ICRO Teaching Course 2014: Shimla

Apollo Hospitals GROUP
touching lives

Plan Evaluation

Dr. Kausik Bhattacharya
Senior Consultant, Radiation Oncology
Apollo Cancer Institute
Hyderabad

- YROC
- Dates: Jan 2015
- Venue: Bhubaneswar
- Contact: Dr. Sanjib Mishra

Apollo Cancer Conclave
Dates: Feb 2015
Venue: Hyderabad
Contact: Vijay Anand

- Learning objective
  - Ability to compare salient data points and clinical issues in 2D, 3D & IMRT Plans
  - Choose from multiple plans to suit clinical objective

Conflict of interests & disclosures: Travel grant received

Acknowledgement: Depts of Radiation Oncology & Medical Physics.

Apollo Cancer Institute, Hyderabad

Planning Workflow

- Immobilization
- Image acquisition and registration

• Contouring • Constraints	Physician's Responsibility
• Planning	
• Plan evaluation	

- Plan implementation

Planning Workflow

- Immobilization
- Image acquisition and registration
- Contouring
- Constraints
- Planning
- **Plan evaluation**
- Plan implementation

To choose the best among multiple plans:

- Target coverage
- OAR sparing
- Hotspot/Coldspot
- DVH analysis
- Isodose coverage
- Indices (CI & HI)
- Clinical relevance

Objective Assessment

- Dose Volume Histogram
  - Cumulative
  - Differential
- Defined Volumes
  - GTV: Gross Tumor Volume
  - CTV: Clinical Target Volume
  - ITV: Internal Target Volume
  - PTV: Planning Target Volume
  - ❖ OAR: Organs @ Risk
  - ❖ PRV: Planning Vol @ Risk
  - ❖ RVR: Residual Vol @ Risk

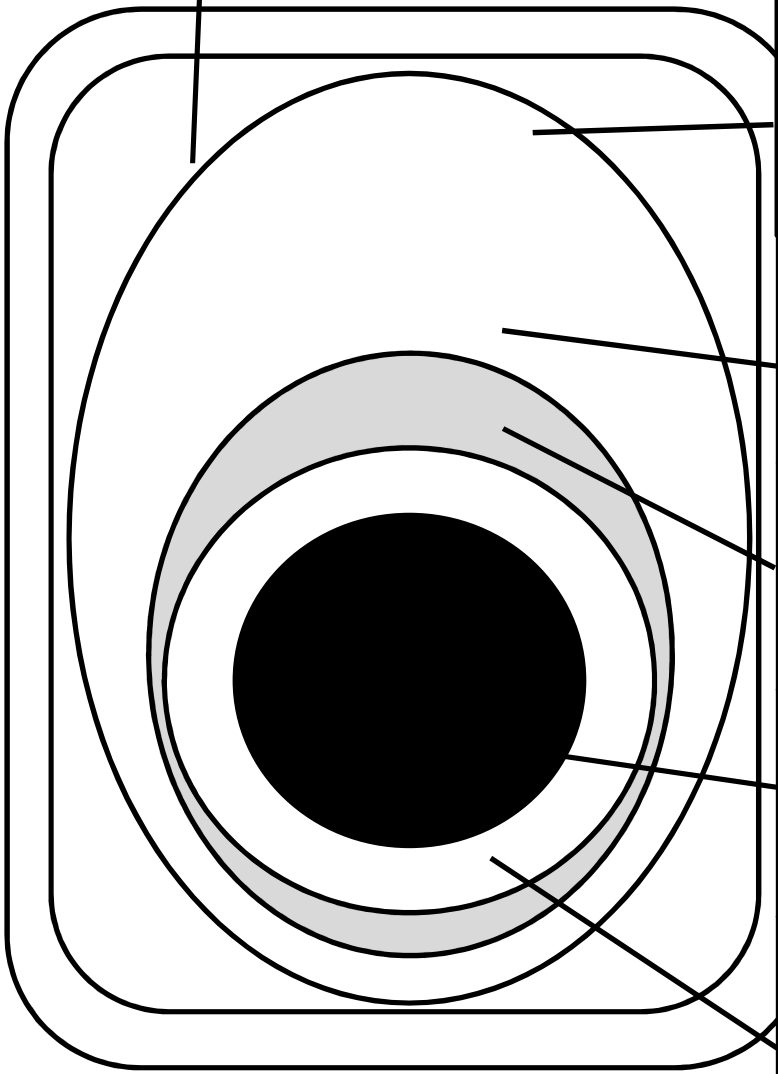
Discretionary/ Evolving

- Assessment of isodose every slice coverage for clinical relevance
- Multimodality Images
- Biological Volumes
- Effect of variation in dose levels
- TCP/ NTCP

International Commission on Radiation Units & Measurements (ICRU)

ICRU Definitions

RVR: Residual Vol @ Risk
Body contour – (CTV + OAR)



TV: Volume apart from PTV receiving clinically significant dose

PTV: Set up errors & organ motion

ITV: Uncertainities of shape, size and position

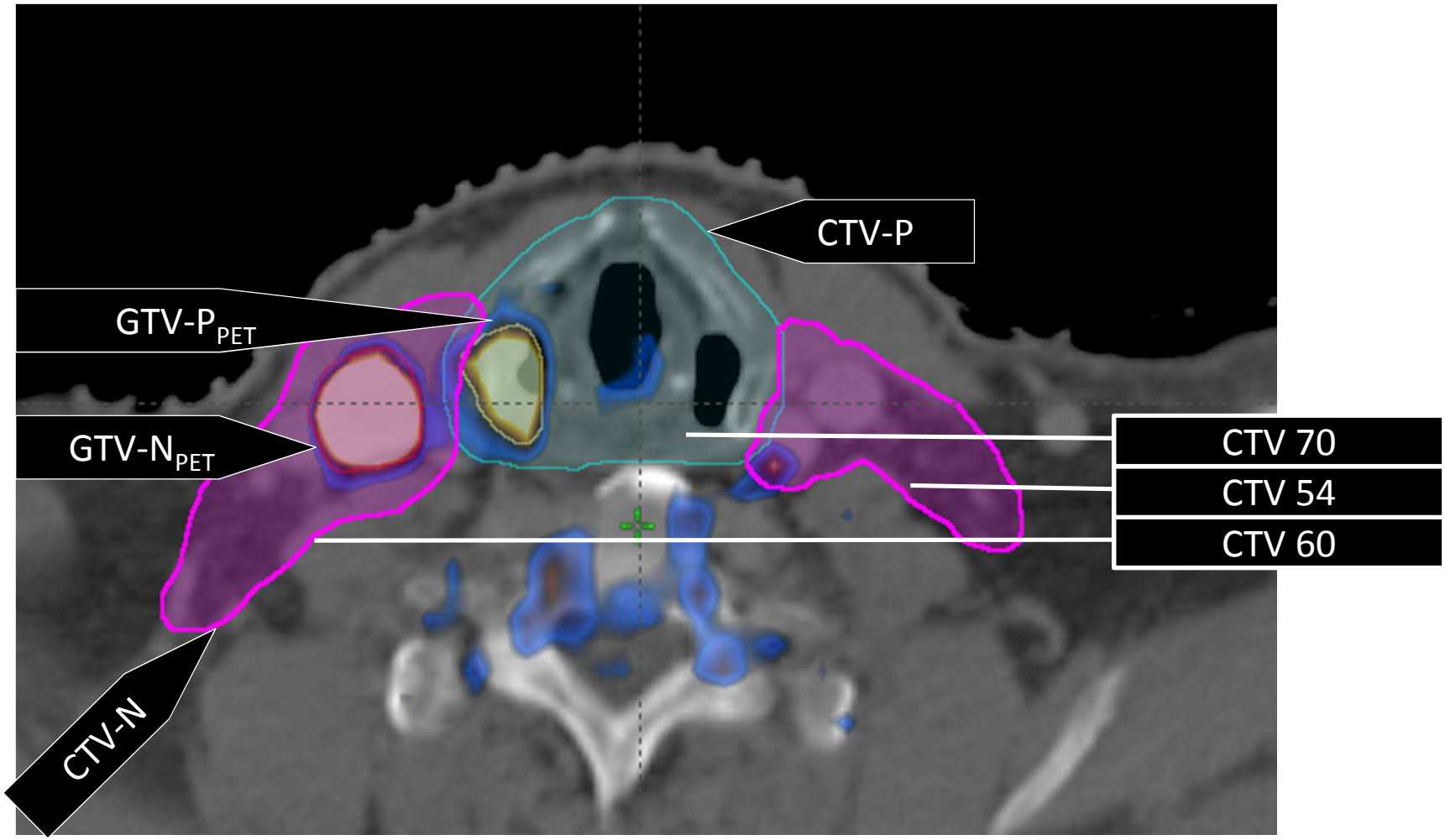
GTV: Clinically or radiologically assessed tumor (GTV-P / GTV-N)

CTV: Subclinical Extension (CTV-P / CTV-N)

Organ@ Risk (OAR)
Serial: Sp Cord
Parallel: Parotid

PRV:Planning Organ @ Risk Volume
OAR + Set up Margin

Types of CTV/PTV

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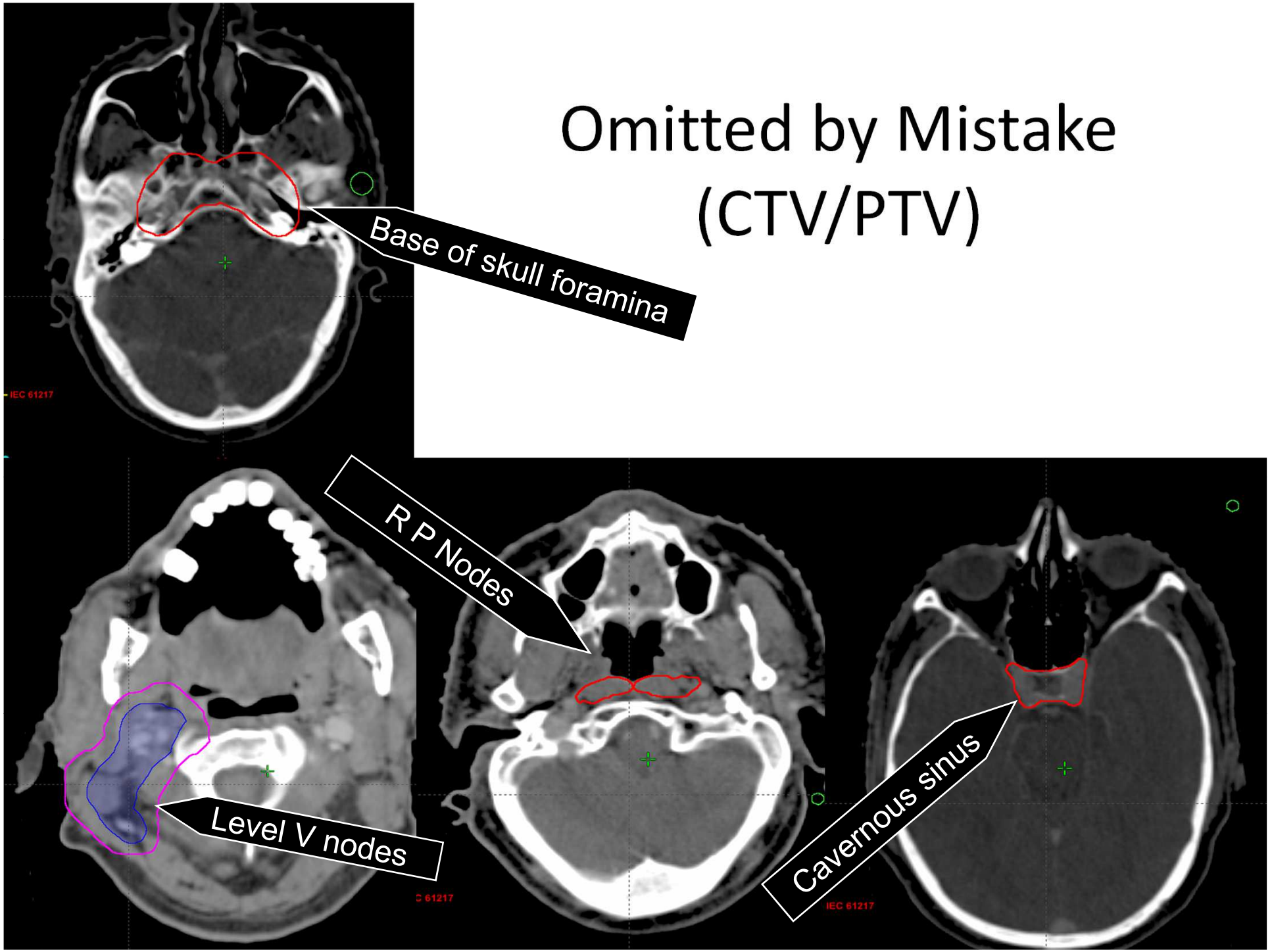
INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS

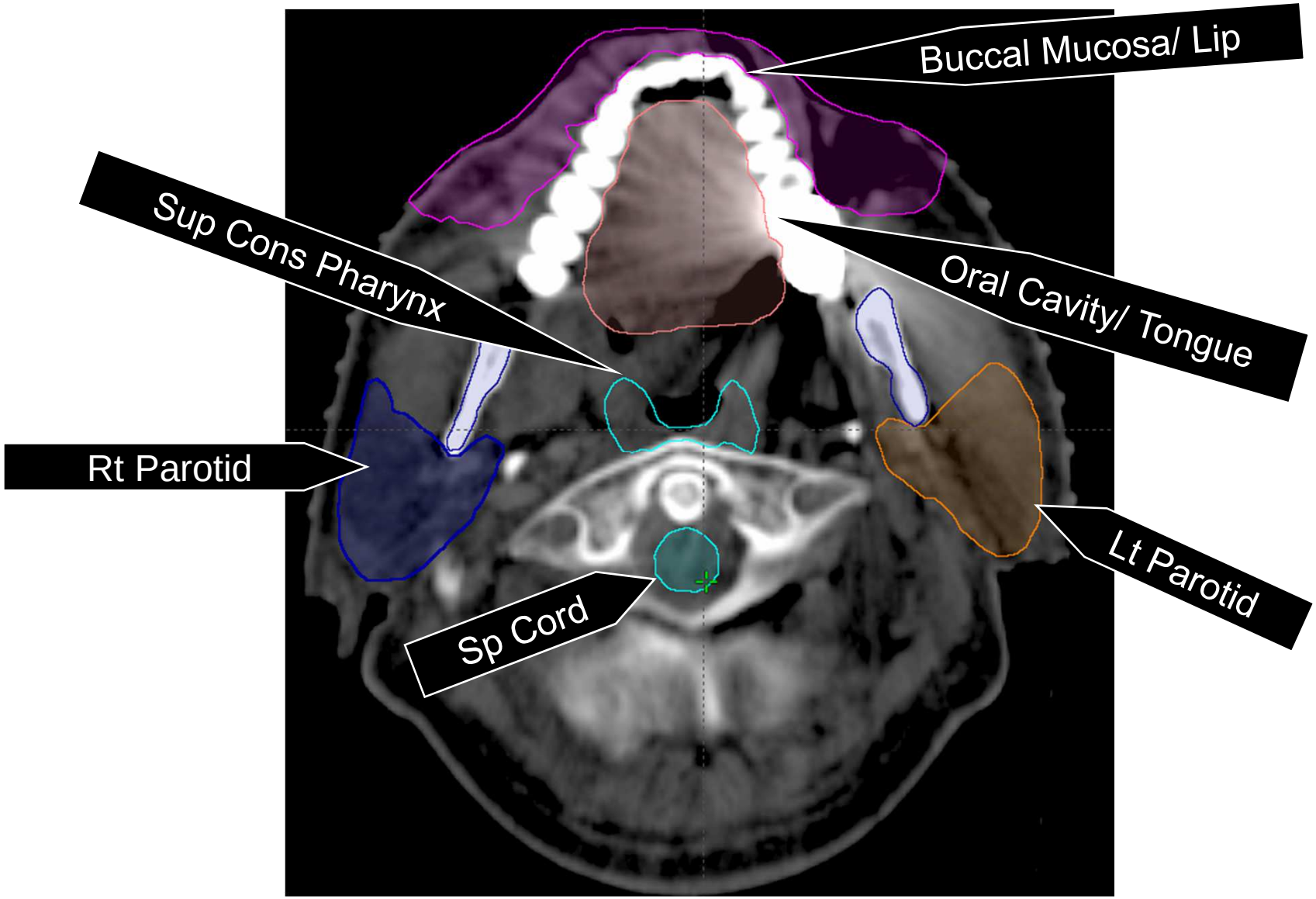
ICRU through ages

ICRU 29 (1974)	ICRU 50 (1993)	ICRU 62 (1999)	ICRU 83 (2010)
Target Volume	GTV	GTV	GTV
	CTV	CTV	CTV
		ITV	ITV
	PTV	PTV	PTV
Treatment volume	Treated volume	Treated volume	Treated volume
Irradiated volume	Irradiated volume	Irradiated volume	Irradiated volume
Organ at Risk	Organ at risk	Organ at risk	Organ at risk
		PRV	PRV
			RVR
Hotspot (more than 100% - 2 sq cm)	Hotspot (more than 100% - 15 mm dia)	Hotspot (more than 100% - 15 mm dia)	High dose to RVR
Dose heterogenity (no values)	Dose heterogenity (+7 to -5 %)	Dose heterogenity (+7 to -5 %)	Not specified

Omitted by Mistake (CTV/PTV)



Organs at Risk (OAR)



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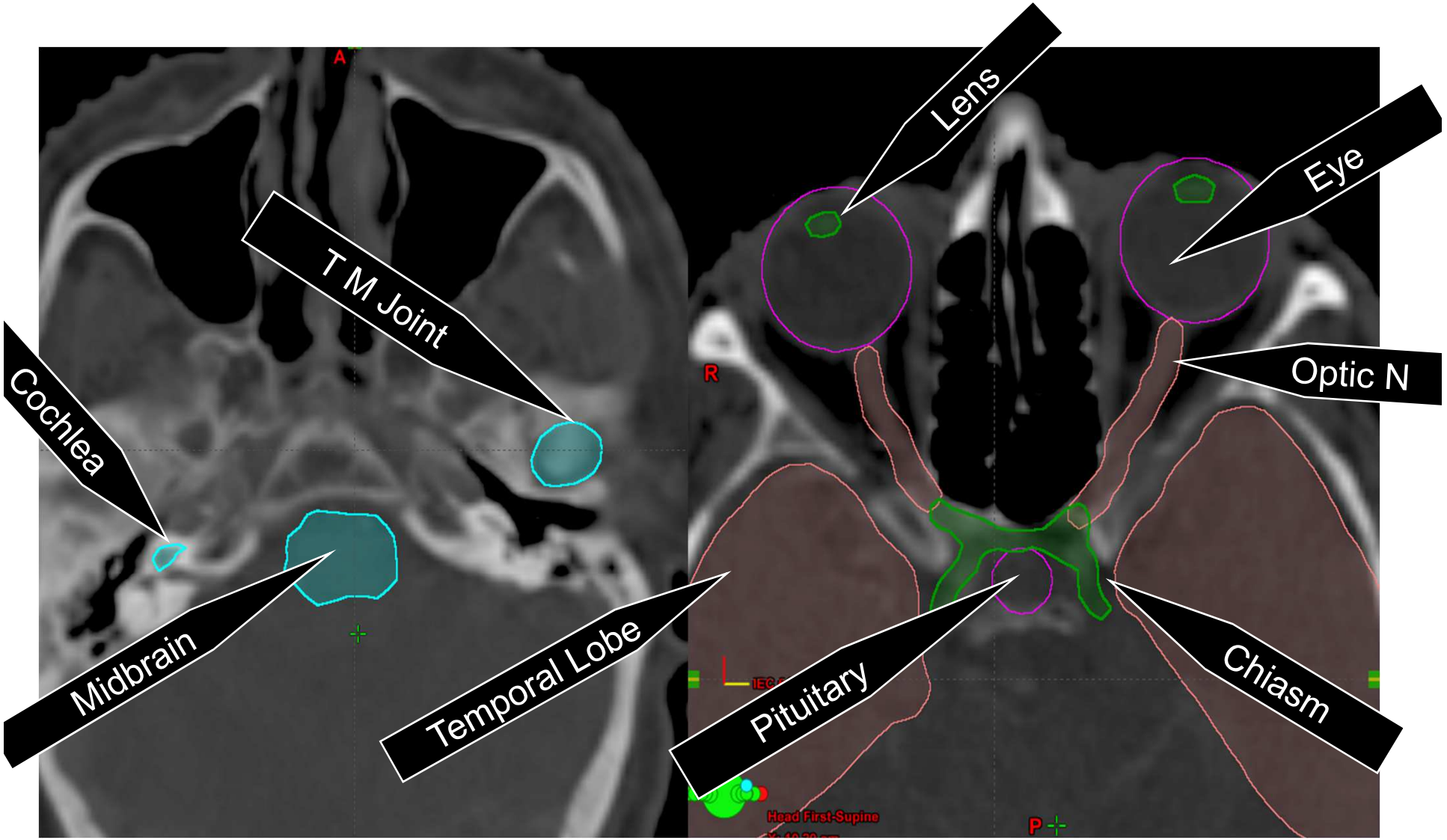


Dose Evaluation

3D & IMRT

ICRU Concepts at Work

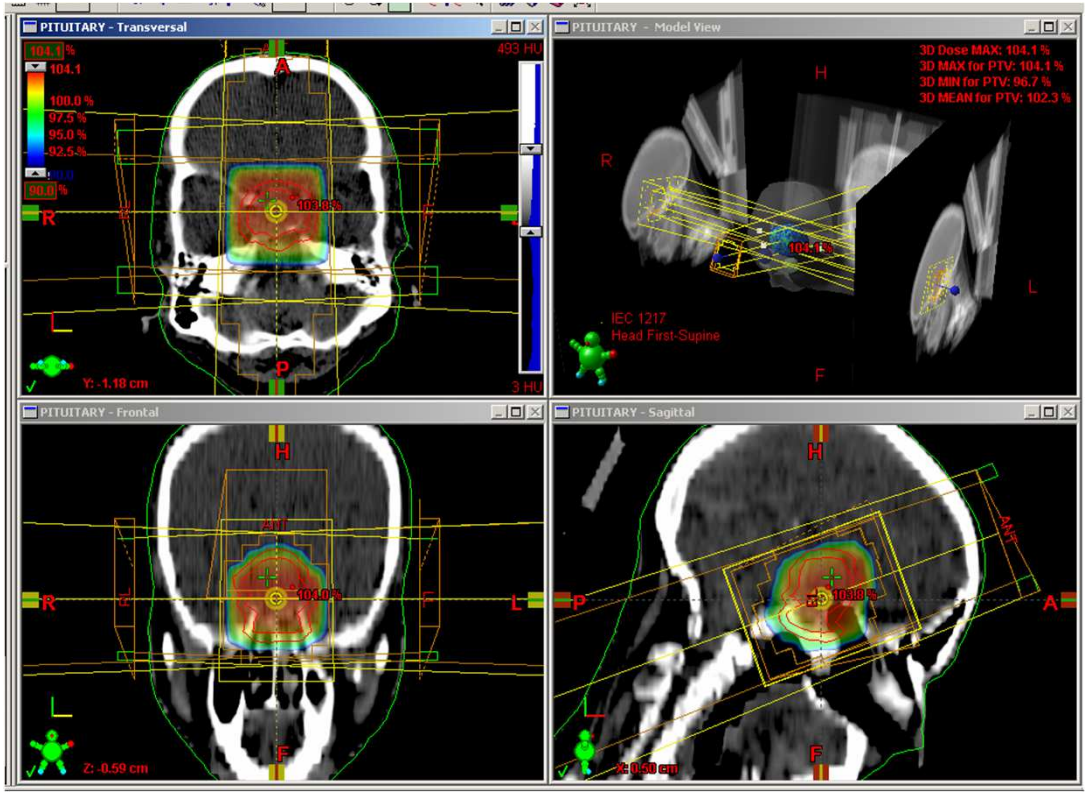
Dose Reporting in 3D (ICRU 50)

- Dose must be reported to the ICRU reference point
  - ICRU reference point is usually isocenter
  - It could be a point in the center of the PTV
  - Uniform dose to PTV (-5 to +7%)

  Maximum & minimum dose must be reported in PTV

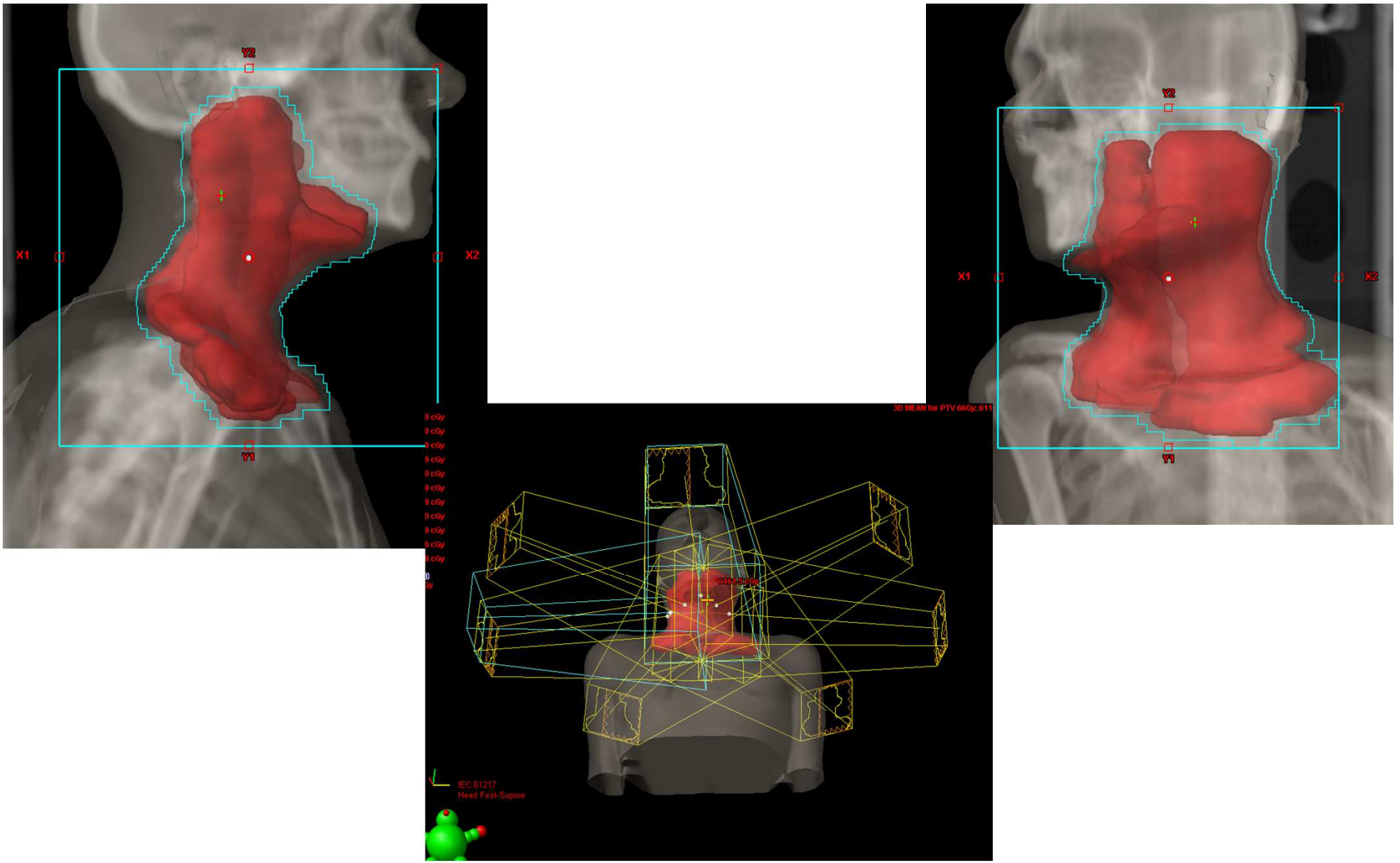
  Whenever possible dose should be reported to PRV

3D Plan Verification



- Visualisation in Axial, Coronal & Saggital
- Coverage of PTV
- Sparing of OAR
- 95% dose to Cover
- No cold spots

Room View & Beam's Eye View



Paradigm Shift with IMRT

IMRT represents a paradigm shift

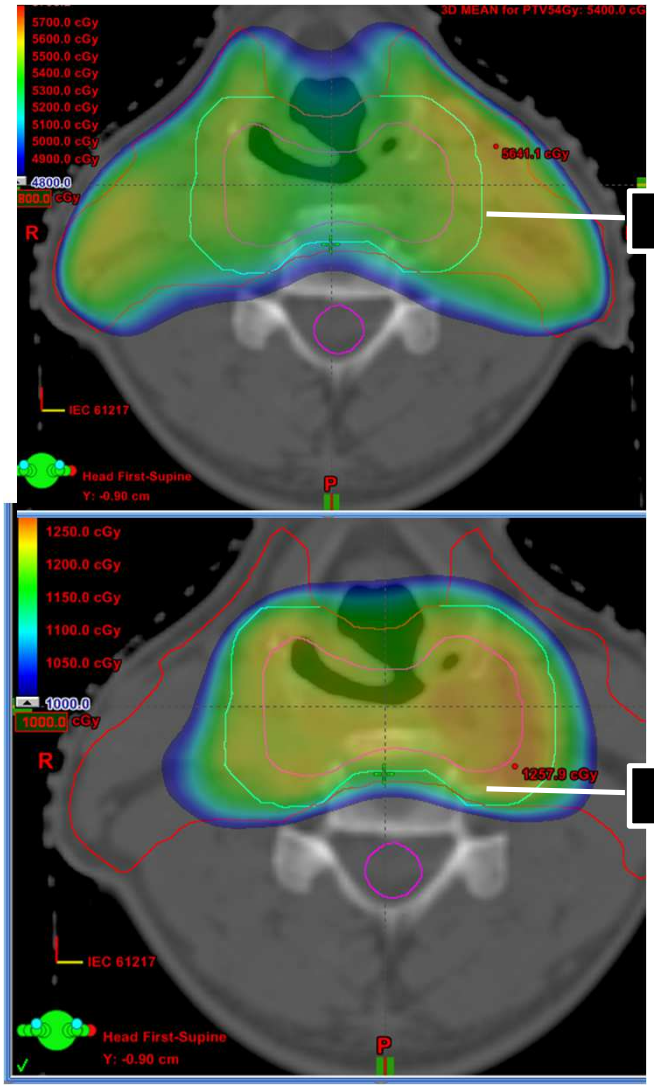
Non uniform dose (dose painting)

Large dosimetric variations

Isocenter dose is meaningless

Radiobiological consequence of large heterogeneous dose is uncertain (i.e 180c Gy/day versus 250c Gy/day)

IMRT: Sequential

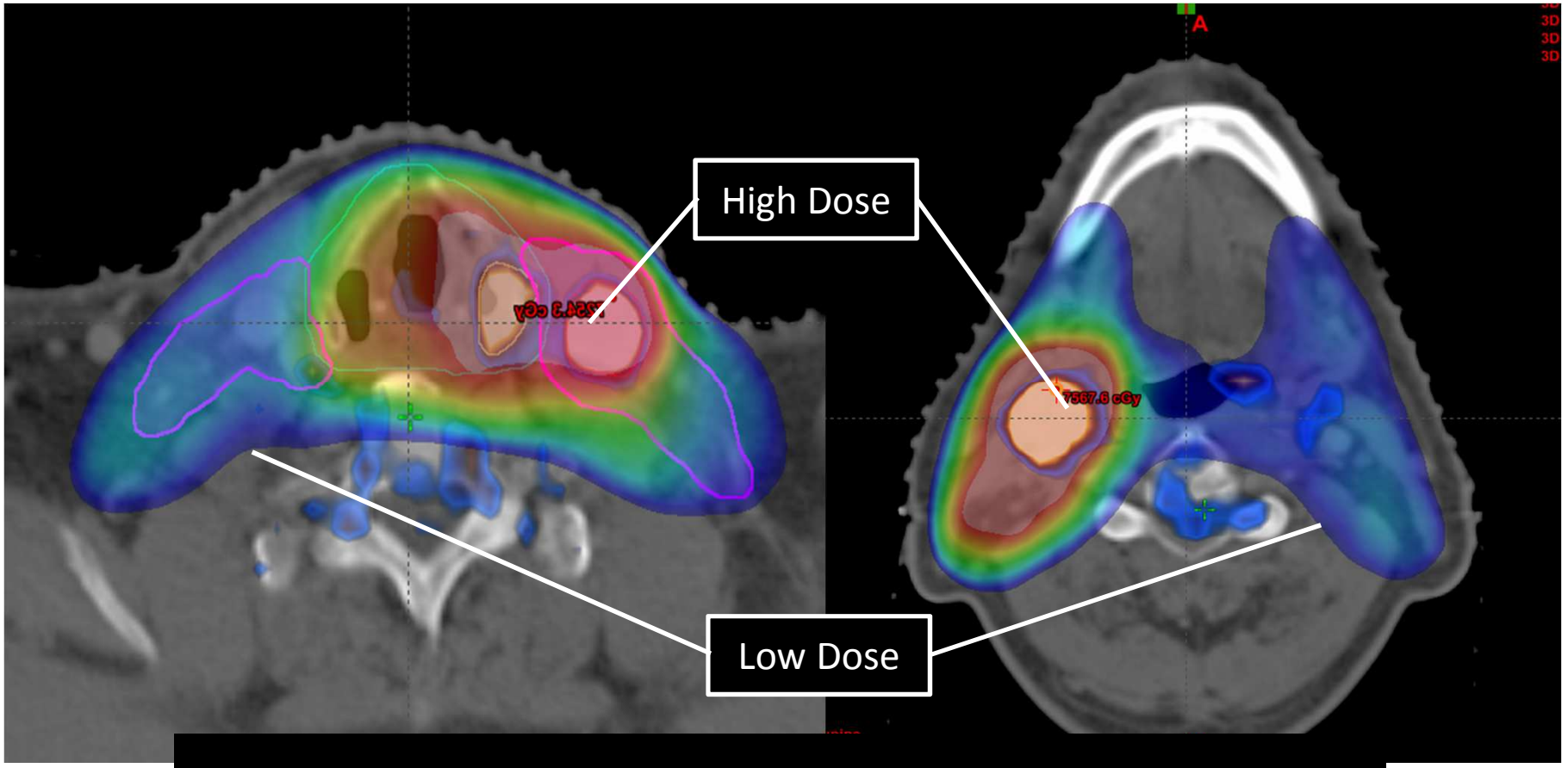


Phase I: Low Dose: Nodal+ Primary

Summation of Both Plans

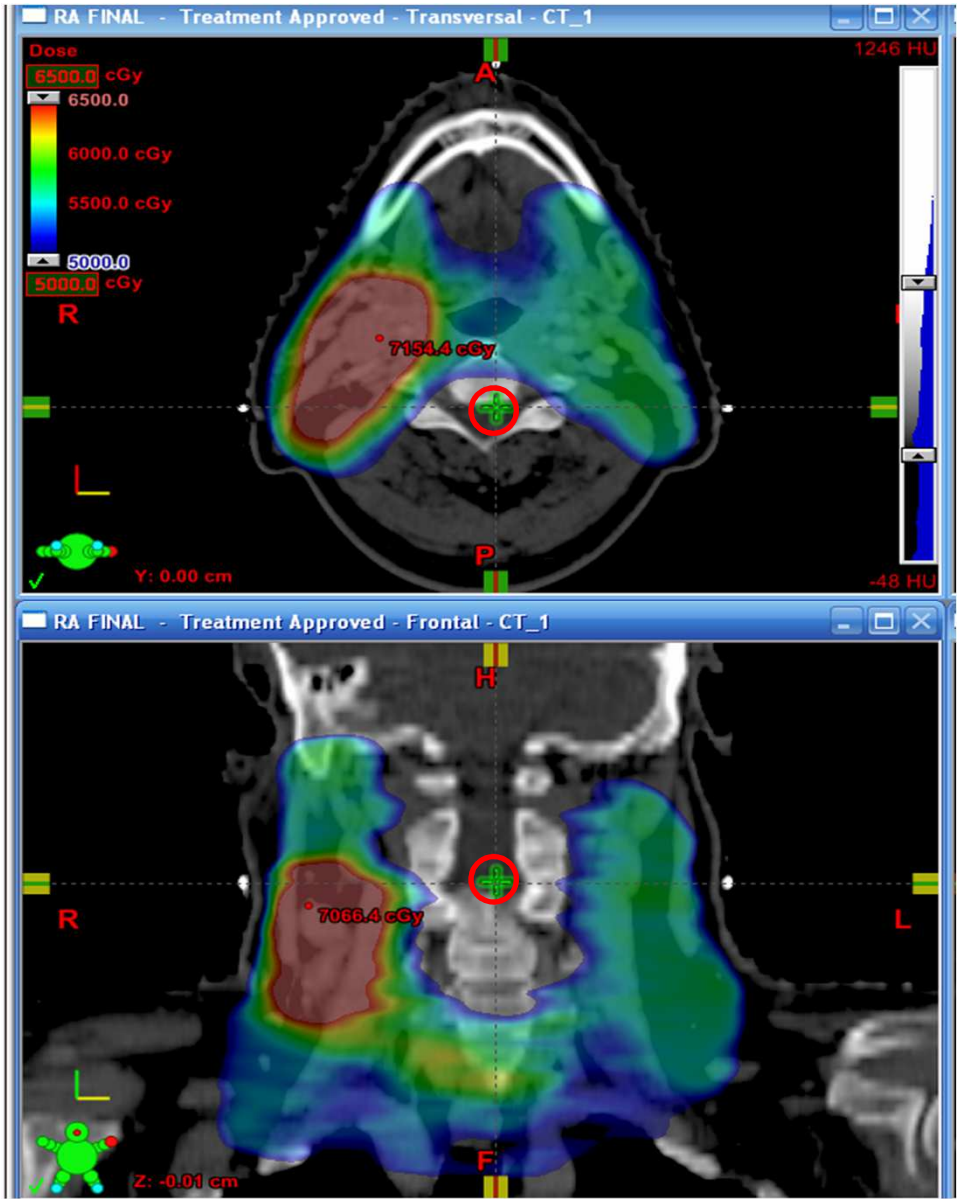
Phase II: HighDose: Primary / Boost

IMRT: Simultaneous Integrated Boost

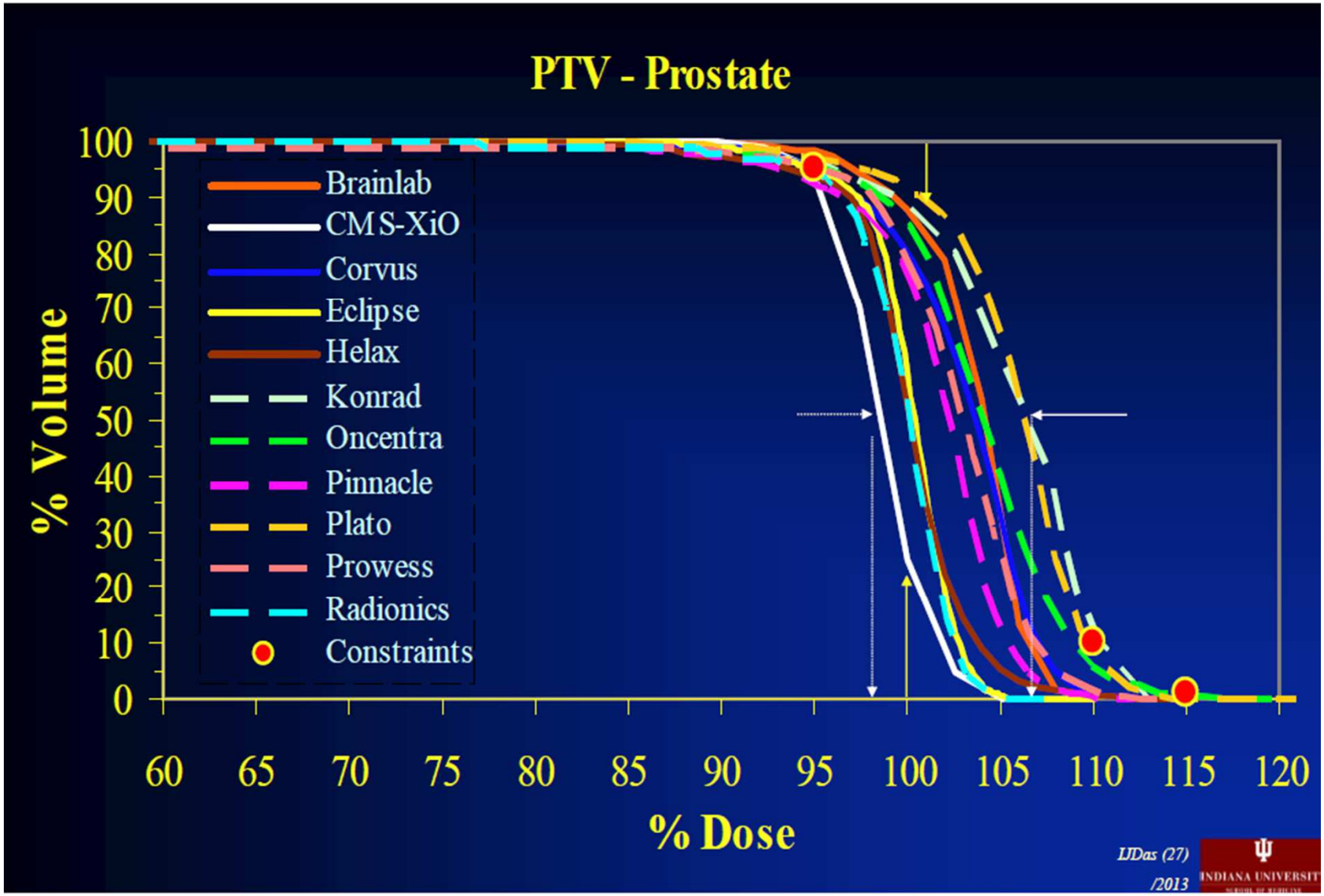


Both Low Dose & High Dose Volumes Treated Simultaneously

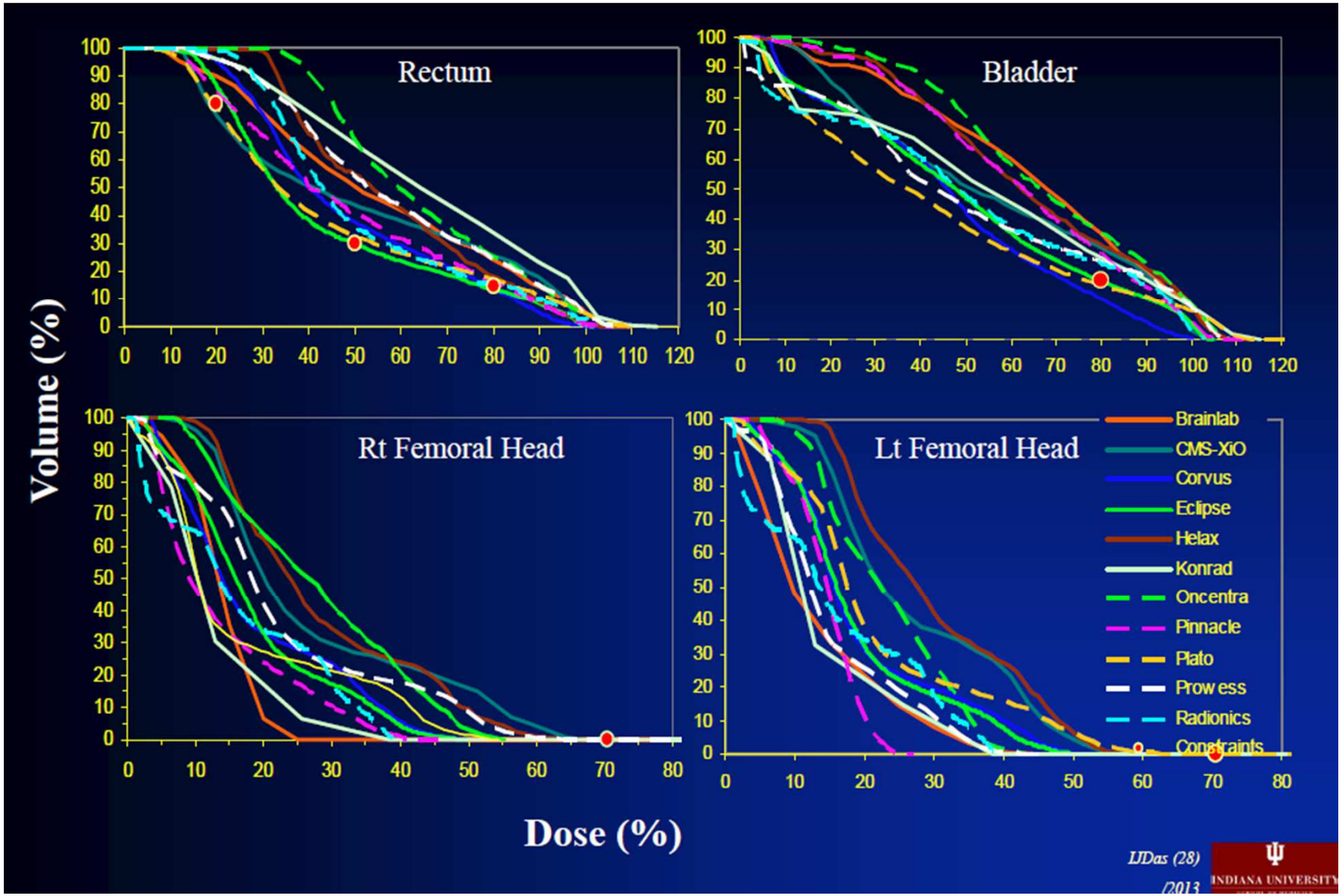
Isocenter dose is non-reprsentative



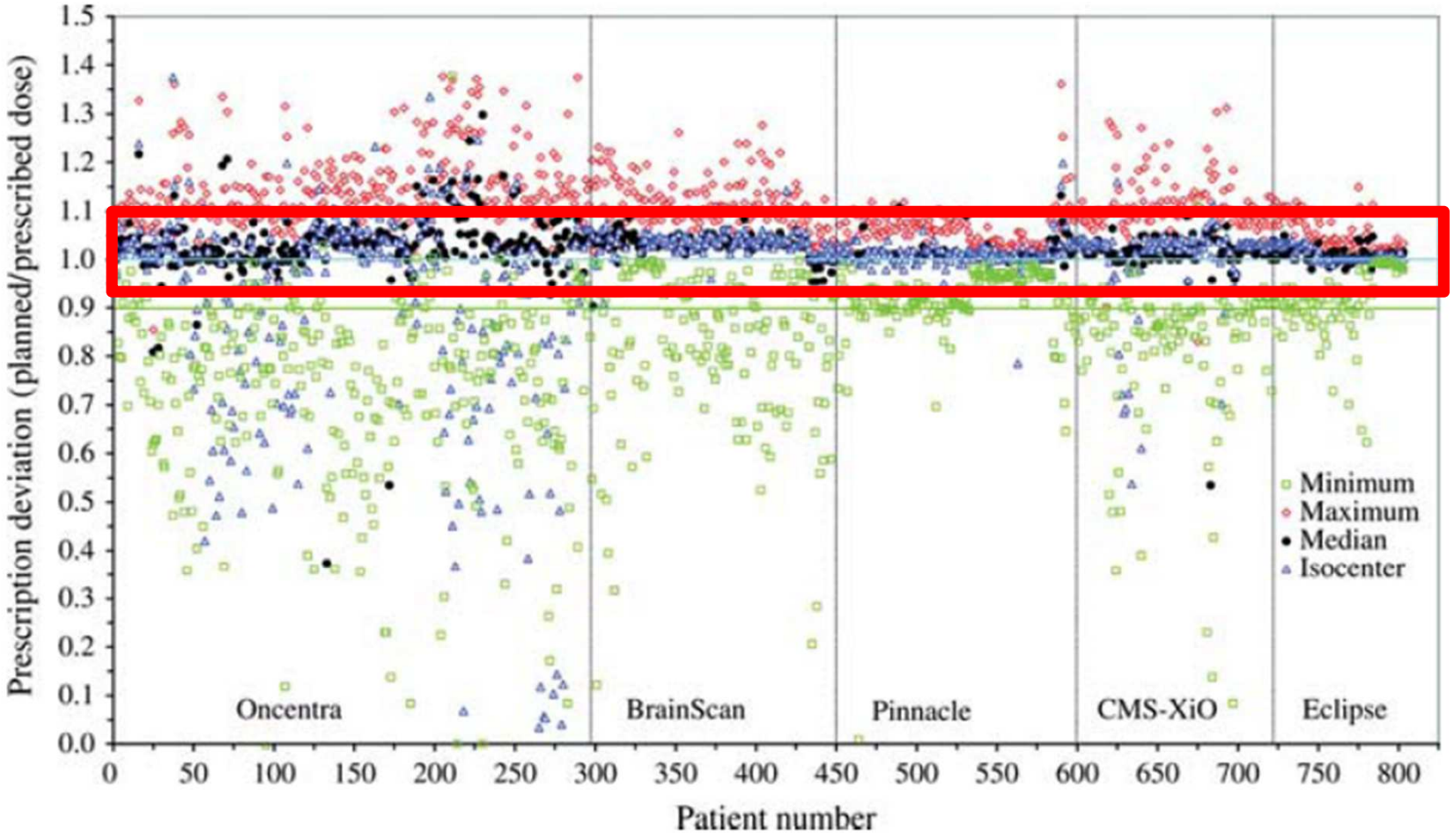
IMRT: Variability in PTV Dose



IMRT: Variability in OAR Dose



Variation of doses among 850 patients in 5 Institutions

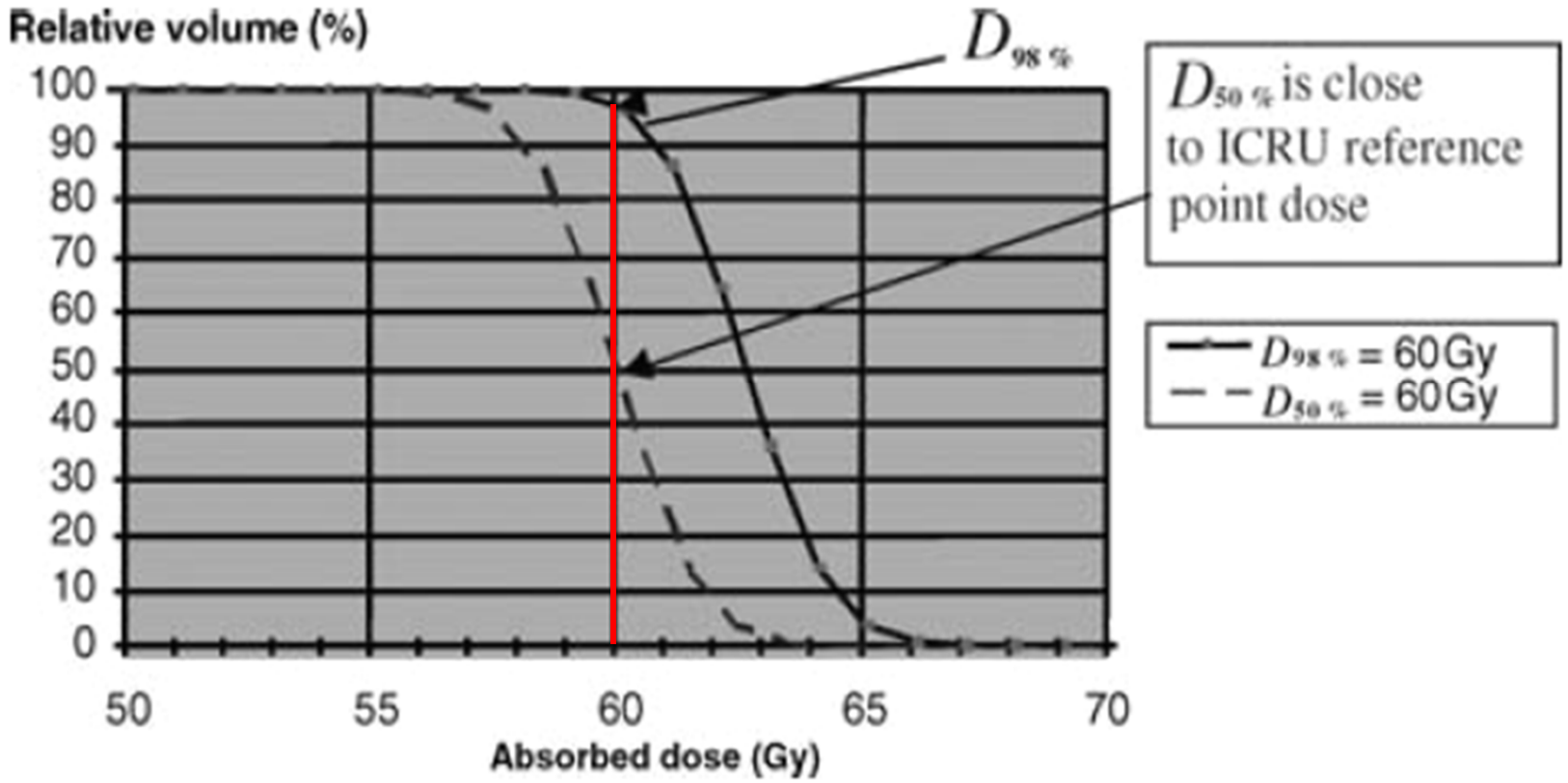


Median Dose is most consistent

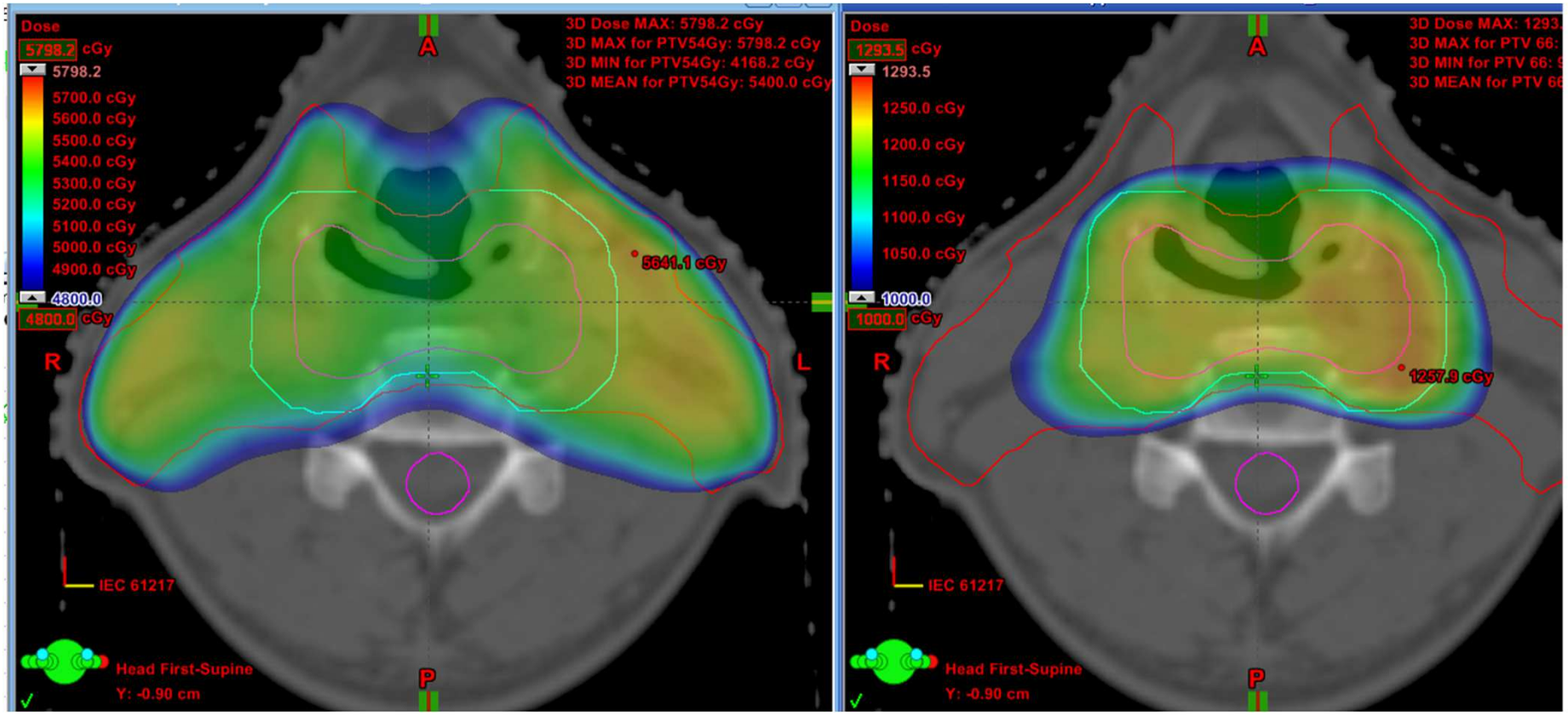
ICRU-83: PTV

- Dose Volume Reporting
  - $D_{50\%}$ (Median Dose)
    - Most representative of prescribed sose
  - $D_{\text{mean is nearly identical to }} D_{50\%}$
  - $D_{98\%}$ (Near Minimum Dose)
    - Dose received by 98% of PTV
  - $D_{2\%}$ (Near Maximum Dose)
    - Dose received by 2% of PTV

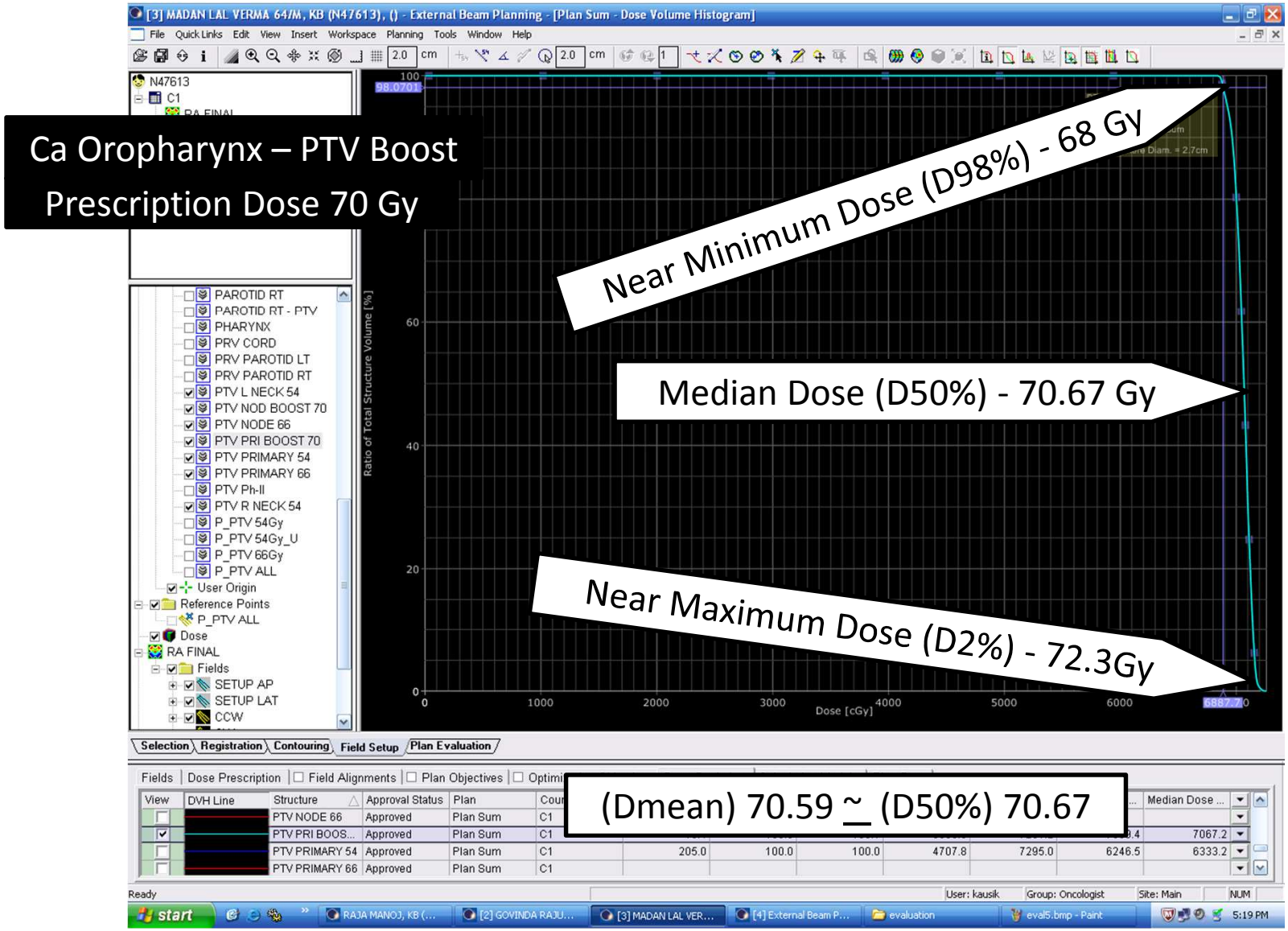
Comparison of ICRU reference point dose to $D_{98\%}$



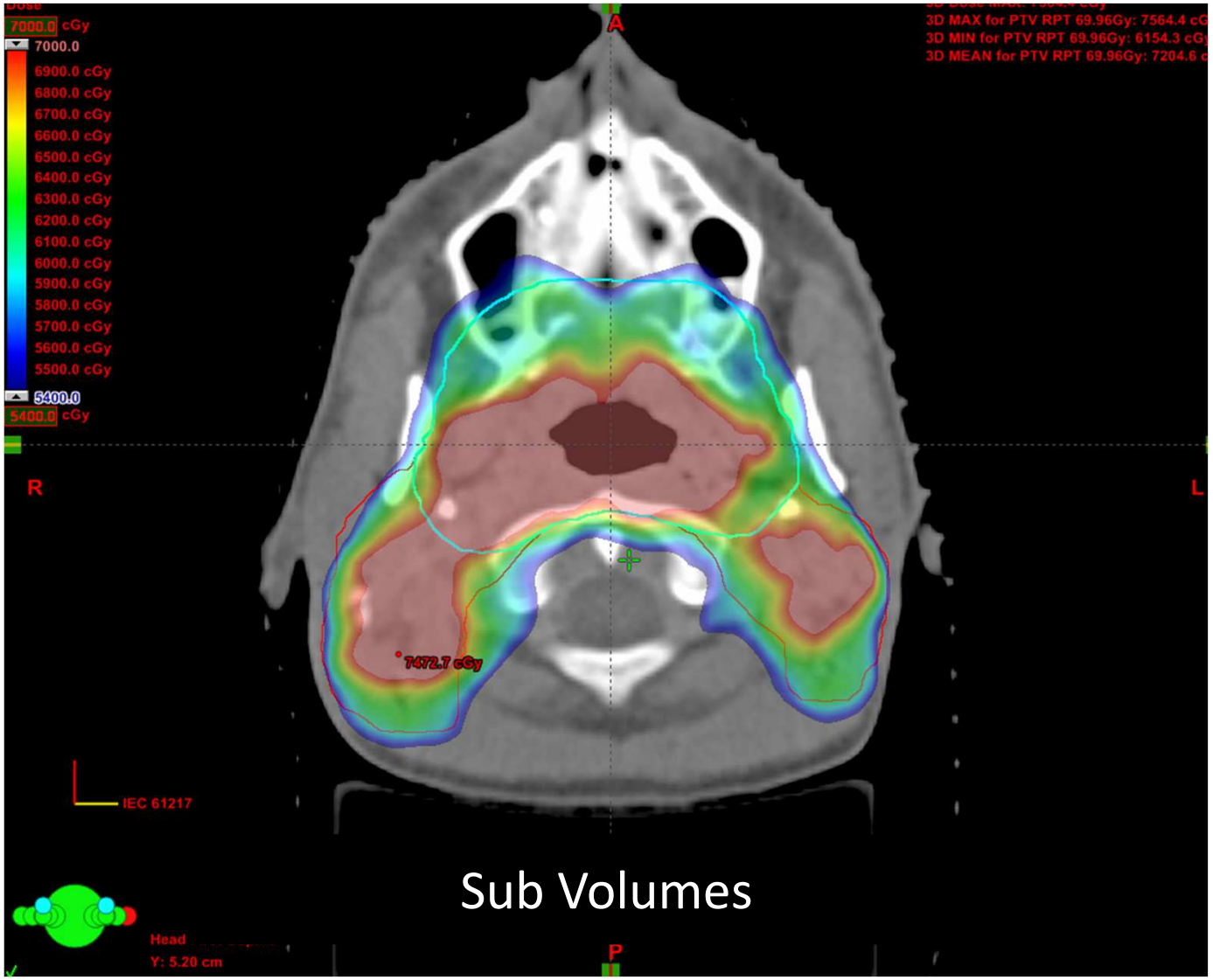
Application of ICRU 83 in Single Dose Level Plans



DVH of PTV


[3] MADAN LAL VERMA 64/M, KB (N47613), () - External Beam Planning - [Plan Sum - Dose Volume Histogram]
Ca Oropharynx – PTV Boost
Prescription Dose 70 Gy
Near Minimum Dose (D98%) - 68 Gy
Median Dose (D50%) - 70.67 Gy
Near Maximum Dose (D2%) - 72.3Gy
Ratio of Total Structure Volume [%]
Dose [cGy]
(Dmean) 70.59 ~ (D50%) 70.67

Nasopharynx with SIB
(60Gy & 70Gy in 33Fr)

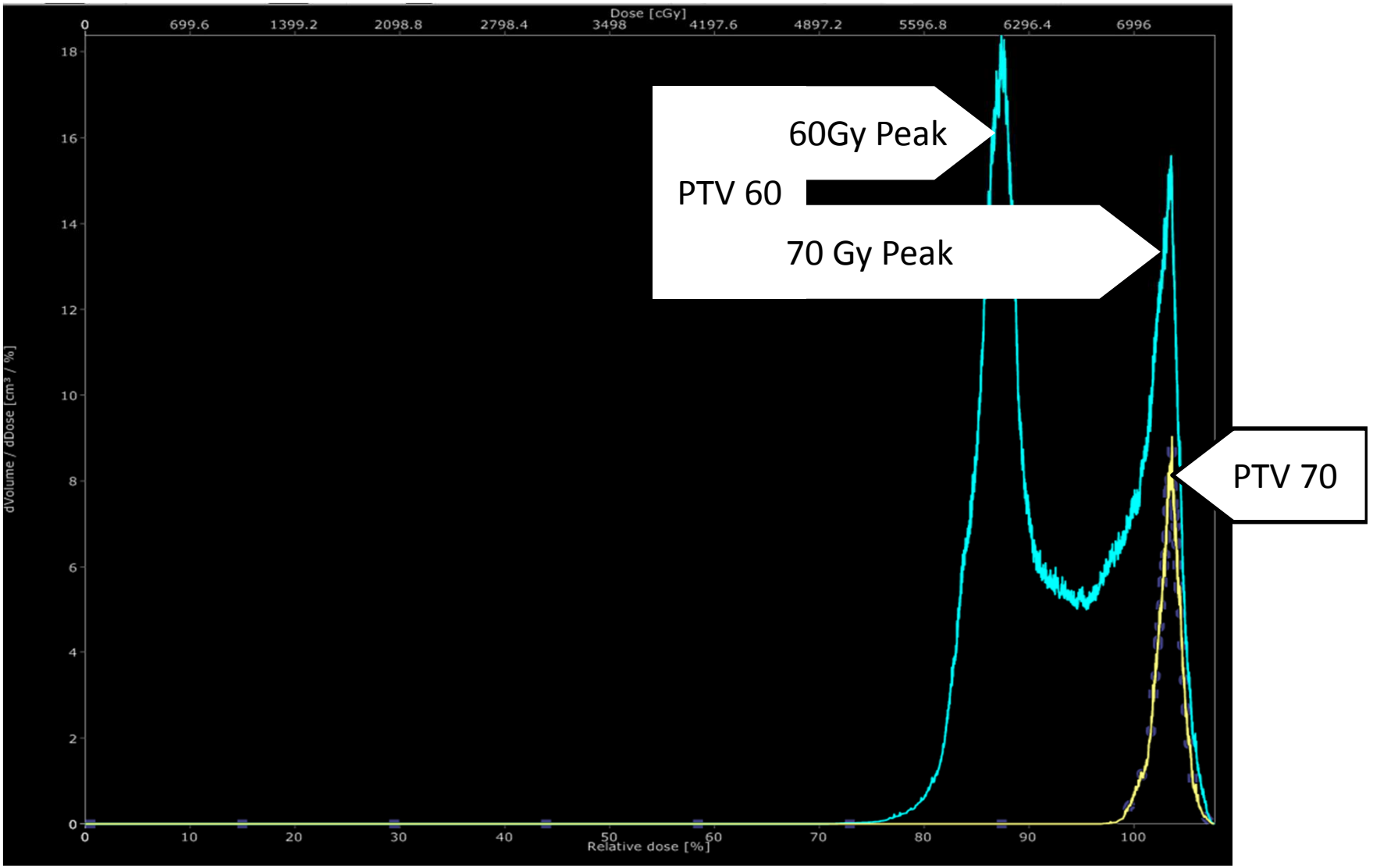


Sub Volumes

DVH of PTV


Dose [cGy]
0
699.6
1399.2
2098.8
2798.4
3498
4197.6
4897.2
5596.8
6296.4
6996
Ratio of Total Structure Volume [%]
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Relative dose [%]
PTV 70
PTV 60

Differential DVH



Organs at Risk: QUANTEC

Quantitative Analysis of Normal Tissue Tolerance in Clinic

Organ	Volume segmented	Irradiation type (partial organ unless otherwise stated)†	Endpoint	Dose (Gy), or dose/volume parameters†	Rate (%)	Notes on dose/volume parameters
Brain	Whole organ	3D-CRT	Symptomatic necrosis	Dmax <60	<3	Data at 72 and 90 Gy, extrapolated from BED models
	Whole organ	3D-CRT	Symptomatic necrosis	Dmax = 72	5	
	Whole organ	3D-CRT	Symptomatic necrosis	Dmax = 90	10	
	Whole organ	SRS (single fraction)	Symptomatic necrosis	V12 <5–10 cc	<20	Rapid rise when V12 > 5–10 cc
Brain stem	Whole organ	Whole organ	Permanent cranial neuropathy or necrosis	Dmax <54	<5	
	Whole organ	3D-CRT	Permanent cranial neuropathy or necrosis	D1–10 cc‖ ≤59	<5	
	Whole organ	3D-CRT	Permanent cranial neuropathy or necrosis	Dmax <64	<5	Point dose <<1 cc
	Whole organ	SRS (single fraction)	Permanent cranial neuropathy or necrosis	Dmax <12.5	<5	For patients with acoustic tumors
Optic nerve / chiasm	Whole organ	3D-CRT	Optic neuropathy	Dmax <55	<3	Given the small size, 3D CRT is often whole organ‡‡
	Whole organ	3D-CRT	Optic neuropathy	Dmax 55–60	3–7	
	Whole organ	3D-CRT	Optic neuropathy	Dmax >60	>7-20	
	Whole organ	SRS (single fraction)	Optic neuropathy	Dmax <12	<10	
Spinal cord	Partial organ	3D-CRT	Myelopathy	Dmax = 50	0.2	Including full cord cross-section
	Partial organ	3D-CRT	Myelopathy	Dmax = 60	6	
	Partial organ	3D-CRT	Myelopathy	Dmax = 69	50	
	Partial organ	SRS (single fraction)	Myelopathy	Dmax = 13	1	Partial cord cross-section irradiated
	Partial organ	SRS (hypofraction)	Myelopathy	Dmax = 20	1	3 fractions, partial cord cross-section irradiated

Organ	Volume segmented	Irradiation type (partial organ unless otherwise stated)†	Endpoint	Dose (Gy), or dose/volume parameters†	Rate (%)	Notes on dose/volume parameters
	Bilateral whole parotid glands	3D-CRT	Long term parotid salivary function reduced to <25% of pre-RT level	Mean dose <39	<50	For combined parotid glands (per Fig. 3 in paper) ¶
Pharynx	Pharyngeal constrictors	Whole organ	Symptomatic dysphagia and aspiration	Mean dose <50	<20	Based on Section B4 in paper
Larynx	Whole organ	3D-CRT	Vocal dysfunction	Dmax <66	<20	With chemotherapy, based on single study (see Section A4.2 in paper)
	Whole organ	3D-CRT	Aspiration	Mean dose <50	<30	With chemotherapy, based on single study (see Fig. 1 in paper)
	Whole organ	3D-CRT	Edema	Mean dose <44	<20	Without chemotherapy, based on single study in patients without larynx cancer**
	Whole organ	3D-CRT	Edema	V50 <27%	<20	
Cochlea	Whole organ	3D-CRT	Sensory neural hearing loss	Mean dose ≤45	<30	Mean dose to cochlear, hearing at 4 kHz
	Whole organ	SRS (single fraction)	Sensory neural hearing loss	Prescription dose ≤14	<25	Serviceable hearing
Parotid	Bilateral whole parotid glands	3D-CRT	Long term parotid salivary function reduced to <25% of pre-RT level	Mean dose <25	<20	For combined parotid glands¶
	Unilateral whole parotid gland	3D-CRT	Long term parotid salivary function reduced to <25% of pre-RT level	Mean dose <20	<20	For single parotid gland. At least one parotid gland spared to <20 Gy¶

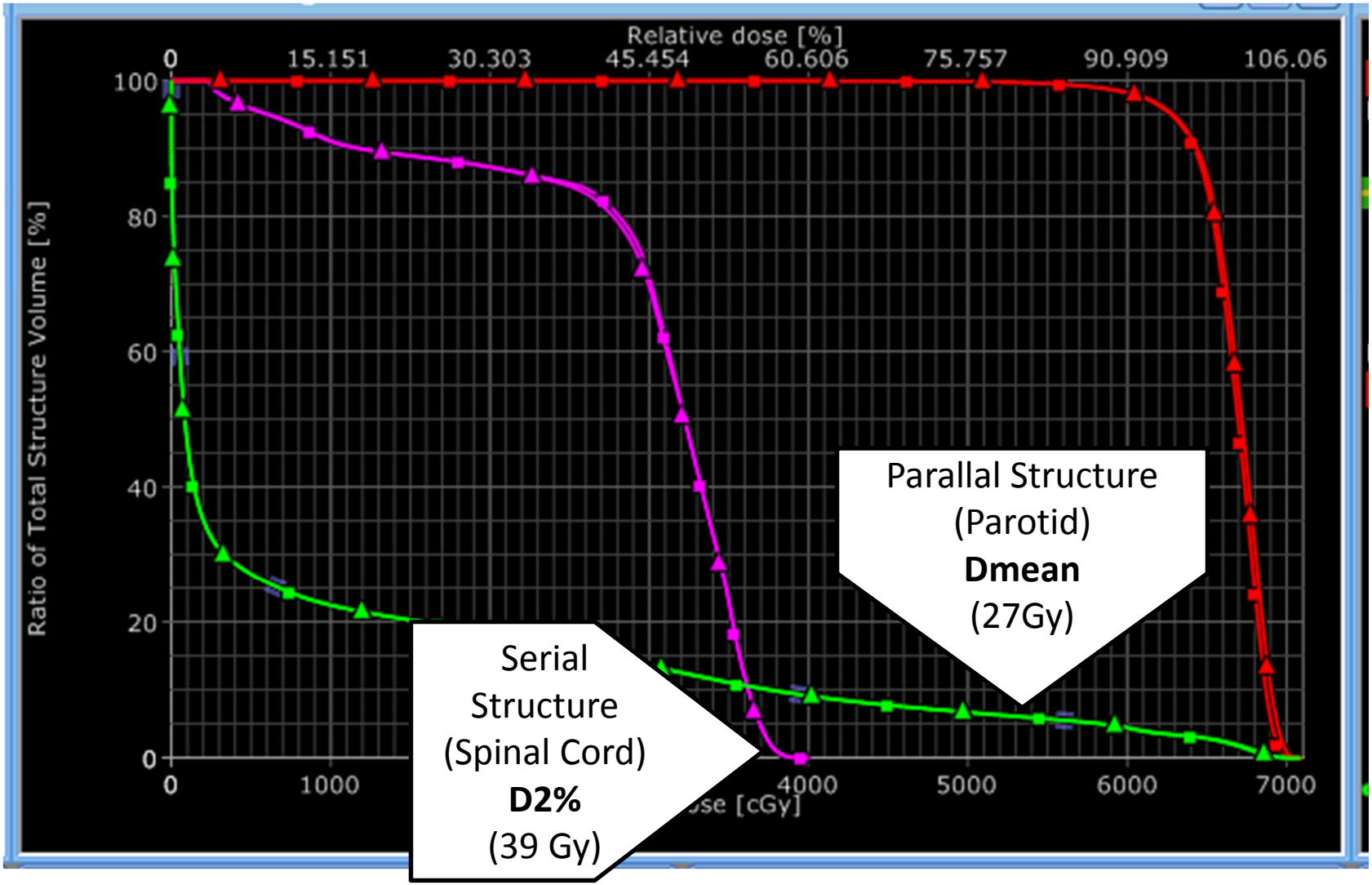
STRUCTURES	CONSTRAINT
Oral cavity	mean<40Gy
Parotid gland	mean <26Gy(atleast in one gland) or atleast 20cc of the combined volume of both parotids should receive<20Gy or atleast 50% of the gland will receive <30Gy
Cochlea	V55 <5%
Eyes	mean <35Gy
Lens	max <25Gy
Glottis	mean<45Gy
Esophagus	
Postcricoid pharynx	mean<45Gy
Brainstem	max 54Gy or 1%PTV not more than 60Gy
Optic nerves	max 54Gy or 1%PTV not more than 60Gy
Optic chiasm	max 54Gy or 1%PTV not more than 60Gy
Spinal cord	max 45Gy or 1cc PTV not more than 50Gy
Mandible and TM joint	max <70Gy or 1cc PTV not more than 75Gy
Brachial plexus	max <66Gy
Temporal lobes	max<60Gy or 1% of PTV not more than 65Gy.

RTOG 0615

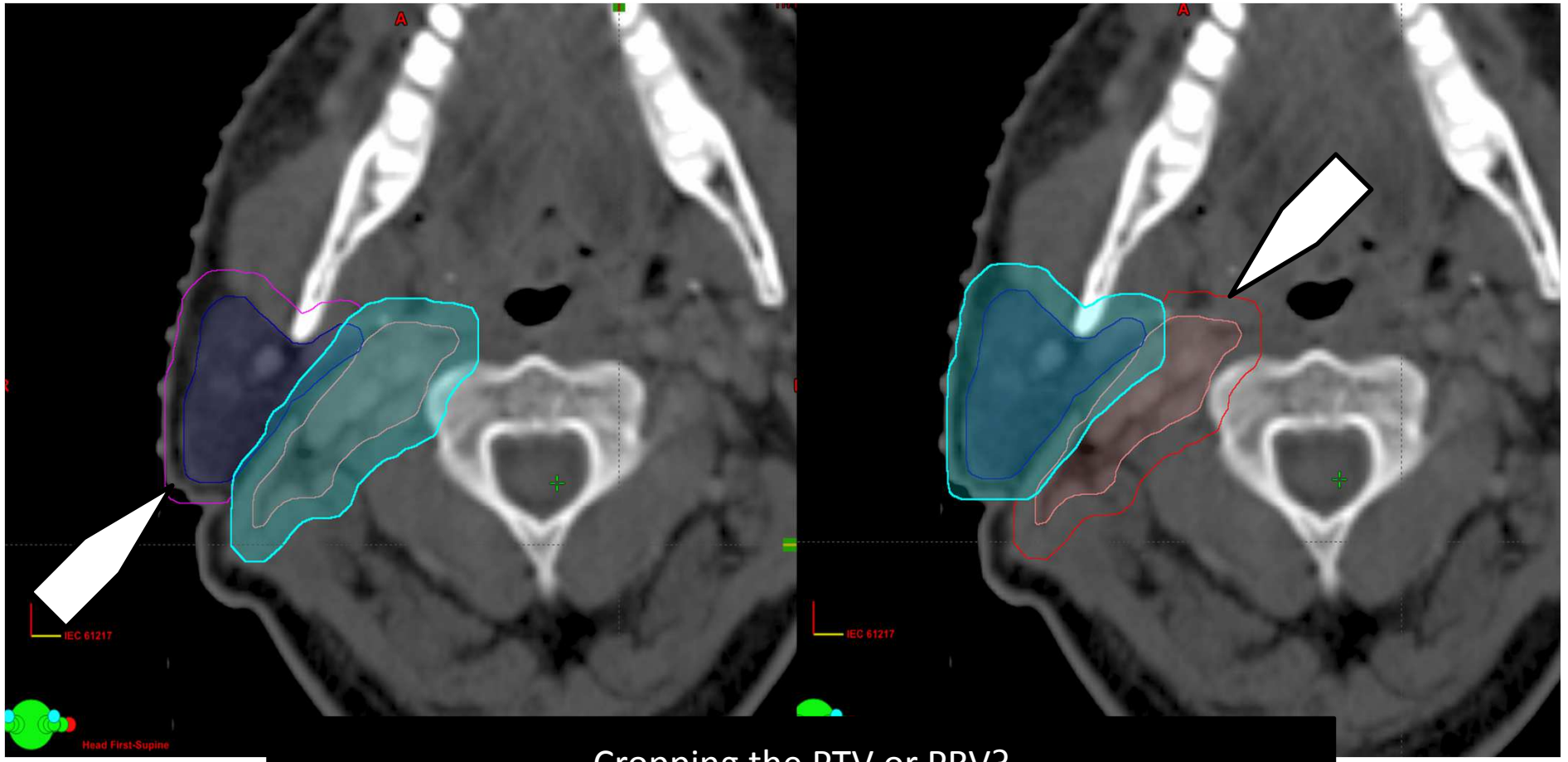
OAR & PRV

- Serial Organs: Spinal Cord, Esophagus
  - $D_{2\%}$ is important
  - Entire organ should be considered if possible
  - Minimum dimension of 15mm to be considered.
- Parallel organs: Parotid, Liver, Lung
  - D_{mean} is important
  - D_{mean} and D_{median} may not be same
- V_d in cases like Lungs (V_{20})

DVH of OAR (PRV)

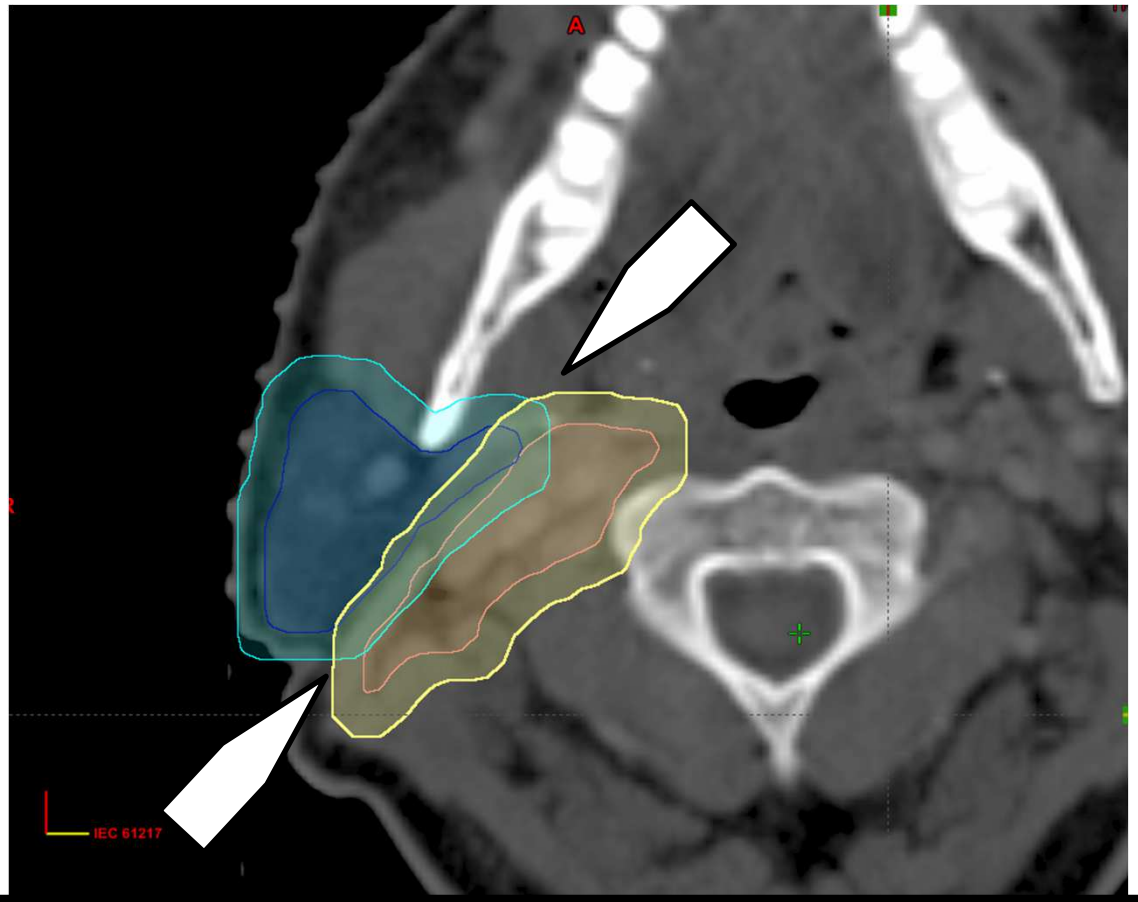


Overlapping CTV & OAR



Cropping the PTV or PRV?

No Cropping!



Planning constraints and priorities to be adjusted for desirable dose

Conformity Index ICRU 50

- Conformity Index (CI) = TV/PTV
- TV = treated volume is the tissue volume that receives at least the dose selected and specified
- CI => optimised close to 1.0
- For small volumes CI up to 2 can be acceptable (SRS)
- For bigger volumes, CI should be closer to 1

Homogeneity Index (RTOG-1993)

$$HI_{RTOG} = I_{max}/RI$$

(I_{max} = maximum isodose in the target, RI reference isodose)

Ideal HI $\leq$ 2

Minor violation = 2 to 2.5

Major violation > 2.5 (Clinical discretion needed)

Alternative formula

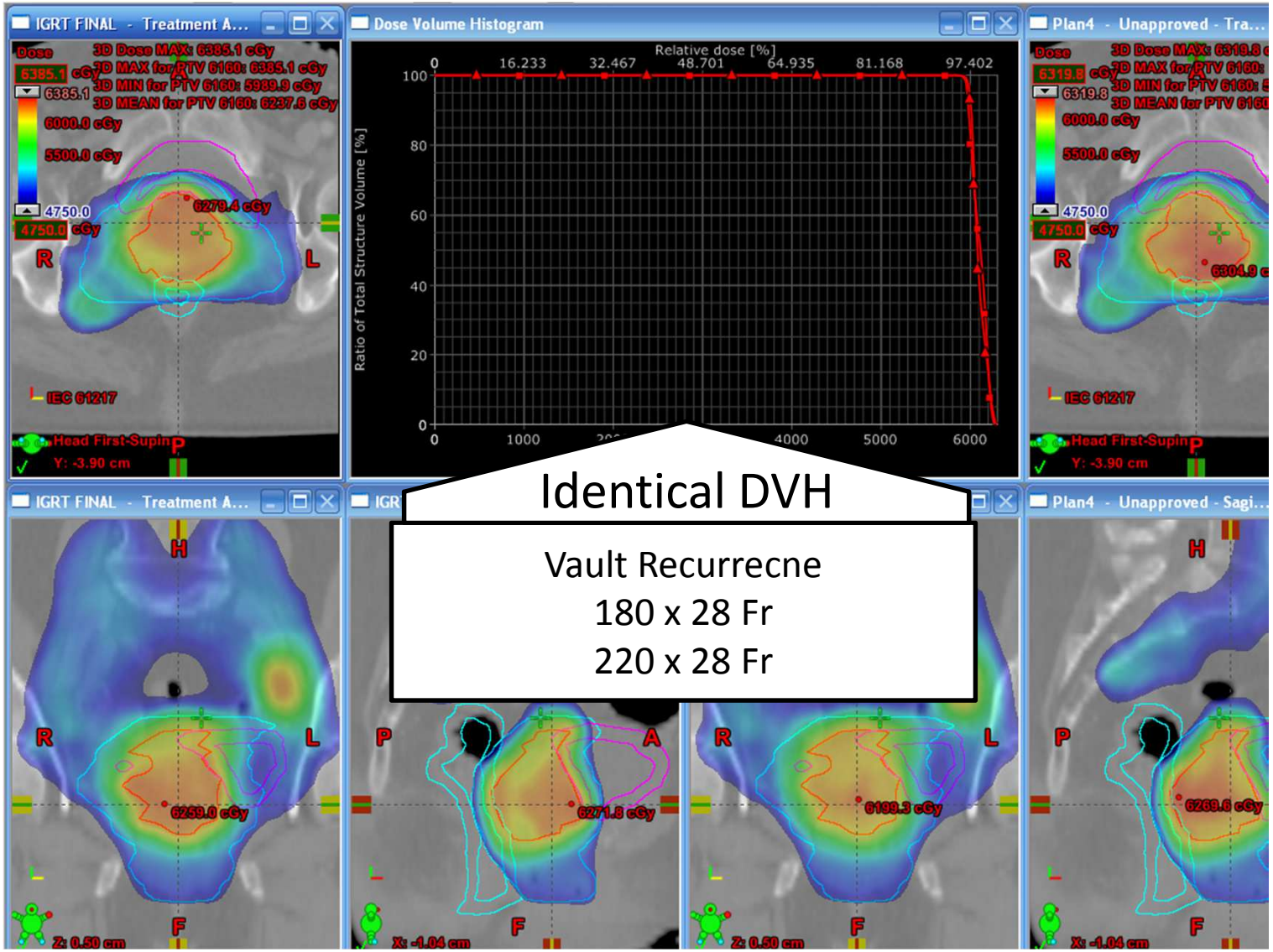
$$HI = D_2 - D_{98}/DP \times 100$$

(D_2 =minimum dose to 2 % of the target

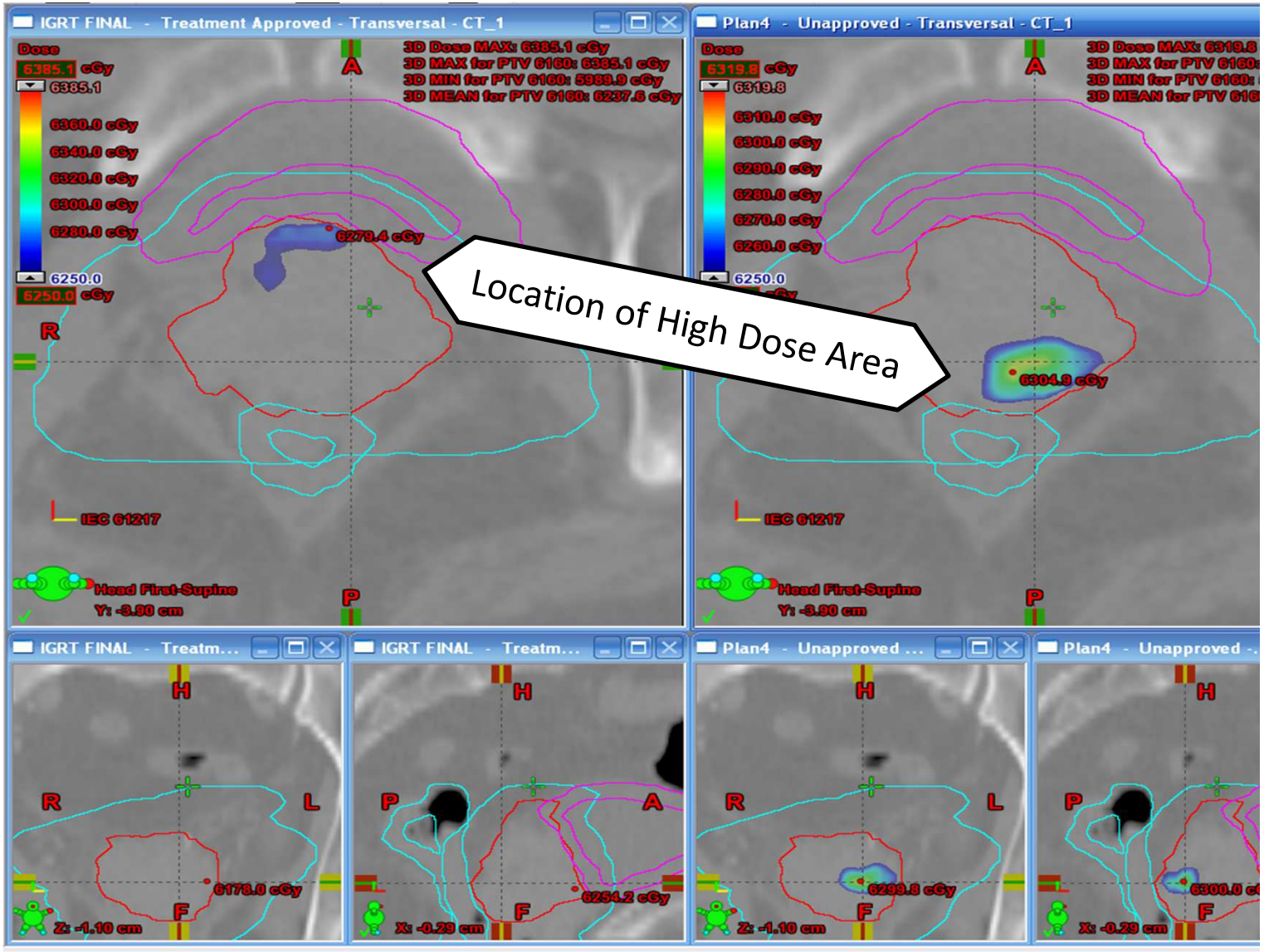
D_{98} = minimum dose to 98% of the target

D_P = prescribed dose)

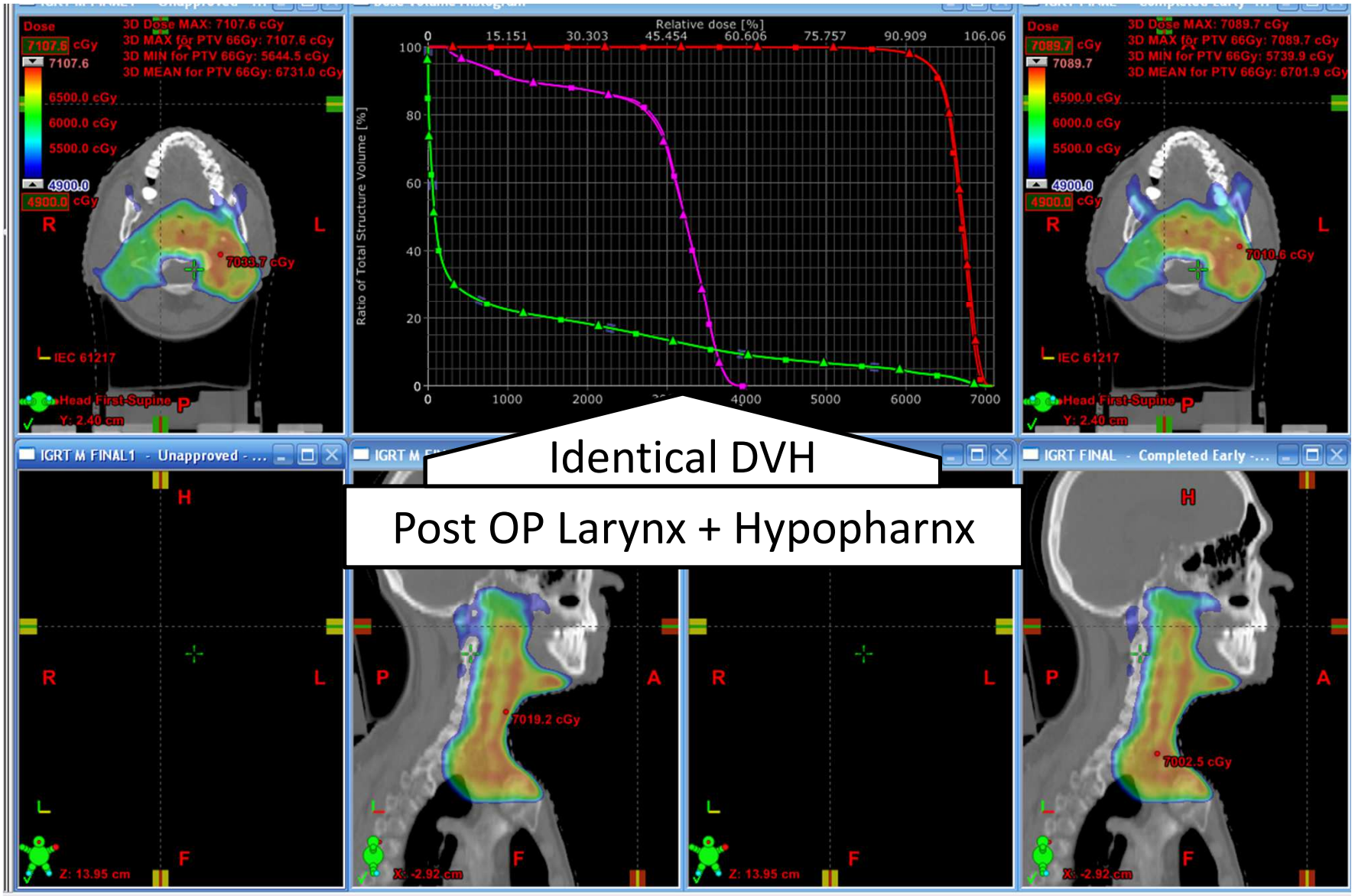
What the DVH doesn't tell



What the DVH doesn't tell



What the DVH doesn't tell



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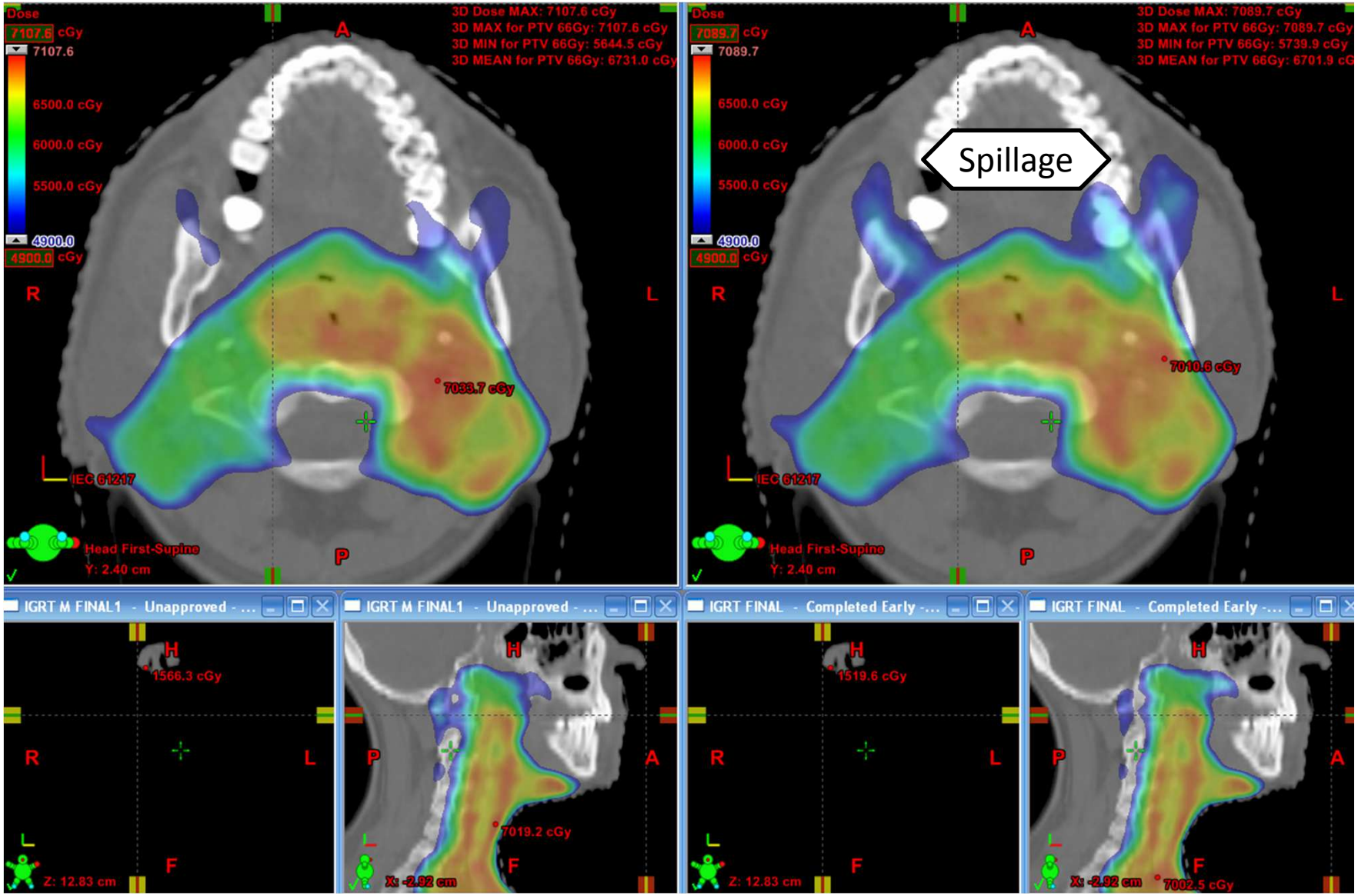
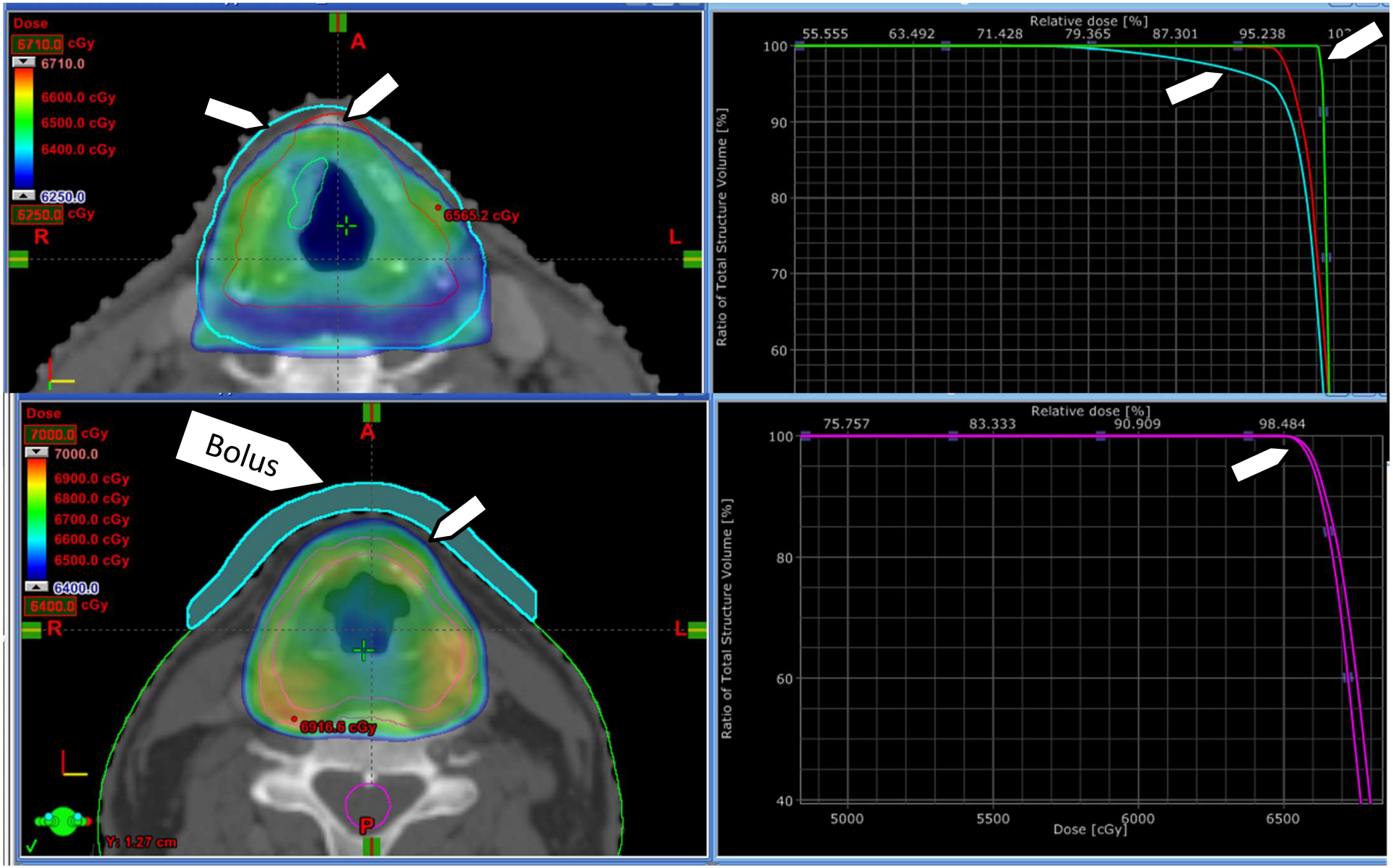


Unacceptable Skin Sparing



Learning for the day

- Definitions of different volumes
- 2D to 3D to IMRT planning
- Evaluation of dose at a relevant point
- Evaluation of dose as a volume
- Accounting for inhomogeneity

Learning for the day

- Mathematical and graphical representation of dose across a volume
- Hot spots & cold spots
- Conformity & Homogeneity indices
- Clinical relevance of a given isodose line
- Ability to choose a proper radiation plan on the basis of these variables

Thank You


WELCOME
STOCKHOLDERS
A·BACALL
"That concludes my prepared remarks. I will now evade your questions."