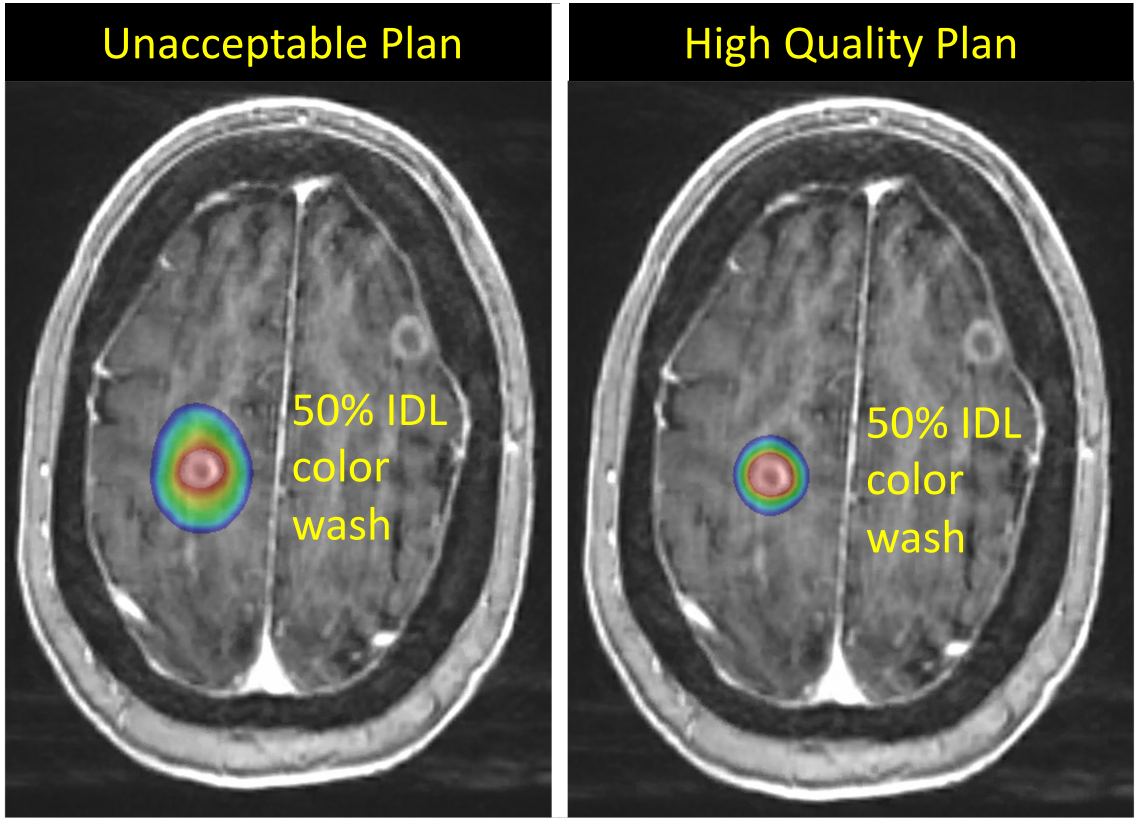
- 2400 cGy / 1 Fx SRS Brain
- **Physician and planner** both ***inexperienced*** with SRS
- Physician instructs planner to create a ***"uniform dose"***
- Dosimetrist complied:
  - Max Dose = 106%, CI = 1.03, Brain V12Gy = 9cc

Issue Identified:

- GI > 10!

Improvement:

- Replanned with
  - Max Dose = 133%, CI = 1.02, V12 = 2.5cc
  - GI = 4.5
- ***Education*** provided to staff on interplay between dose gradient and dose heterogeneity and why a "uniform" dose was not desirable for an intact brain met



MPPG 9.a recommends that clinics organize on-site review and proctoring of their first clinical SRS/SBRT procedure, conferring with professionals with experience relevant to the new service

Clinical Aspects: DVHs

Patient Simulation → Plan Creation/ Plan Quality Review → Physician Review → Physics Pre-treatment Check → Treatment

Clinical Aspects

- Images
- Registrations
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- Isodose
- **DVHs**
- Plan Sum Evaluation

DVHs

- Understand national and institutional normal tissues goals
  - Prioritized from MD written directive on a per-patient basis
- Reflect appropriate prioritization of planning goals in optimization
  - OAR constraints > target coverage > OAR goals

Example of Prioritization of Objectives

- Sample Written Directive for conventional lung radiotherapy
  - **Priority 1: OAR Constraints**
    - Take precedence **over target coverage**
    - Generally driven by well-established organ tolerances
  - **Priority 2: Target Coverage**
  - **Priority 3: OAR Goals**
    - Designed to push for better plan quality
    - Do not sacrifice target coverage to meet these goals

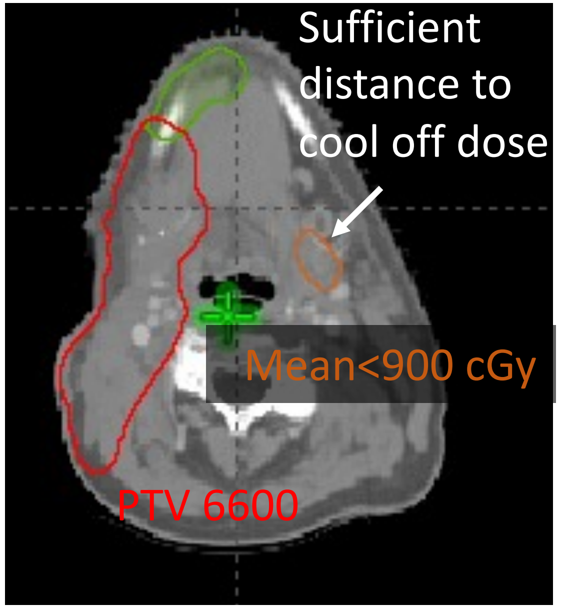
Target Coverage – Priority 2		
Target	Goal	Description
PTV_p	$D_{95\%} \geq Rx_{PTV\_P}$	Coverage: Minimum 95%
	$D_{2\%} \leq 110\%\ Rx_{PTV\_P}$	Maximum Dose: 110% Rx_{PTV}
	$D_{98\%} \geq 90\%\ Rx_{PTV\_P}$	Minimum Dose: to least exposed 2%

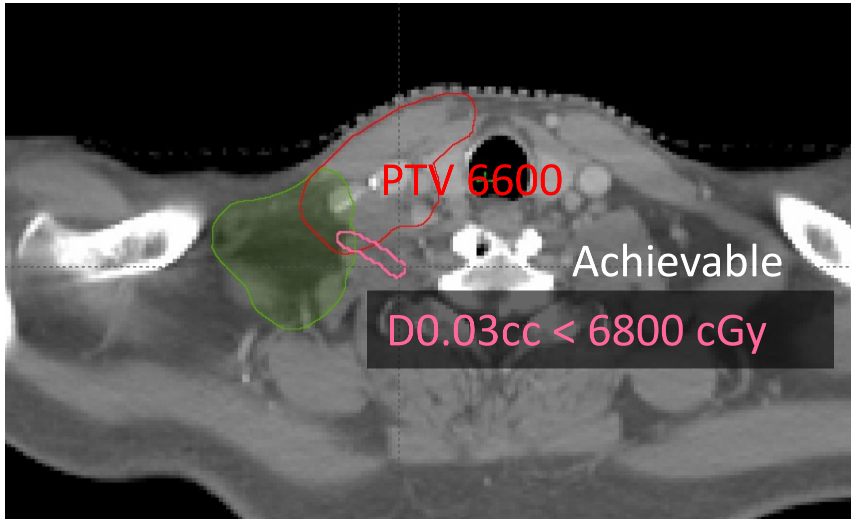
Organs at Risk		
Organ	Priority 3 - Goal	Priority 1 - Constraint
☐ BrachialPlex_L/R	$V_{60\ Gy} \leq$ 0.1 cc	$V_{66\ Gy} \leq$ 0.1 cc
☐ BrachialPlex_L/R_PRV05	$V_{66\ Gy} \leq$ 0.1 cc	
☒ Esophagus	$V_{50\ Gy} \leq 30\%$	
	$V_{60\ Gy} \leq 20\%$	
	$D_{mean} \leq 30$ Gy	$D_{mean} \leq 34$ Gy
	$V_{Rx_{PTV\_P}} <$ 0.1 cc	$V_{105\%\ Rx_{PTV\_P}} <$ 0.1 cc
☒ Esophagus_PRV05	$V_{110\%\ Rx_{PTV}} \leq$ 0.1 cc	
☒ Heart	$V_{40\ Gy} < 60\%$	$V_{40\ Gy} < 80\%$
	$V_{45\ Gy} < 40\%$	$V_{45\ Gy} < 60\%$
	$V_{60\ Gy} < 20\%$	$V_{60\ Gy} < 30\%$
	$D_{mean} \leq 26$ Gy	$D_{mean} < 30$ Gy
☒ Lungs-CTV	$V_{5\ Gy} \leq 60\%$	$V_{5\ Gy} \leq 75\%$
	$V_{20\ Gy} \leq 30\%$	$V_{20\ Gy} \leq 35\%$
	$D_{mean} \leq 18$ Gy	$D_{mean} \leq 20$ Gy
☒ Skin_PRV03	$V_{45\ Gy} \leq$ 0.1 cc	$V_{50\ Gy} \leq$ 0.1 cc
☒ SpinalCord	$V_{45\ Gy} <$ 0.1 cc	$V_{50\ Gy} <$ 0.1 cc
☒ SpinalCord_PRV05	$V_{50\ Gy} < 2\%$	$V_{55\ Gy} <$ 0.1 cc

Patient Specific Goals		
Organ	Priority 3 - Goal	Priority 1 - Constraint
☐		
☐		
☐		
☐		
Comments:		

Clinical Aspects: Objective Priorities

- **Background**
  - MD specified brachial plexus and submandibular gland sparing are ***OAR constraints***
- **Issue**
  - PTV **under-covered** in initial plan
  - **All OARs optimized with <u>equal</u> priority (50)**
- **Improvement**
  - Increase priorities for brachial plexus and submandibular gland to reflect the order requested by MD
  - Achieved ***<u>BOTH</u>*** the PTV coverage and OAR constraints





Clinical Aspects: Plan Sum Evaluation

Patient Simulation → **Plan Creation/ Plan Quality Review** → Physician Review → Physics Pre-treatment Check → Treatment

Clinical Aspects

- Images
- Registrations
- Contours
- Isodose
- DVHs
- **Plan Sum Evaluation**

Plan Sum Evaluation

- Use EQD2 when comparing different delivered fractionation scheme
  - Retreatment cases
  - Mixed modalities
- Consider appropriate registration for important aspects of the evaluation (may require multiple)
- University of Michigan has formalized the process
  - Special Medical Physics Consultation – Previous Treatment Evaluation
  - Resource: https://www.advancesradonc.org/cms/10.1016/j.adro.2019.05.007/attachment/511ab5a9-b32c-4075-b6ba-e75be68cbd74/mmc2.pdf

Clinical Aspects: Plan Sum Evaluation

Background:

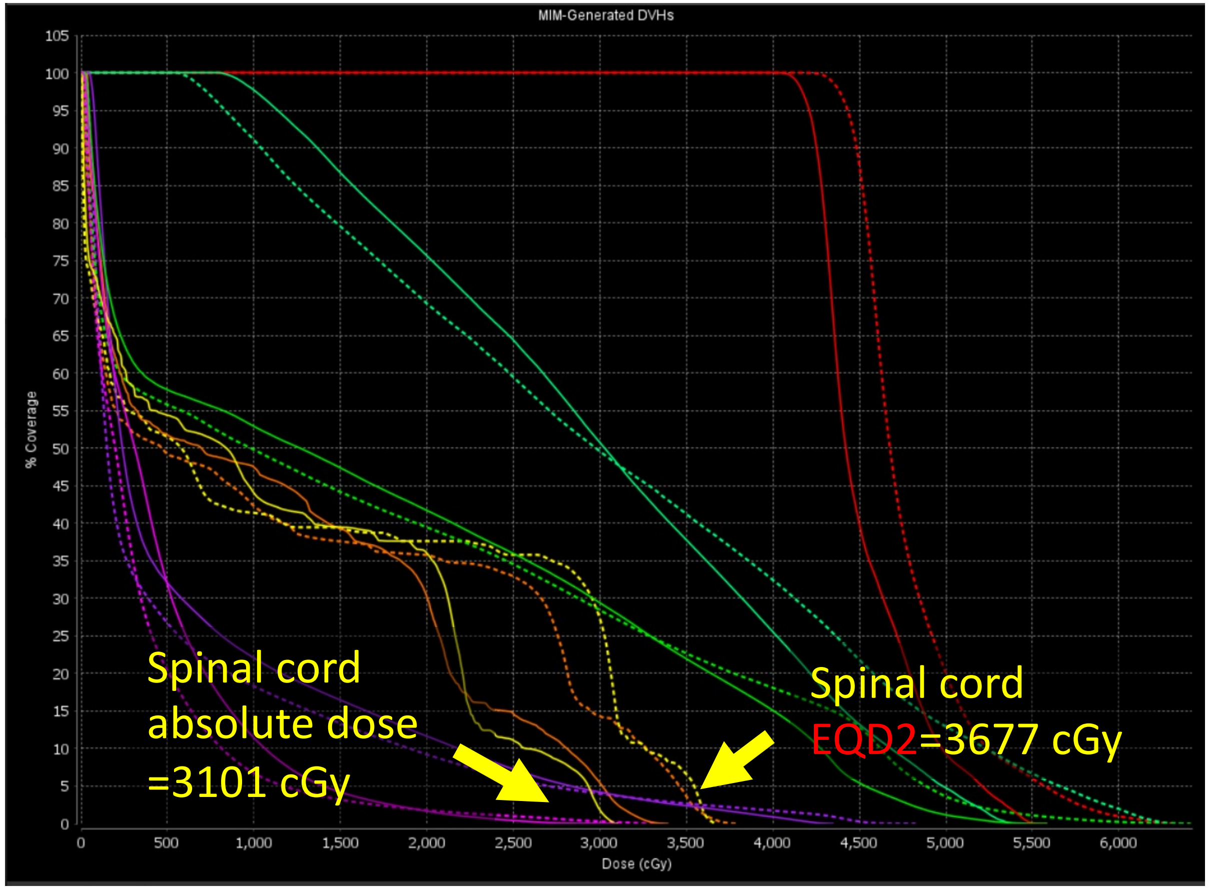
- Previously treated to T-spine with **400 cGy x 5 fx** = 2000 cGy.
- New plan to the LT Lung for ***267 cGy x 15 fx*** = 4005 cGy overlaps with T-spine plan.
- Physician wants to ensure that OAR tolerances are not exceeded.

Issue Identified:

- Using absolute doses can ***severely underestimate*** both target and OAR doses when fractional doses are larger than 2 Gy.

Improvement:

- Dose distributions from both plans were converted to equivalent dose in 2 Gy per fraction (EQD2) prior to summation.



Accumulated Dose Abs 2022-02-20

Enforce same line styles for eac... TCP Calc Save to CSV...

Name	Volume	Max Dose	Min Dose	Mean Dose	SD
Lung_R	1705.05	3091	9	448	466
Lung_L	1292	5586	20	1747	1678
SpinalCord	46.2	3101	6	1109	1063
Heart	826.86	4346	43	688	922
GreatVessels	110.85	5427	792	3031	1202
Esophagus	31.25	3391	34	1121	1079
LtLungPTV_4005	174.55	5586	3954	4537	304

Accumulated Dose EQD2 2022-02-20

Enforce same line styles for eac... TCP Calc Save to CSV...

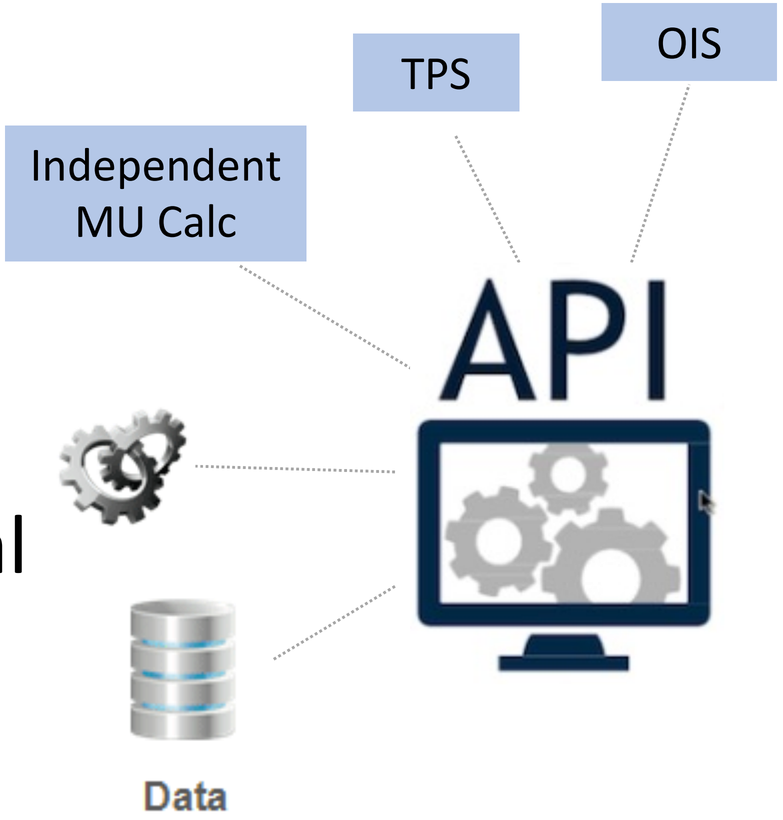
Name	Volume	Max Dose	Min Dose	Mean Dose	SD
Lung_R	1705.05	3391	5	341	453
Lung_L	1292	6422	12	1734	1817
SpinalCord	46.2	3677	4	1335	1428
Heart	826.86	4853	26	576	919
GreatVessels	110.85	6387	544	3078	1540
Esophagus	31.25	3800	20	1255	1341
LtLungPTV_4005	174.55	6327	4065	4789	345

Learning Objectives

- To define quality in radiotherapy treatment planning
- To understand the role of a physicist in determining quality
- To learn how to evaluate technical features that impact plan quality
- To learn how to evaluate clinical features that impact plan quality
- ***To understand how automation and data-driven plan quality control tools can be used clinically to support quality***

Why automate a process?

- Standardization
- Equivalent or higher quality
- Does something not previously practical
- Patient safety
- Higher efficiency



Application Programming Interface

A set of functions allowing the creation of applications that access the features or data of an operating system, application, or other service.

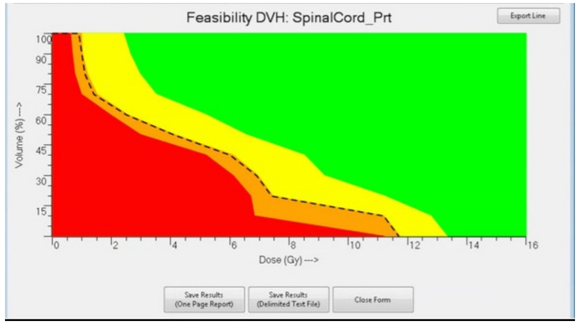
Quantifying plan quality

- Population-based scoring methods
  - QUANTEC/Clinical trials for specific treatment sites
  - TG-101/HyTEC for SBRT

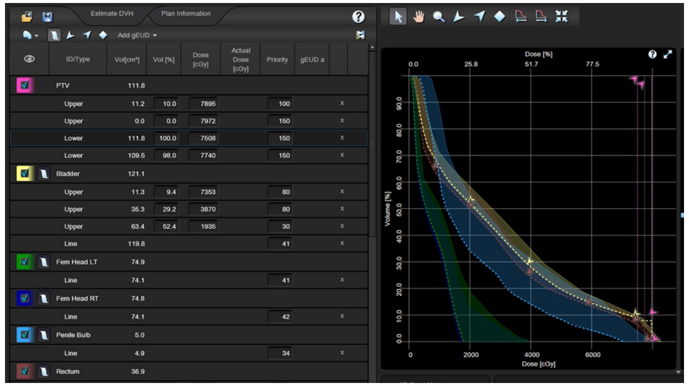
- Patient-specific (data-driven) scoring methods
  - Predicts dose value that depends on the unique features of each patient

Patient-specific scoring methods

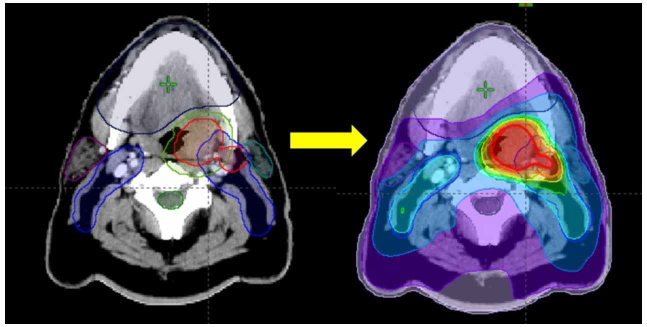
- First principle (FP) technique
  - Calculates the ***dose gradients*** around the target volume based on individual patient anatomy and dosimetry



- Knowledge-based DVH prediction
  - Calculates ***achievable DVH metric*** based on patient anatomy and past planning experience



- Deep learning 3D dose prediction
  - Calculates ***optimal 3D dose distribution*** based on patient anatomy and past planning experience



Population-based scoring

Treat Prep Check Template

Report Template

Standard

Course

0 Ethos test

Plan

PrstSBRT_VMAT

Dose

PrstSBRT_VMAT

725cGy x 5 = 3625cGy

Report

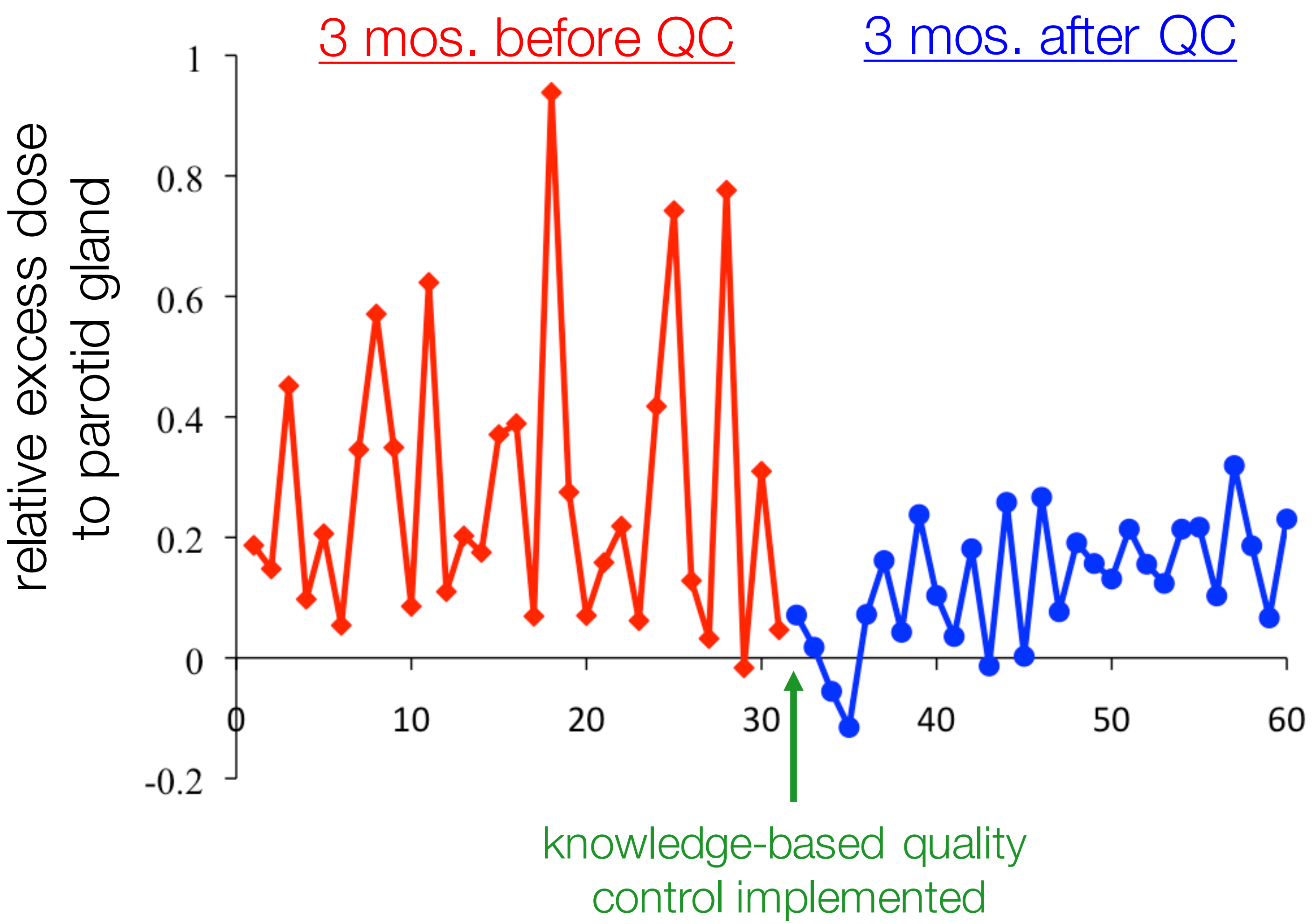
UCSD Prostate (SBRT 36.25/5) (GU) Constraints

Priority	Structure Template	Structure Plan	Type	Prescription	Constraint	Goal	PrstSBRT_VMAT	Pass/Fail	Verify OK	Comment
1	PTV_3625	PTV_3625	Target	Prostate: 3625cGy	V100% ≥ (Soft)	95-94%	95%	✓		
1	PTV_3625	PTV_3625	Target	Prostate: 3625cGy	V98% ≥ (Soft)	98%	98.173%	✓		
1	PTV_3625	PTV_3625	Target		Max ≤	4300cGy	3918.3cGy	✓		
1	PTV_3625	PTV_3625	Target	Prostate: 3625cGy	Hot Spot Within	108.091%	108.091%	✓		
2	Rectum	Rectum	OAR		Max	cGy	3782.4cGy			
2	Rectum	Rectum	OAR		D0.03cc ≤	4000cGy	3735.5cGy	✓		
2	Rectum	Rectum	OAR		D1cc ≤	3600cGy	3606.5cGy	✓	☑	(Verified by Kevin Moore 3/11/2022 1:52:32 PM)
2	Rectum	Rectum	OAR		D3cc ≤	3400cGy	3395.8cGy	✓		
2	Rectum	Rectum	OAR		D10% ≤	3300cGy	2732.6cGy	✓		
2	Rectum	Rectum	OAR		D20% ≤	2900cGy	1916.8cGy	✓		
2	Rectum	Rectum	OAR		D50% ≤	1800cGy	997cGy	✓		
2	Bladder	Bladder	OAR		Max	cGy	3918.3cGy			
2	Bladder	Bladder	OAR		D0.03cc ≤	3900cGy	3852.4cGy	✓		
2	Bladder	Bladder	OAR		D10cc ≤	3600cGy	2711.6cGy	✓		
2	Bladder	Bladder	OAR		D10% ≤	1800cGy	1740.4cGy	✓		
2	PenileBulb	PenileBulb	OAR		Max	cGy	2546.4cGy			

Rectum did not meet the institutional guideline → ACCEPTABLE PLAN

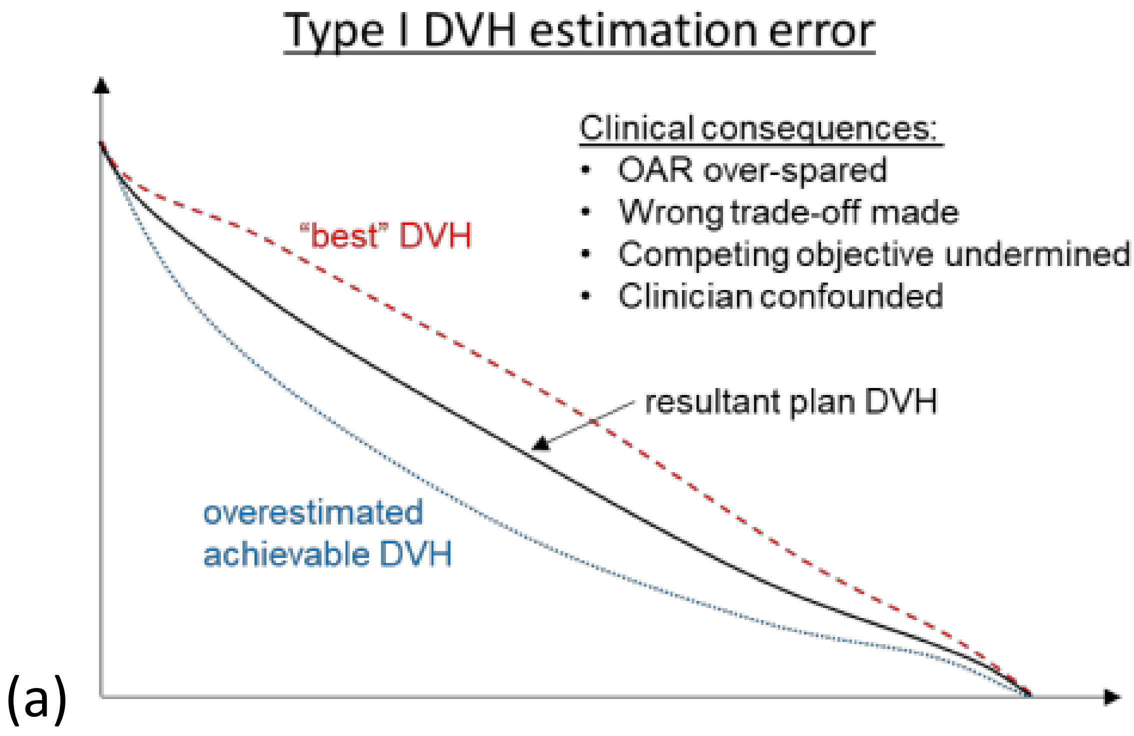
Patient-specific scoring

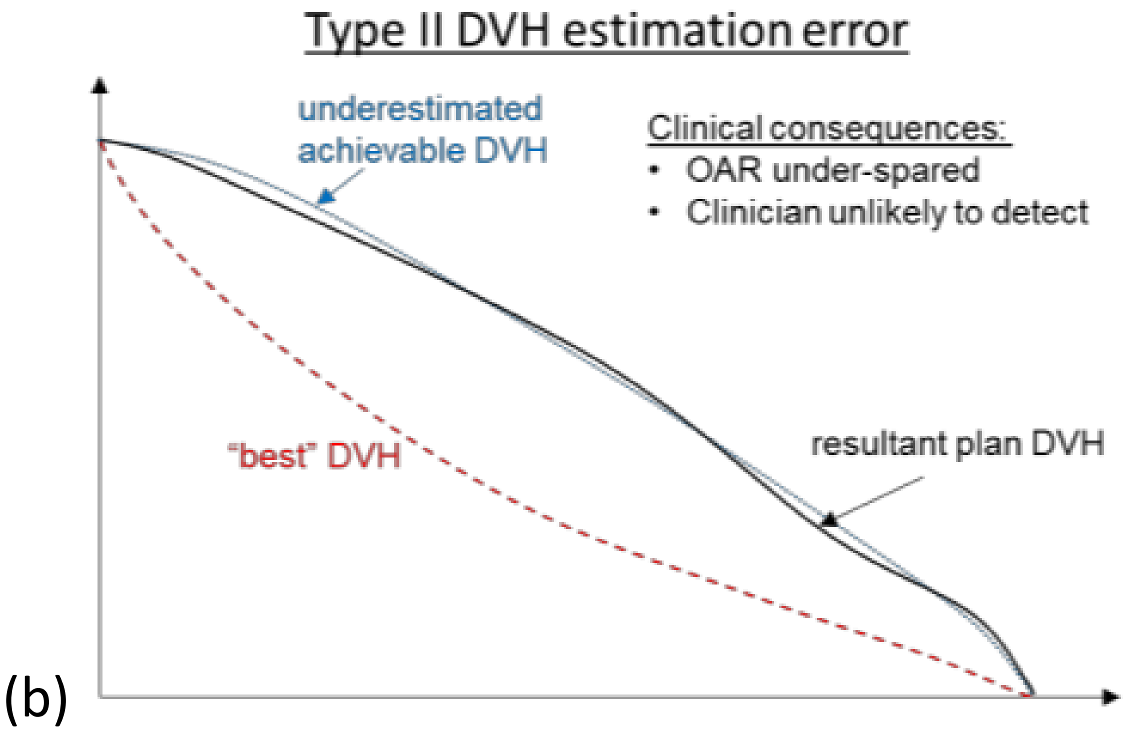
Clinical effect of data-driven plan QC



Moore *et al*, IJROBP **81**, 545-551 (2010)

Safety profile of data-driven plan quality check





Easy to Detect

Not Easy to Detect

*Slide Courtesy of Kevin Moore, Ph.D.

Clinical implementation of data-driven quality control and automated treatment planning

AAPM Task Group No. 308 https://www.aapm.org/org/structure/?committee_code=TG308

Building a Model

- Case selection
- Data curation and labeling
- Model training
- Model Evaluation

Utilizing model trained in other institutions

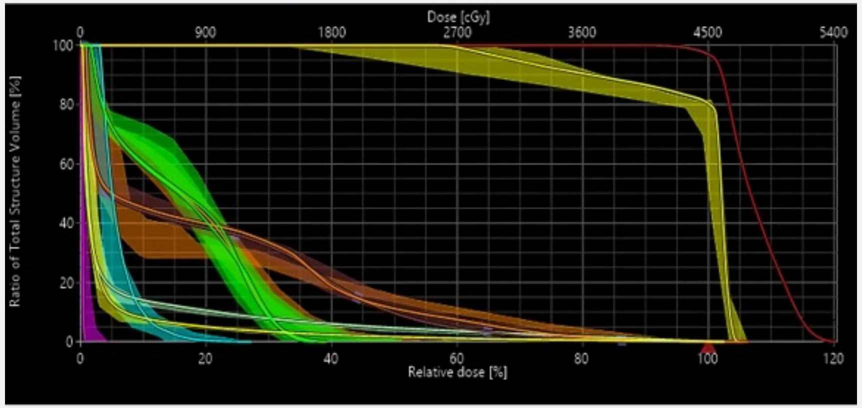
- ORBIT-RT
- Understanding the case characteristics
  - Contour
  - Dose/fx
  - Training set plan quality

Model Validation

- Independent from the patient used for model training
- Represent the range of patient geometries, plan geometries, and plan prescriptions for which the model will be clinically used
- Run the model prediction and evaluate the quality of plans generated

Clinical Use of Model

- Develop guideline for clinical use
- Range of clinical cases
- Standardization protocol
  - Contour
  - Beam arrangement
  - Plan evaluation metrics



Utilizing Automation for Plan Quality Check

– Examples of Scriptable Checks

- Automating review of technical and clinical aspects upstream can improve plan quality
- Planners run checker before physics plan quality review

Technical Aspects	Auto check
Beam Configuration Number of Arcs/Beam Arc/Beam Angle Selection Collimator/Jaw Selection	 → Check # arc/fields → Check clearance → No zero collimator angle, Jaw-tracking turned on
Optimization Objective Priorities	*Not trivial*
Plan Modulation	→ Check Total MU/FX dose
Treatment Devices	→ Check correct couch is inserted
Density Overrides	→ Check bolus & metal override
Clinical Aspects	**Auto check**
Images	→ Check sim date/scan protocol
Registrations	*Not trivial*
Contours	→ Check missing critical OARs, interpolation, stray pixel
Isodose	→ Check hot spot outside targets
DVHs, Dose Gradients, Plan Sum Evaluation	→Score card, data-driven tool

Example of Checker for Planners to Run Before MD Review

- Checks 27 high priority technical & clinical aspects that can lead to replan
- EzPreCheck: Catching planning deficiency in early planning phase

EzPrecheck

Patient MRN: PELVIC_PHAN (Course ID: 1 Plan ID: JawTracking) **DateTime: 2/13/2020, 3:57:54 PM** ? Yang K. Park

Precheck Result

Result	Action	Title	Value	Message	Comment	Approval
☹	OK	Proper Couch Inserted	ACK Required	No couch found. Is it a HN case?		
☹	OK	Jaw Tracking		Jaw Tracking is OFF		
☹	OK	CTISO Check		No CTISO or SBRTISO reference point found.		
☹	OK	Energy	arc1: 6X arc2: 6X arc3: 6X arc4: 6X arc5: 6X	The average water equivalent length >= 15 cm and low energy (6X) was used		

*Slide Courtesy of Mu-Han Lin, Ph.D. and Yang Kyun Park, Ph.D.

Resources of Automatic Checkers

- Commercialized products
  - API script-based and standalone checkers
- Institution developed checkers

Eclipse

EclipsePlanCheck

UT Southwestern Medical Center CACCI

UAB

Memorial Sloan Kettering Cancer Center

RayStation

UW Medicine Plan Check Tool

University of North Carolina Chapel Hill

School of Medicine and Public Health
UNIVERSITY OF WISCONSIN–MADISON

- Scripting workshops hosted by vendor
- Online resources
  - GitHub
  - Webinars

Conclusion

- Physics review of technical and clinical aspects that impact plan quality upstream can improve plan quality

- Physicists are encouraged to increase exposure to planning and exercise planning skills to aid plan quality checks

- Automation can improve the plan quality and efficiency

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