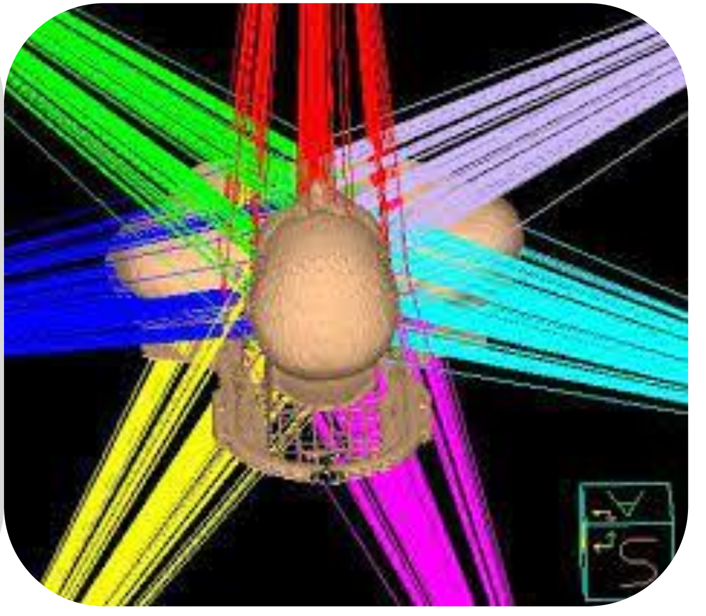
Plan evaluation in high technique radiotherapy



DR KANHU CHARAN PATRO

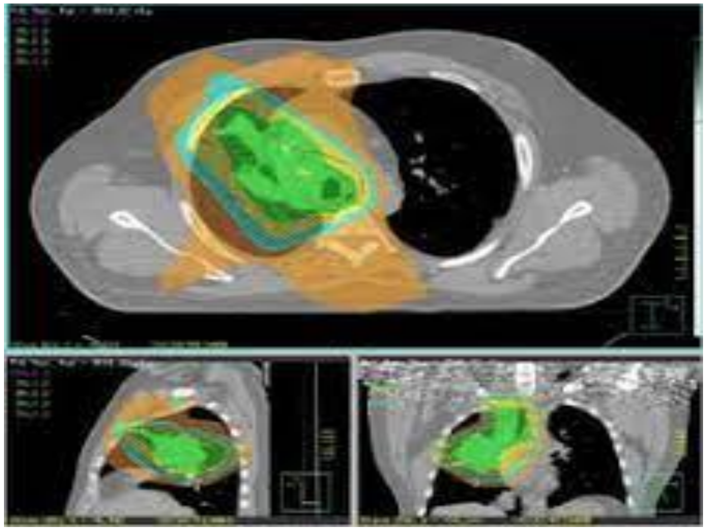
MD,DNB(RADIATION ONCOLOGY),MBA,FAROI(USA),PDCR,CEPC

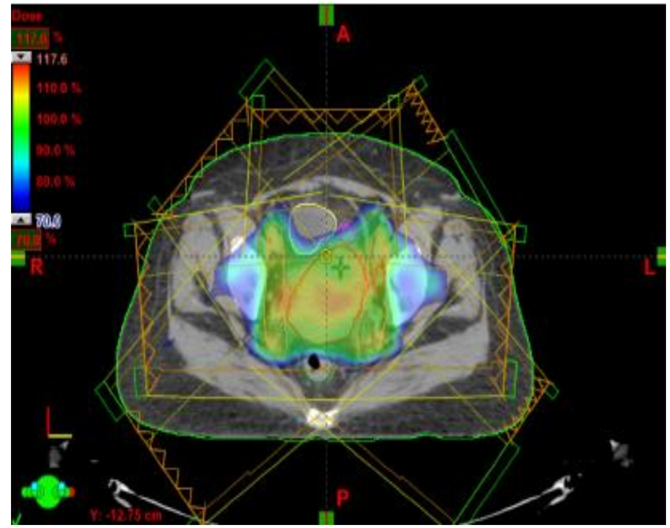
HOD,RADIATION ONCOLOGY

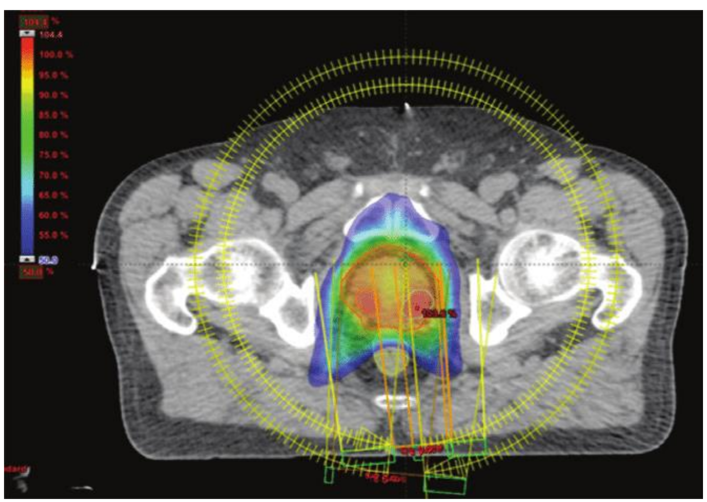
Mahatma Gandhi Cancer Hospital And Research Institute, Visakhapatnam

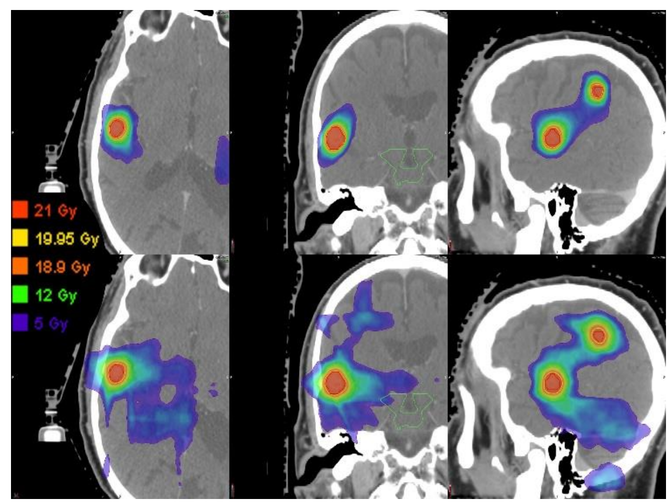
drkcpatro@gmail.com M-9160470564

Different plans

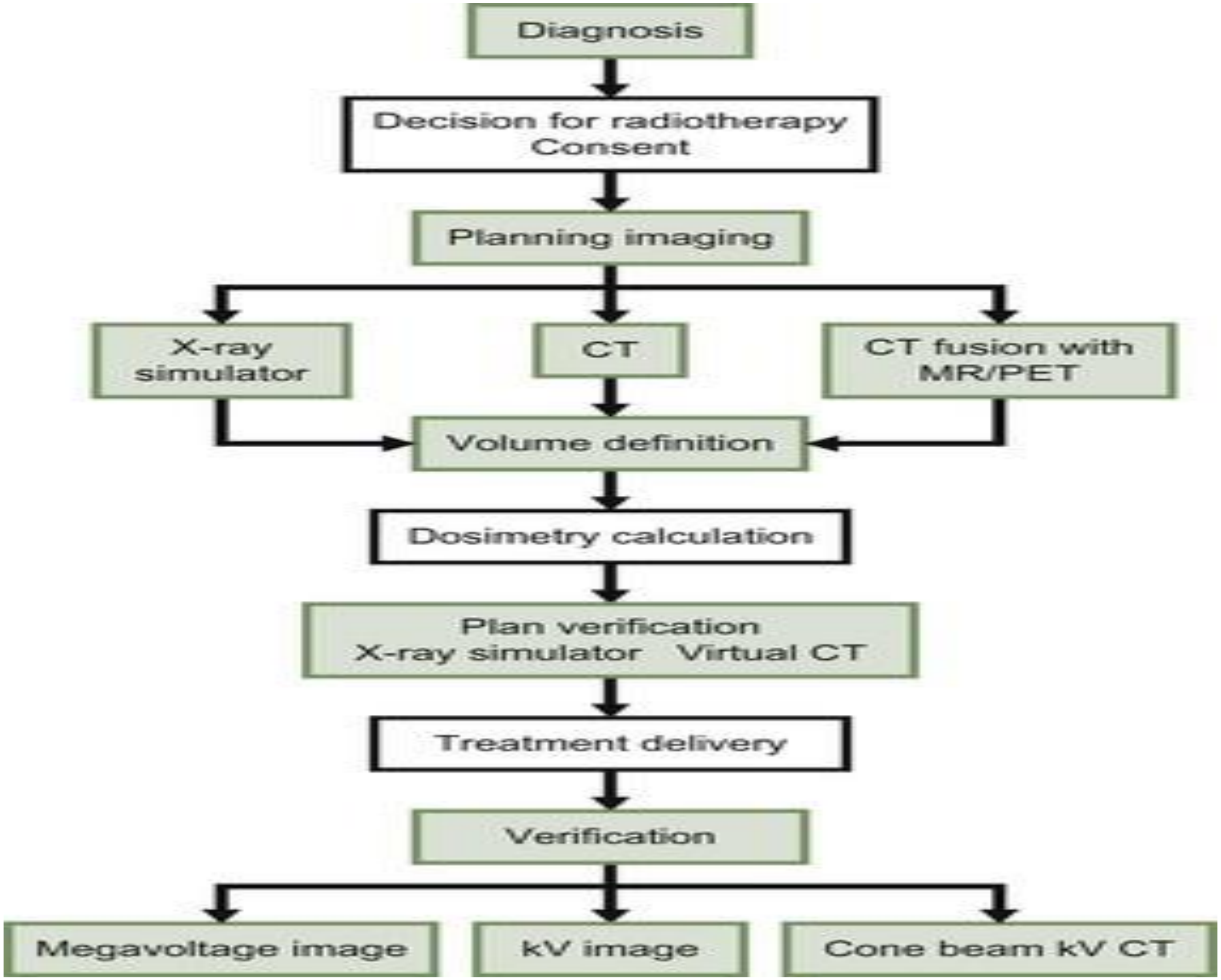




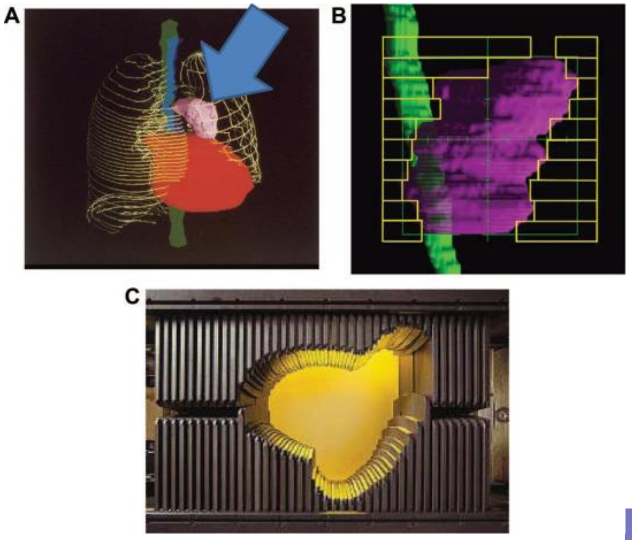


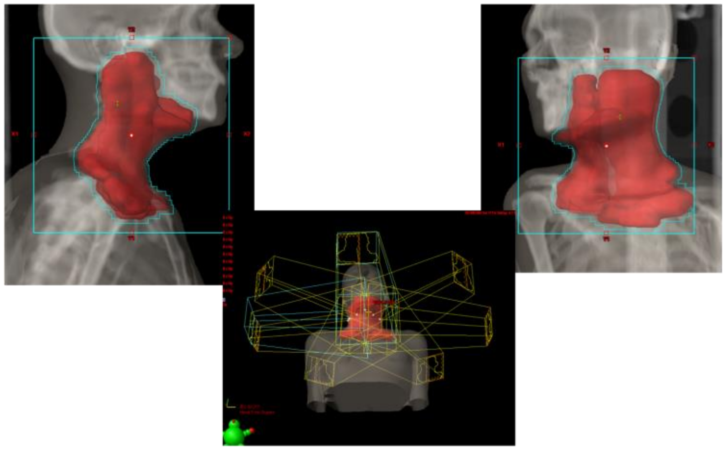


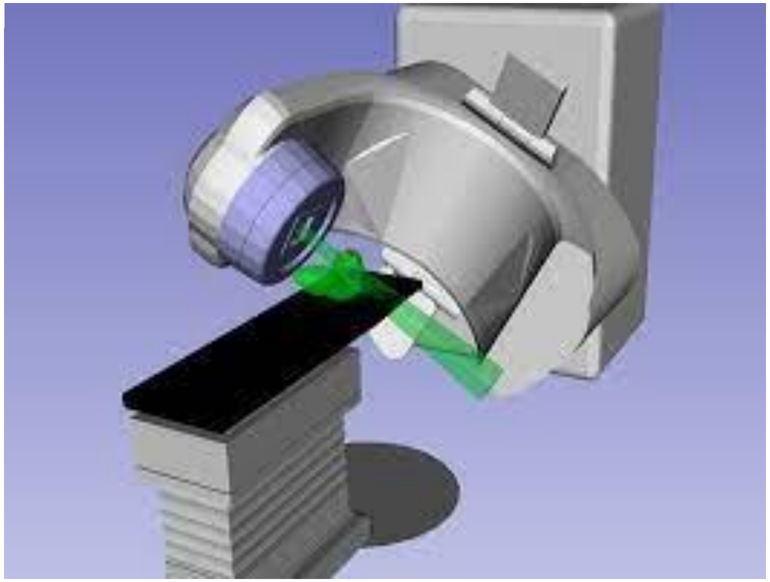
Basics - steps



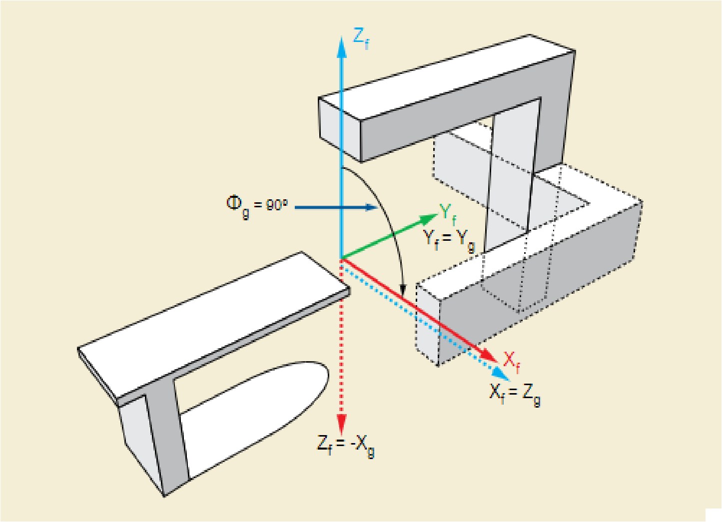
Basics – eye views

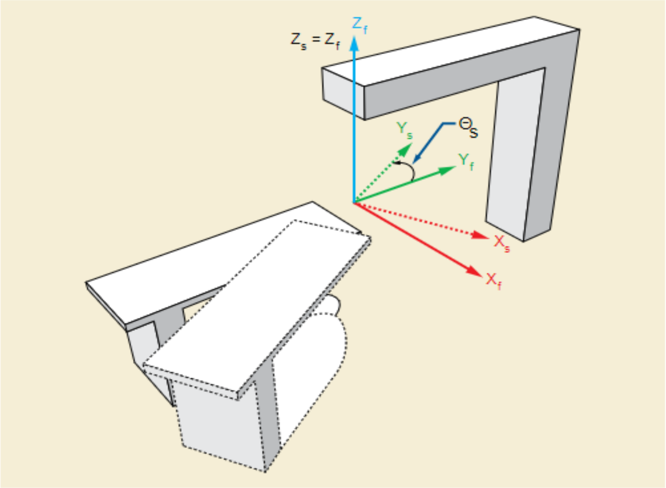




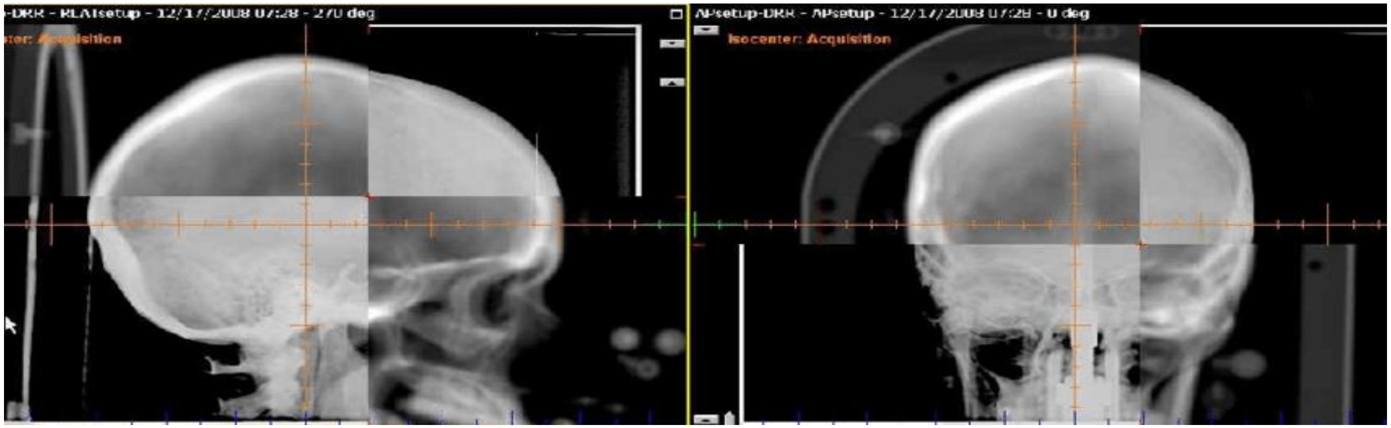


Basics – isocentric vs nonisocentric





Basics – 2d verification vs 3d verification



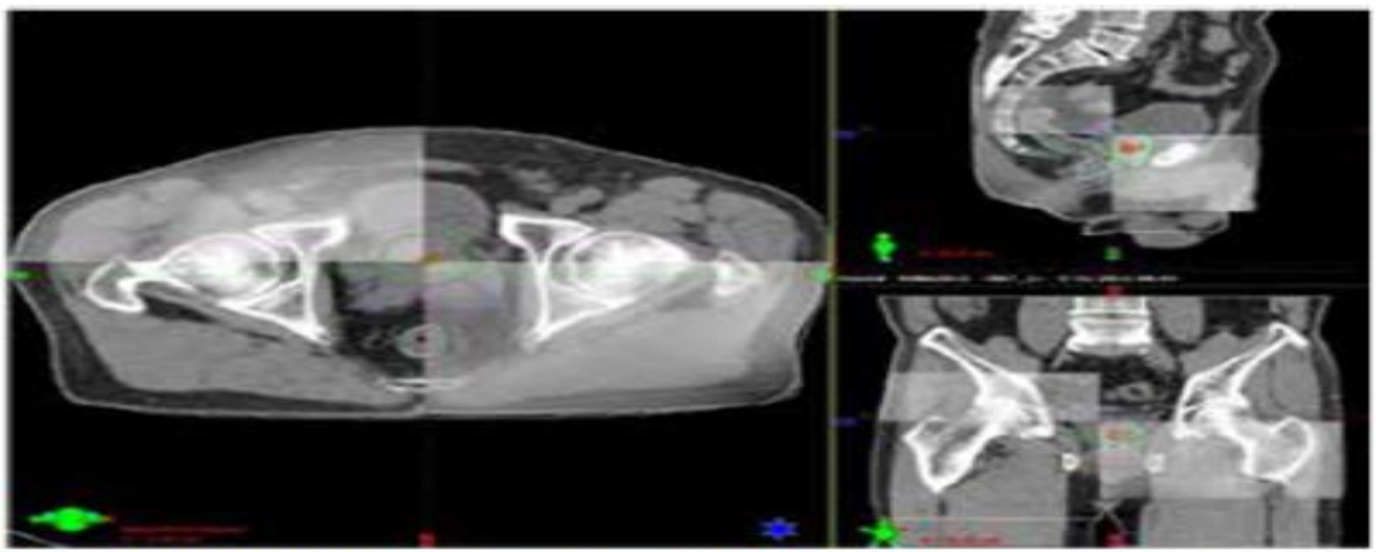
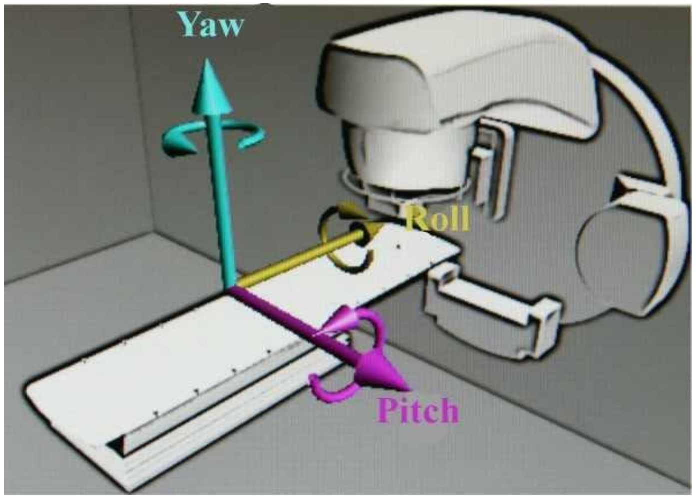
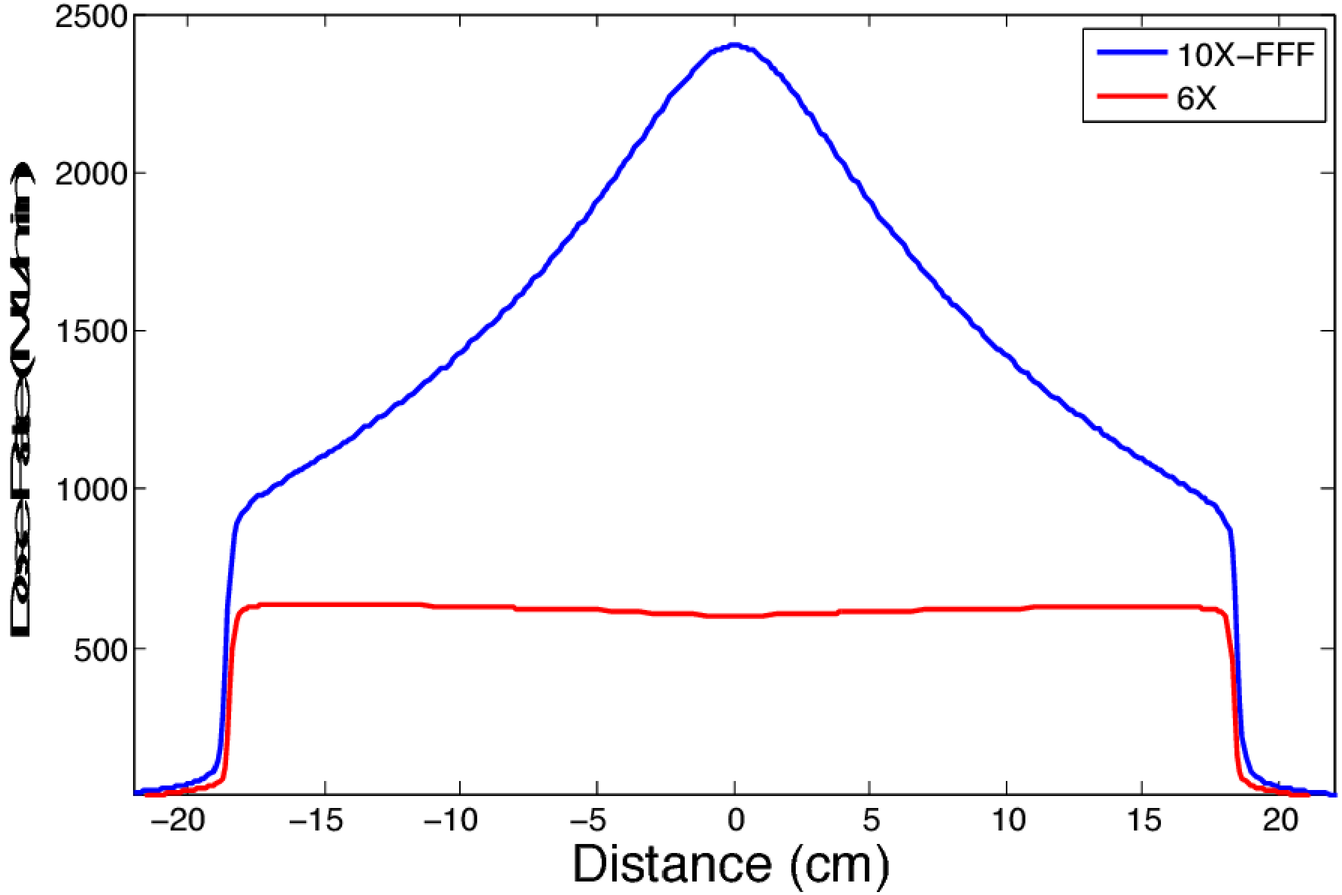


Figure 6: On-board imaging used for IGRT- On-board Cone Beam CT images are registered onto planning CT scan to calculate shifts which are then applied onto the patient's couch to achieve perfect targeting

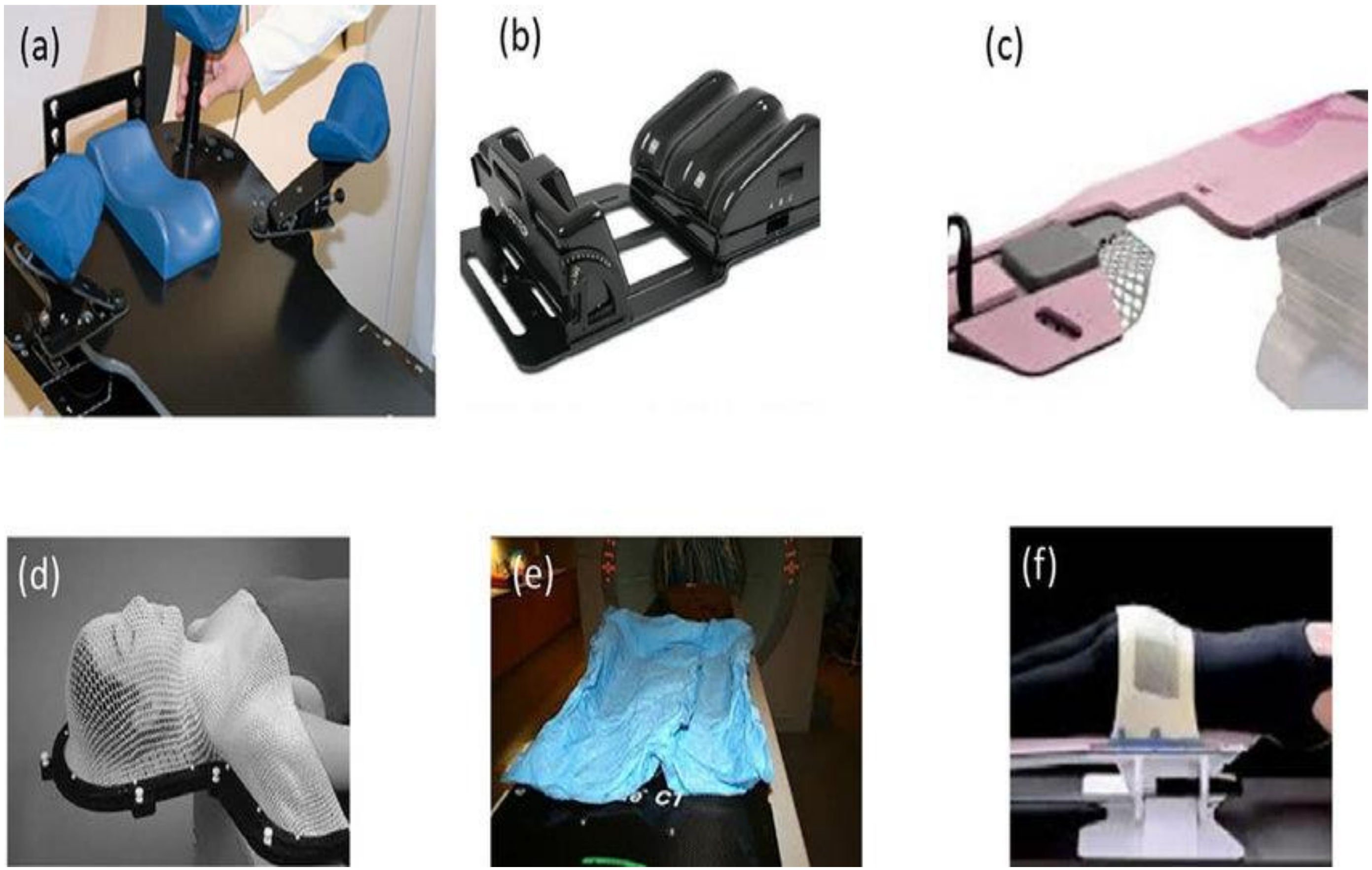
Basics – hexapod couch



Basics – FFF vs no FFF



Basics – Immobilization



Basics of plan evaluation – review your contour

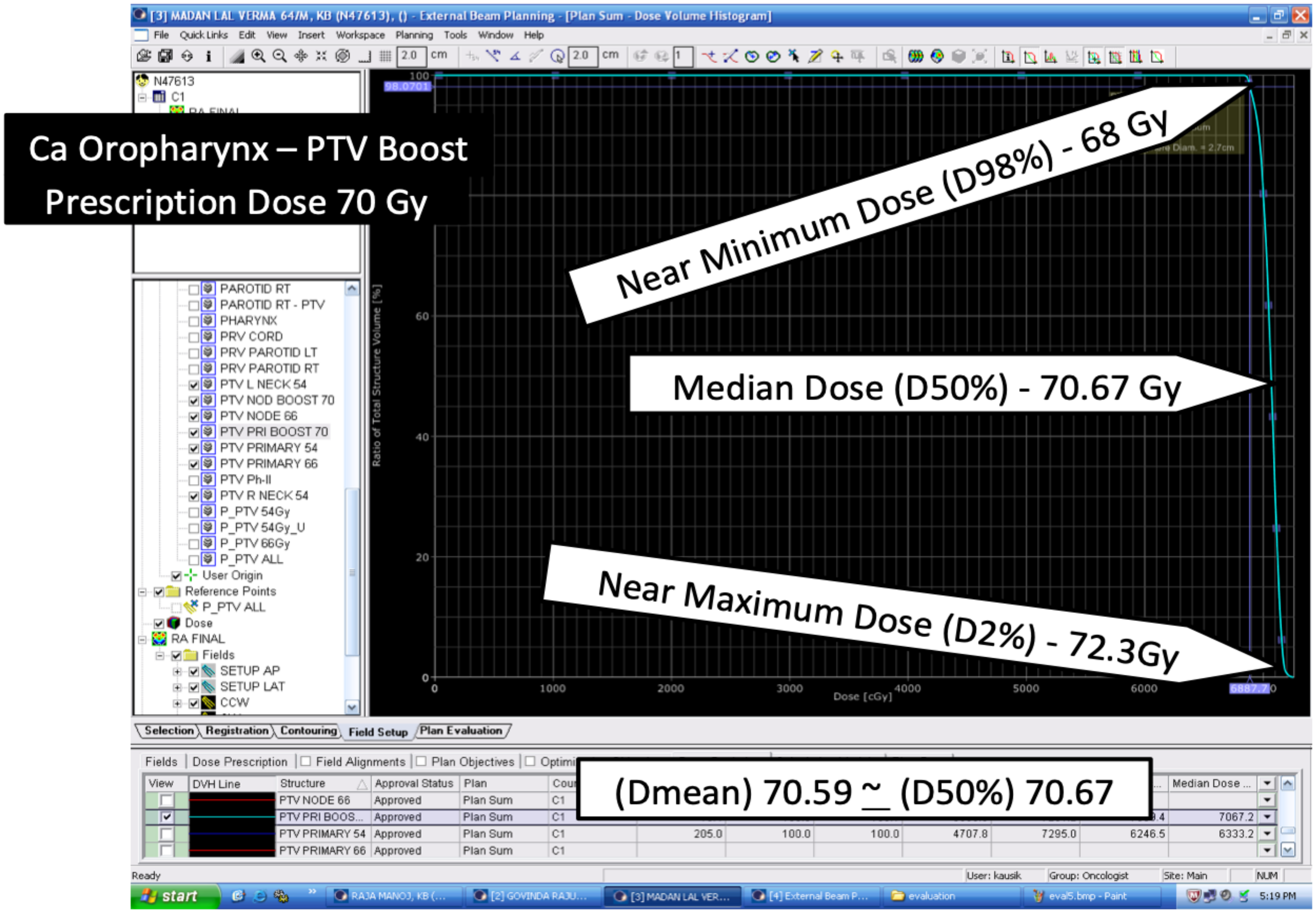
Basics – Notes to physics

Basics of plan evaluation – Defining the dose

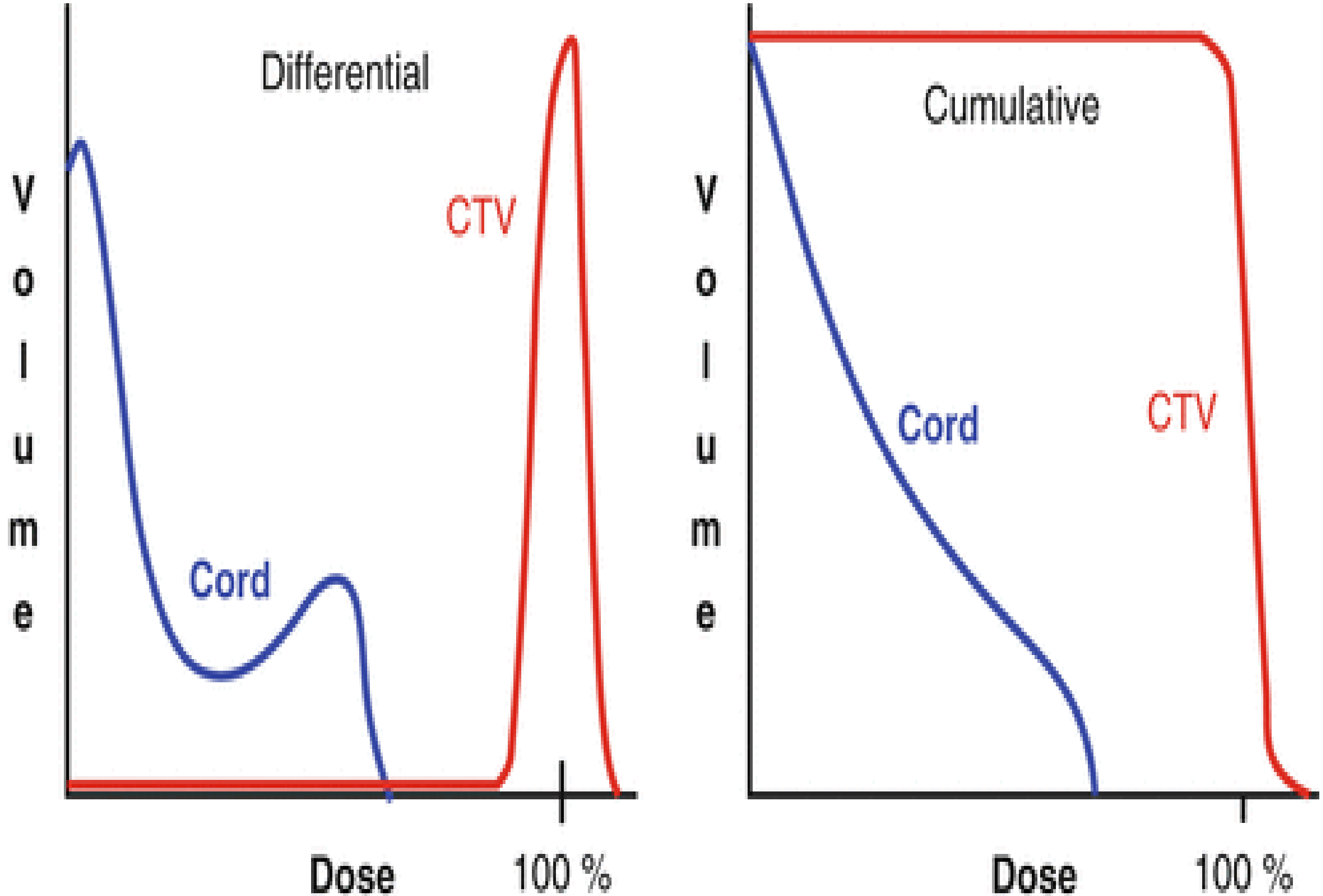
Dose Volume Reporting

1. **D50% (Median Dose)**
    1. **Most representative of prescribed dose**
2. **Dmean is nearly identical to D50%**
3. **D98% (Near Minimum Dose)**
    1. **Dose received by 98% of PTV**
4. **D2% (Near Maximum Dose)**
    5. **Dose received by 2% of PTV**

Basics of plan evaluation – Defining the dose



Basics – DVH

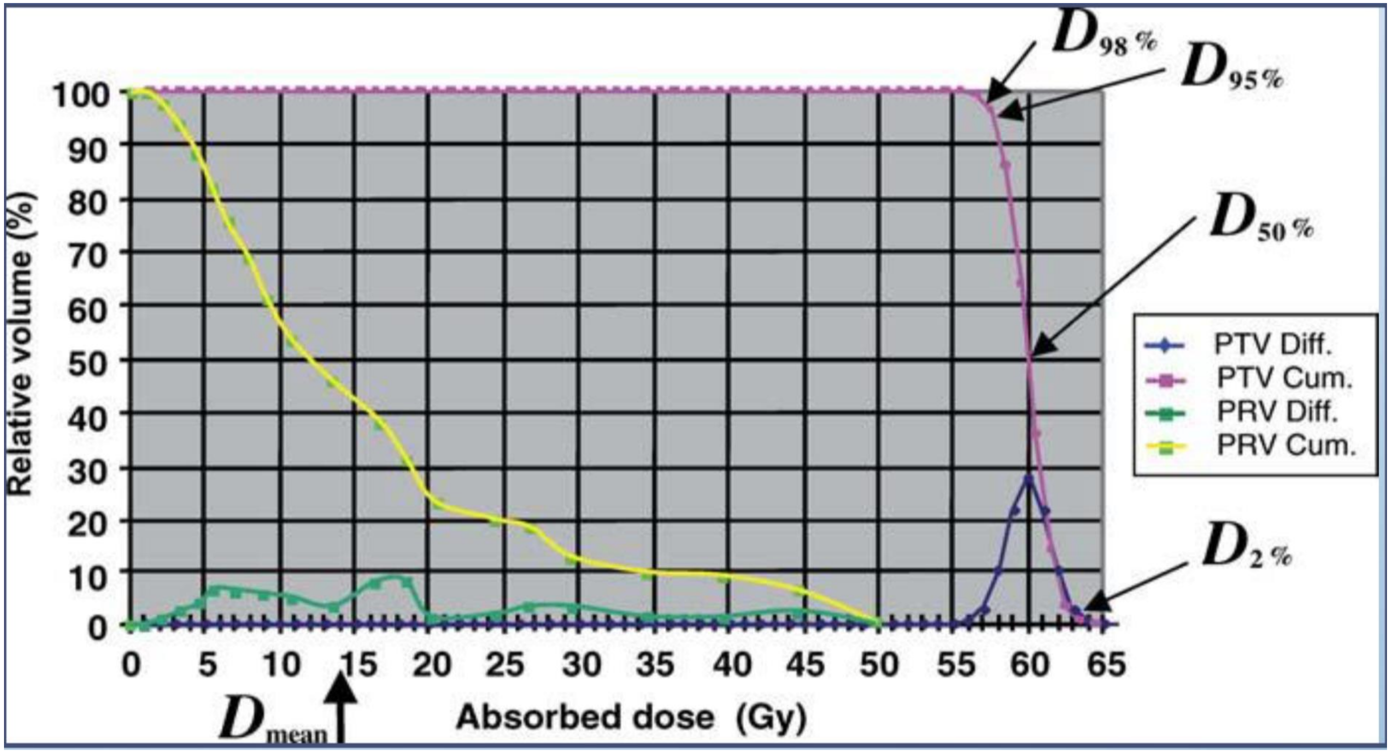

Differential
CTV
Cord
Volume
Dose
100 %
Cumulative
Cord
CTV
Volume
Dose
100 %

Basics – Michael Goitein

Fig. 1 Michael Goitein in 2007 delivering an invited lecture in the Massachusetts General Hospital Ether Dome. Reprinted from [1] with permission from Elsevier

Fig. 2 A team of three senior physicists evaluating a complex treatment plan: Michael Goitein at the center with his colleagues. On the right side of the figure are an operation terminal (lower side) of the VAX computer and a computer-driven image display device (upper side) (probably in the early 1980s). Reprinted from [1] with permission from Elsevier

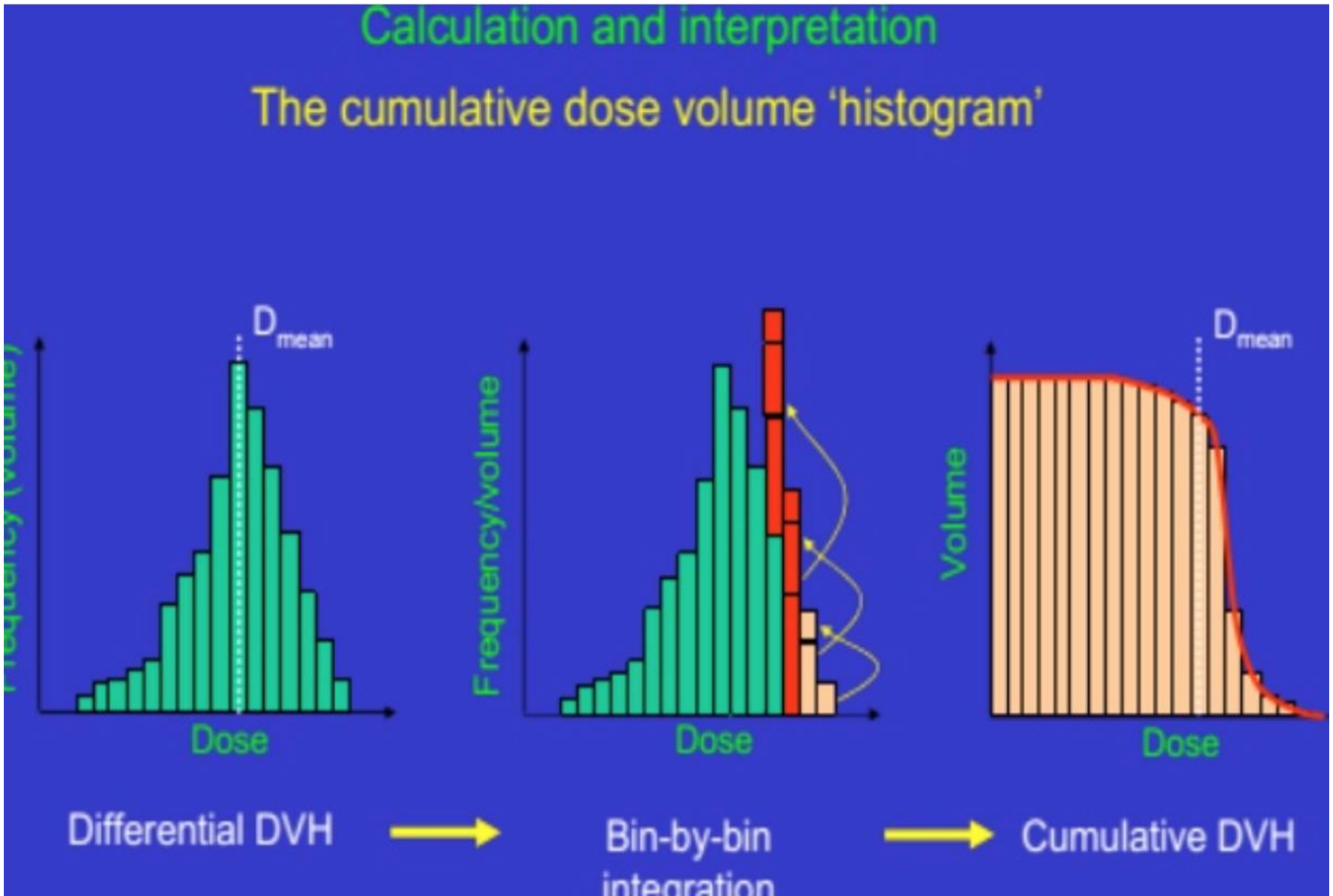
Basics of plan evaluation – DVH



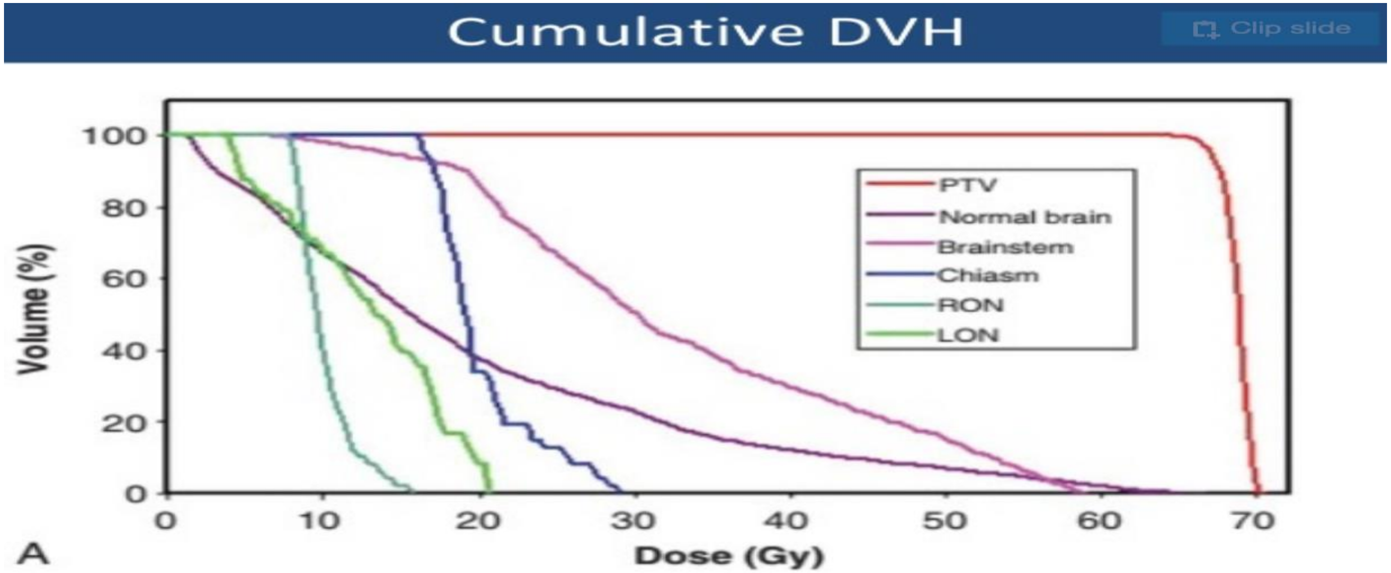
Basics of plan evaluation – DVH pitfalls

1. Insensitive to hot spot and cold spot
2. Shape of DVH alone can be misleading
3. DVH can only be calculated using VOI
4. DVH throws away spatial information
5. DVH is the most direct and informative representation of a treatment plan available
6. 3D dose distribution are large and cumbersome to analyse quantitatively
7. User interactivity is essential to extract the most information from dose distribution.

Basics of plan evaluation – BASIC DVH

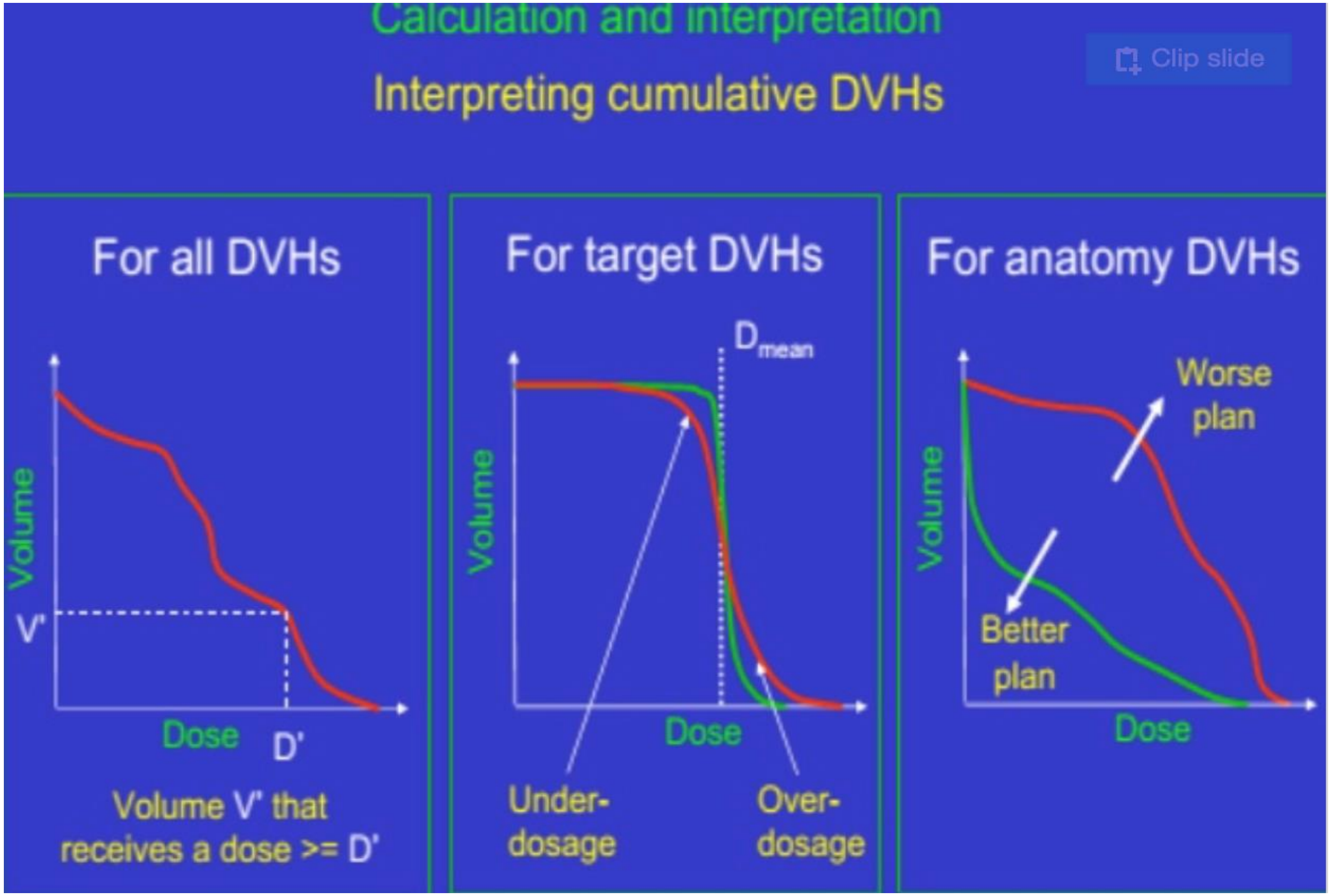


Basics of plan evaluation – CUMULATIVE DVH

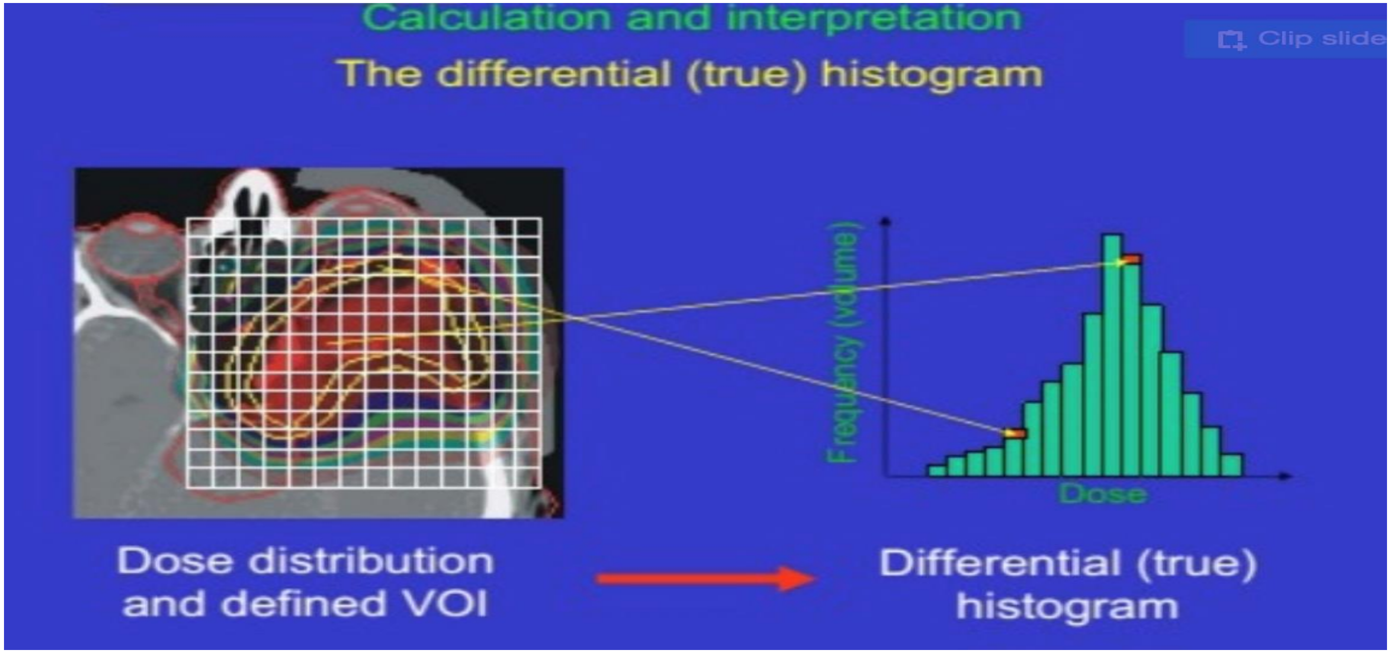


1. Volumes receiving at least a given dose value are ploted.
2. The cumulative DVH integrates the direct histogram, so it always begins at 100% (100% of the organ receives at least 0 dose)
3. It ends at maximum dose

Basics of plan evaluation – Analyzing DVH

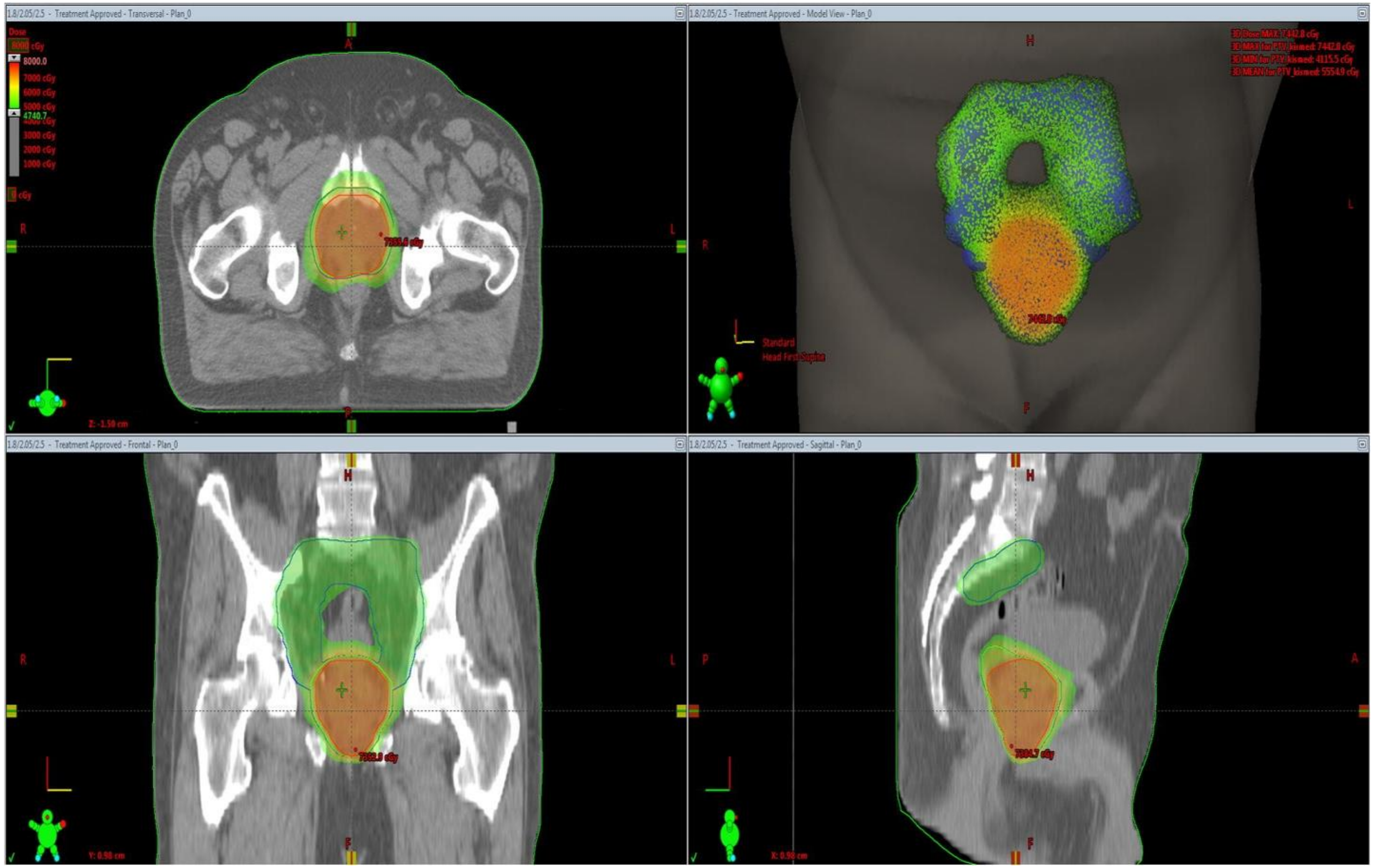


Basics of plan evaluation – Differential DVH



1. The generic form of any histogram, displaying the volume of the organ that receives dose within each bin (1% or 0.5 to 1 Gy is a typical dose bin width.
2. It is useful for display of the dose to target volumes, because one can easily visualise the minimum dose, the maximum dose, and the most representative of the dose to the entire target volume.

Basics – plan evaluation



Basics – ICRU

ICRU

Prescribing, Recording, and Reporting Photon-Beam

ICRU REPORT 29 (1978)

- Dose Specification for Reporting External Beam Therapy with Photons and Electrons

ICRU REPORT 50 (1993)

- Prescribing, Recording, and Reporting Photon Beam Therapy

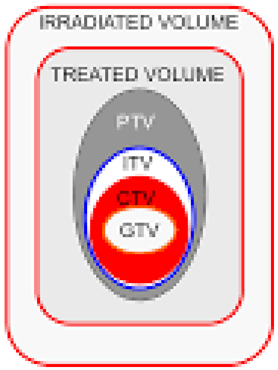
ICRU REPORT 62 (1999)

- A Supplement to Report 50
- conventional external photon-beam irradiation techniques, including 3D-CRT

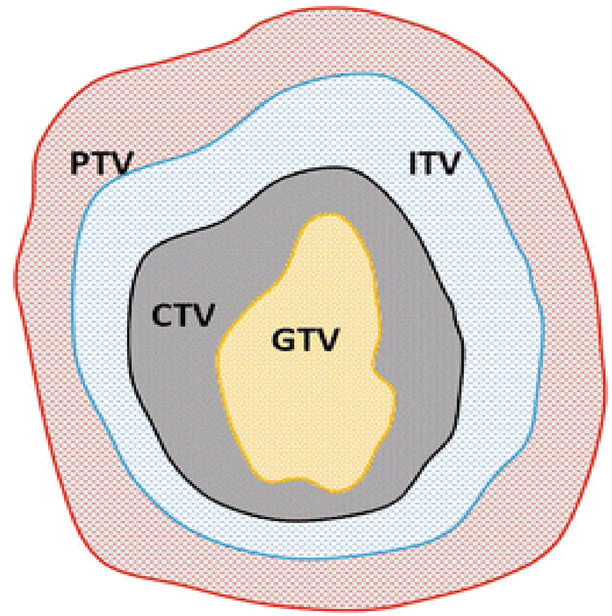
ICRU REPORT 83 (2010)

Basics – GTV-CTV-ITV-PTV

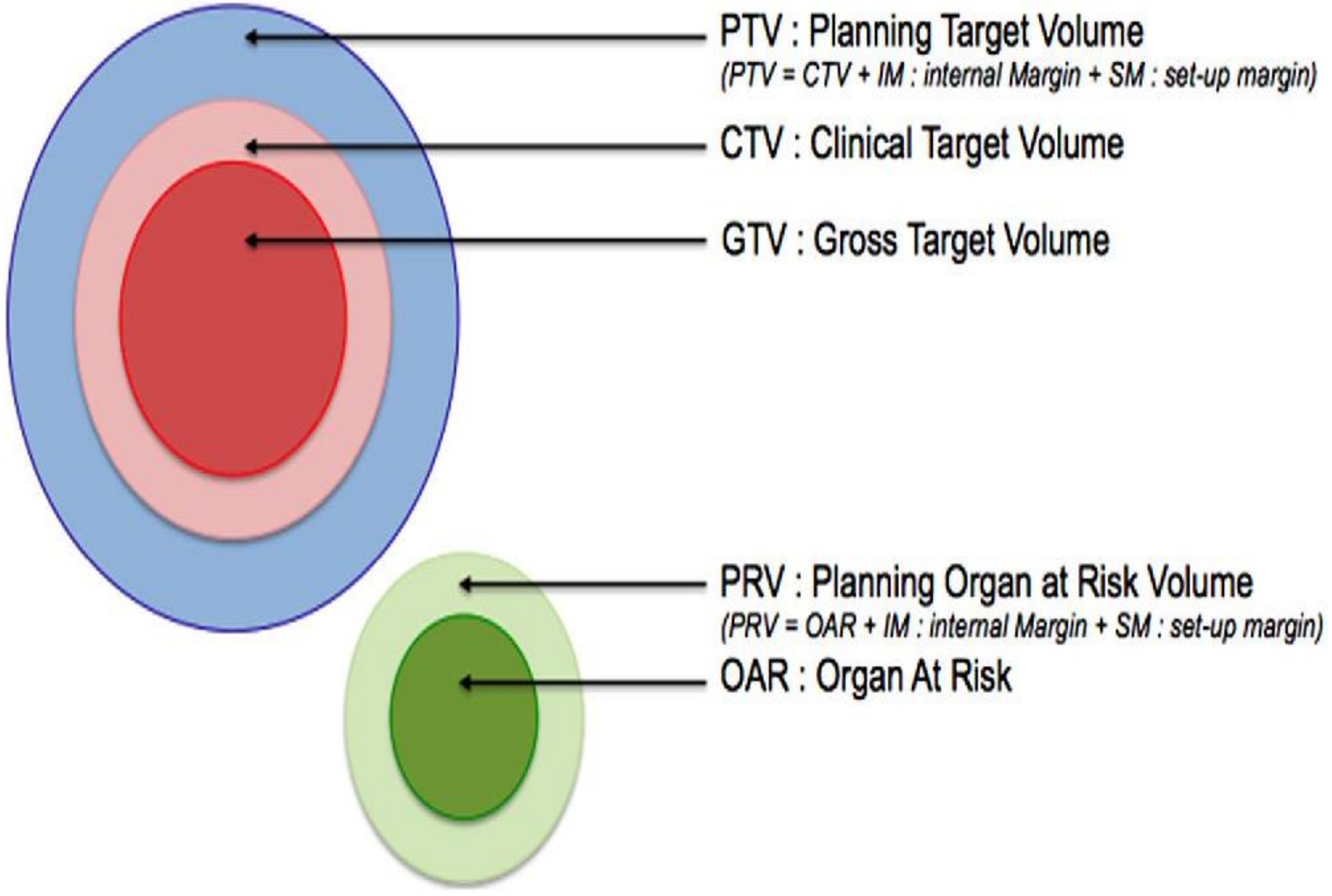
ICRU 50/62/83



- Gross tumor volume (GTV): Tumor visible
- **Clinical target volume (CTV): GTV and microscopic tumor**



Basics – OAR



PTV : Planning Target Volume
(PTV = CTV + IM : internal Margin + SM : set-up margin)
CTV : Clinical Target Volume
GTV : Gross Target Volume
PRV : Planning Organ at Risk Volume
(PRV = OAR + IM : internal Margin + SM : set-up margin)
OAR : Organ At Risk

Basics – mlc and cone

Basics – CBCHOP

CB-CHOP: A simple acronym for evaluating a radiation treatment plan

Mary Dean, MD; Rachel Jimenez, MD; Eric Mellon, MD, PhD; Emma Fields, MD; Raphael Yechieli, MD; Raymond Mak, MD

- **Contours:** Review target volumes and OARS
- **Beam Arrangements/Fields:** Appropriate and reasonable
- **Coverage:** Evaluate on graphic plan and DVH
- **Heterogeneity/Hot Spots:** Value and location
- **Organs at Risk:** Review specified constraints, corresponding isodose lines on plan, and DVH
- **Prescription:** Total dose, dose per fraction, and image guidance

FIGURE 1. *Flowchart diagram summarizing the CB-CHOP acronym and components of plan quality.*

Mary Dean/Applied Radiation Oncology/2017

Basics – COSID INDEX

C

COVERAGE INDEX

O

OAR INDEX

S

SPILLAGE INDEX

I

IMAGING INDEX

D

DELIVERY INDEX

Patro K C/Journal of Current Oncology/2022(UNDER REVIEW)

Basics – Coverage Index

PTV/CTV/GTV

D_2/D_{98}

95-107

Patro K C/Journal of Current Oncology/2022(UNDER REVIEW)

Basics – OAR INDEX

Max dose in series organ

Mean dose in parallel organ

Volumetric analysis

Patro K C/Journal of Current Oncology/2022(UNDER REVIEW)

Basics – Spillage Index

Conformity index

Homogeneity index

Gradient index

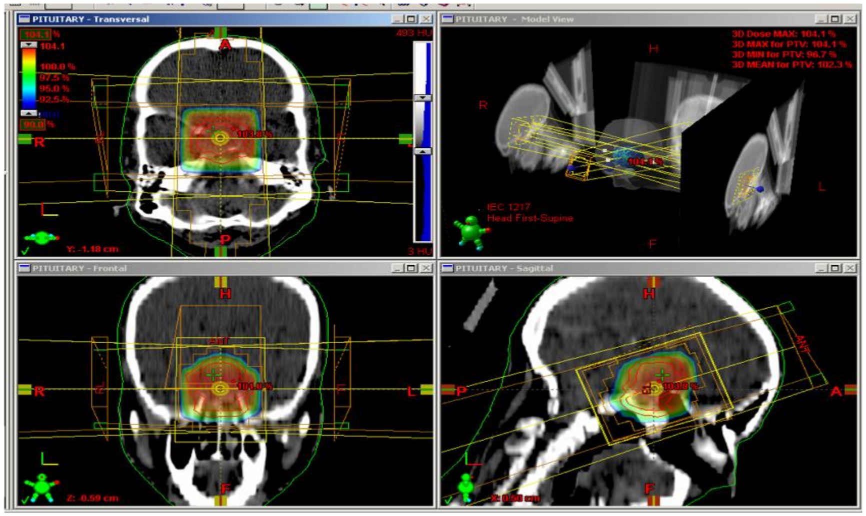
Patro K C/Journal of Current Oncology/2022(UNDER REVIEW)

Basics – Imaging Index

Axial view

Coronal view

Sagittal View



Patro K C/Journal of Current Oncology/2022(UNDER REVIEW)

Basics – Delivery index

Complexity of plan

MU

Basics – Delivery index

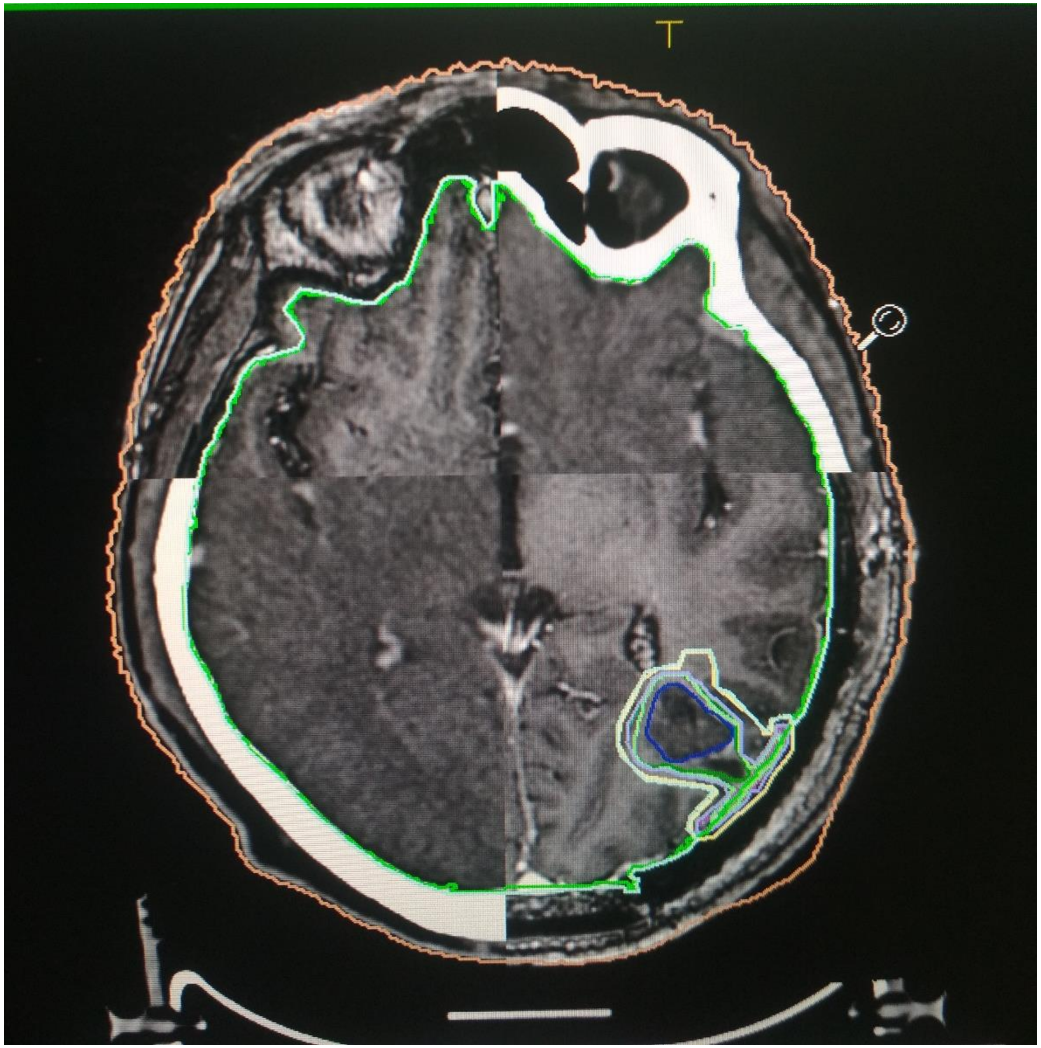
Complexity of plan

Complexity of Delivery

MU

Patro K C/Journal of Current Oncology/2022(UNDER REVIEW)

Example



PTV coverage index

SL NO	PARAMETER	VALUE
1	D_{MAX}	36.43Gy
2	$D_{95\%}$	31.01Gy
3	$D_{100\%}$	28.23Gy
4	$V_{95\%}$	99.99%
5	**$V_{30\ Gy}[V_{100\%}]$**	**99.56%**
6	$V_{110\%}$	44.45%
7	$V_{120\%}$	0.03%
8	$V_{130\%}$	0%

1. Prescription Isodose level is usually not 100% PD covering 100% PTV
2. Often 95% PD covering 95% PTV or higher
3. Or 100% PD covering 95% PTV or higher.

Michael Torrens,/J Neurosurg (Suppl 2)/2014

RTOG conformity index

- FORMULA
    - VOLUME OF PRESCRIPTION ISODOSE/PTV VOLUME
- 43.798/37.491=1.17
- DESIRABLE=1

[Sonja Petkovska
Proceedings of the Second
Conference on Medical Physics and
Biomedical Engineering]

The conformity index was first proposed in 1993 by the Radiation Therapy Oncology Group (RTOG) and described in Report 62 of the International Commission on Radiation Units and Measurements (ICRU). It is presented as a relation between the volume of the reference dose (V_{RI}) and the target volume(TV).

$$\textit{Conformity index}_{RTOG} = V_{RI}/TV \qquad (1)$$

According to the RTOG guidelines, ranges of conformity index values have been defined to determine the quality of conformation. If the conformity index is situated between 1 and 2, the treatment is considered to comply with the treatment

Paddick conformity index

- FORMULA

$$\frac{(\text{VOLUME OF PRESCRIPTION ISODOSE IN AREA OF INTEREST})^2}{\text{PTV VOLUME X VOLUME OF PRESCRIPTION ISODOSE}}$$

- =39.764 x 39.764 /37.494 x43.798 =0.96
- IDEAL= > 0.85. AND <1

This inadequacy has led to the development of the Paddick Conformity Index (PCI).[48] This value is the coverage multiplied by the Selectivity Index:

$TV_{PIV}{}^2/(TV \times PIV)$.

A perfect plan has a score of 1, whereas less perfect plans have a score of < 1. An ideal value for PCI conformity could be > 0.85.

Michael Torrens,/J Neurosurg (Suppl 2)/2014

HOMOGENITY index

- FORMULA
  - MAXIMUM DOSE/PRESCRIPTION DOSE
- 36.43Gy/30Gy=1.21
- DESIRABLE = 1.1-1.3

It is an objective tool to analyse the uniformity of dose distribution in the target volume

Homeogeneity Index (HI) = $D_{2\%} - D_{98\%}/D_{50\%}$

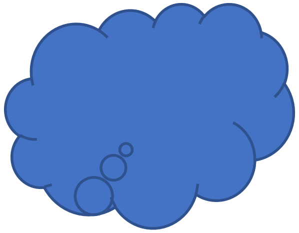
Ideal HI: 1.1 – 1.3

Dose fall off

- Dose fall off observation is very much needed in this evaluation under headings
- Gradient index
- Difference between various isodose lines
- e.g between 80% and 60%- ideal- <2mm
- Between 80% and 40%- ideal- < 8mm
- For that reason we have to calculate equivalent radius

Equivalent radius

- To evaluate dose gradient we have to find out difference between radius of various isodose line
- But none is iso spherical
- We have to find out equivalent radius from formula
- First find out the specified isodose volume
- Then calculate the radius
- $V=4/3\,\pi r^3$
- $r= (3V/4\pi)^{1/3}$



Equivalent radius

SL NO	PARAMETER	VOLUME	RADIUS
1	**100% ISODOSE**	43.79CC	2.19mm
2	**80% ISODOSE**	64.45CC	2.49mm
3	**60% ISODOSE**	101.19CC	2.89mm
4	**50% ISODOSE**	130.84CC	3.15mm
5	**40% ISODOSE**	177.96CC	3.49mm

$$r = (3V/4\pi)^{1/3}$$

Gradient index

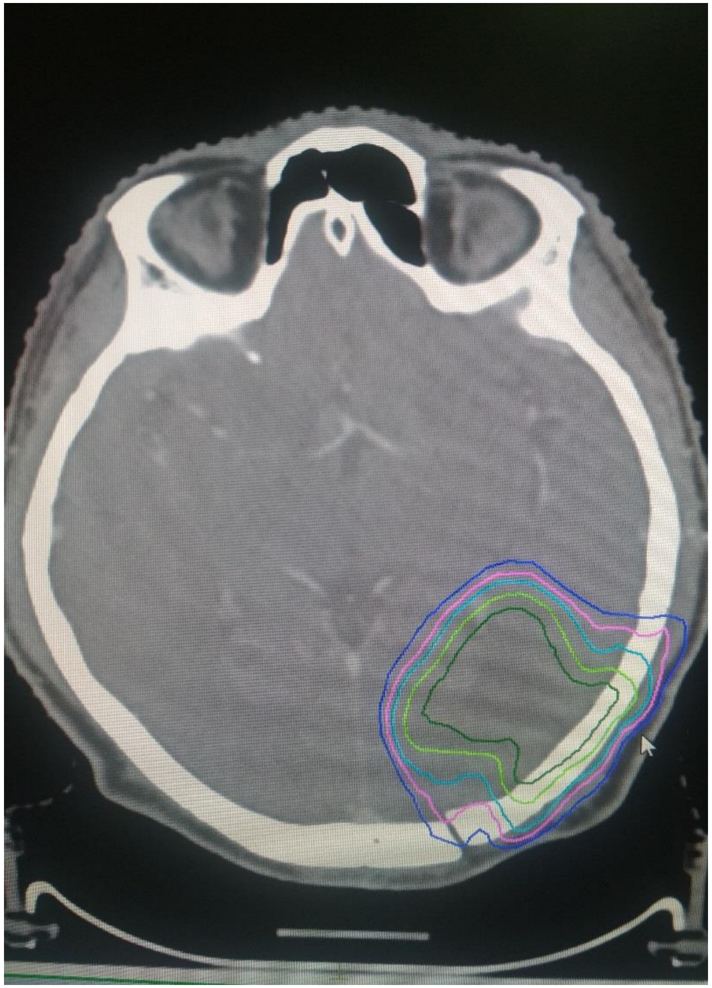
- FORMULA
  - Difference of equivalent radius of prescription isodose and equivalent radius of 50% isodose
- 2.19mm-3.15mm=0.96mm
- It should be between 0.3 to 0.9

Distance between various isodose lines

- BETWEEN 80% AND 60%- IDEAL-<2mm
  - HERE- 0. 4mm
- BETWEEN 80% AND 40%- IDEAL- <8mm
  - HERE- 1mm

EORTC-22952-26001

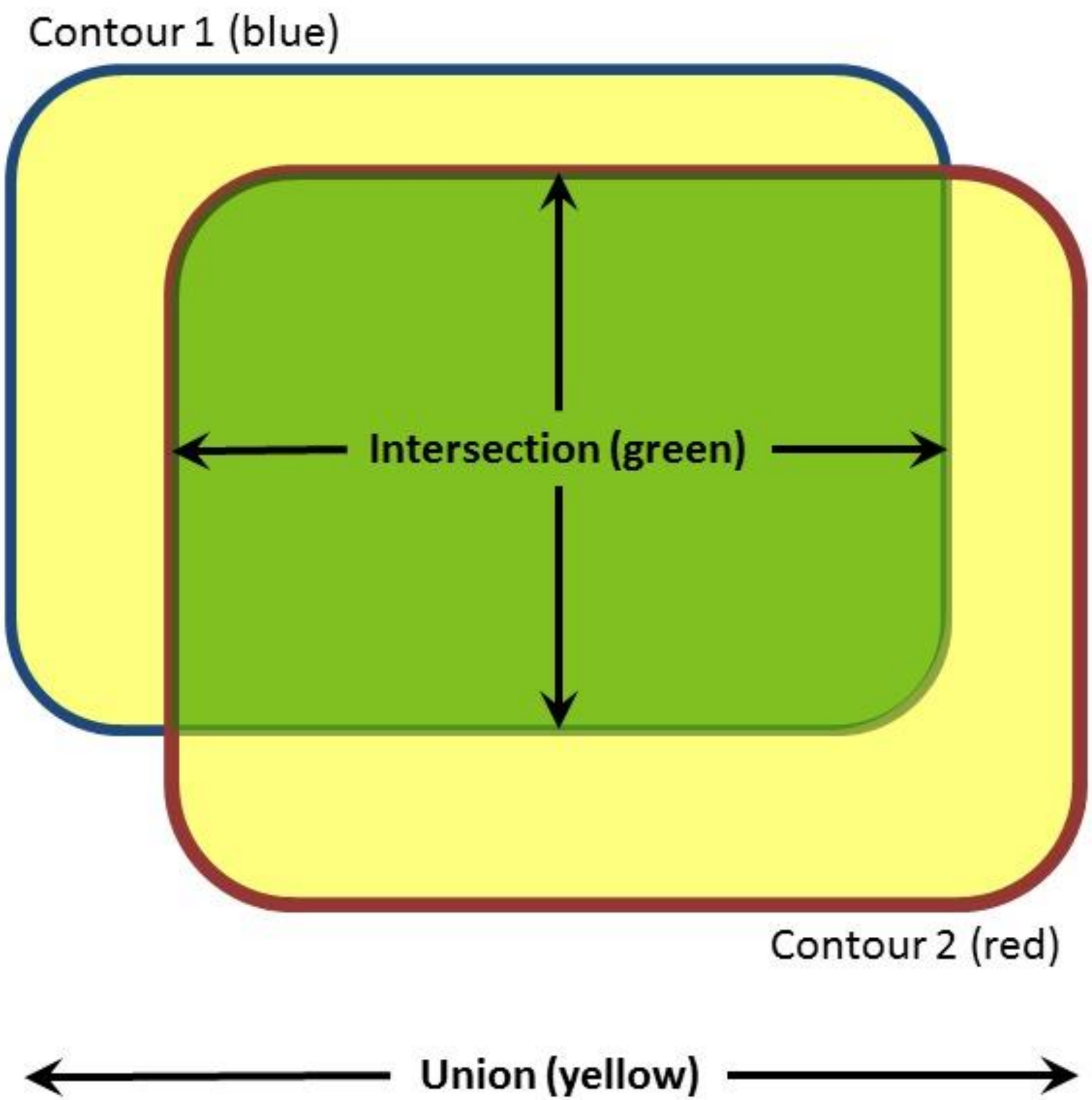
ISODOSE LINES



COLOUR	ISODOSE LINE
Dark green	100%
Light green	80%
Sky green	60%
Pink	50%
Blue	40%

OAR coverage

SL NO	ORGAN	DESIRABLE	ACHIEVED
1	**RT. EYE**	MAX <22.5Gy	1.97Gy
2	**LT. EYE**	MAX <22.5Gy	4.4Gy
3	**RT. OPTIC NERVE**	MAX <22.5Gy	2.3Gy
4	**LT. OPTIC NERVE**	MAX <22.5Gy	5.5Gy
5	**OPTIC CHIASM**	MAX <22.5Gy	7.5Gy
8	**BRAIN STEM**	MAX 23-31Gy	10.01Gy
9	**RT. COCHLEA**	MEAN <25Gy	<1Gy
10	**LT. COCHLEA**	MEAN <25Gy	<1Gy

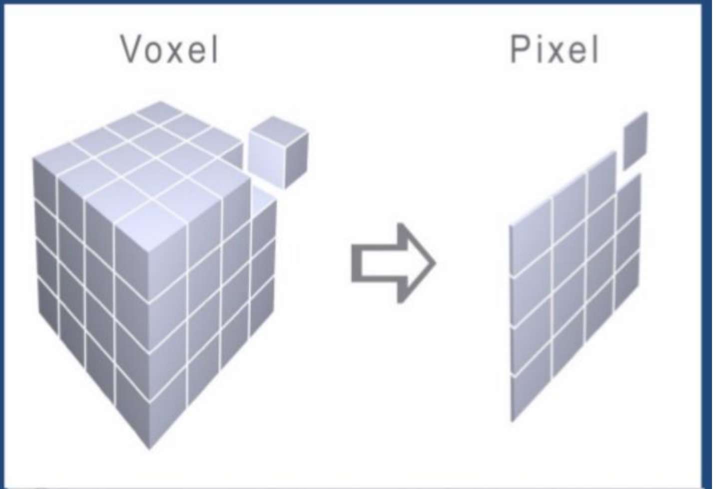


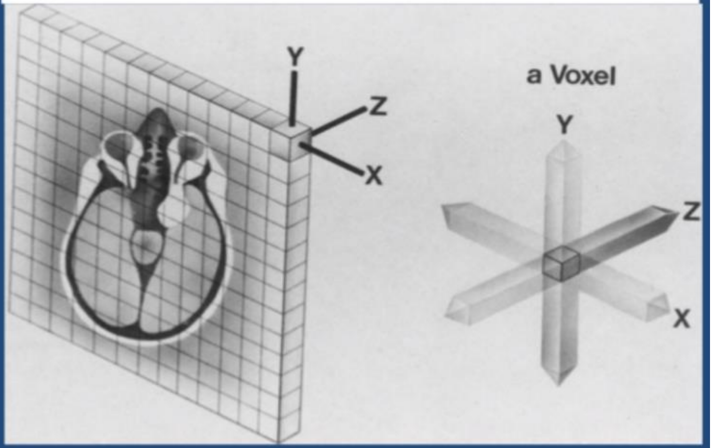
Conformity Index of Contours 1 and 2

$$CI = \frac{\text{Intersection}}{\text{Union}}$$

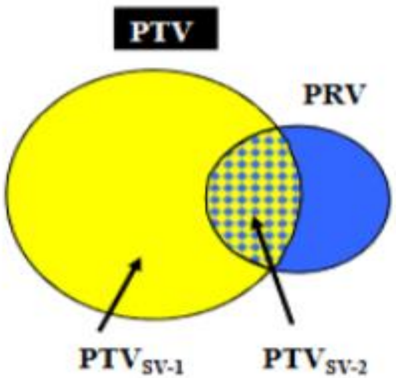
Basics of plan evaluation – Voxel And Pixel

- A **voxel** represents a value on a regular grid in three-dimensional space.
- Voxel is a combination of "volume" and "pixel" where **pixel** is a combination of "picture" and "element"

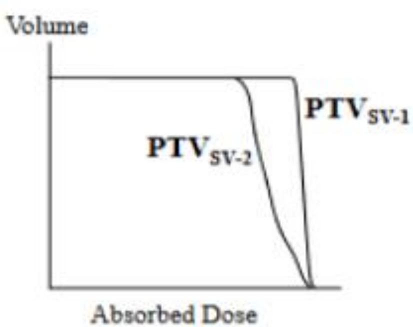


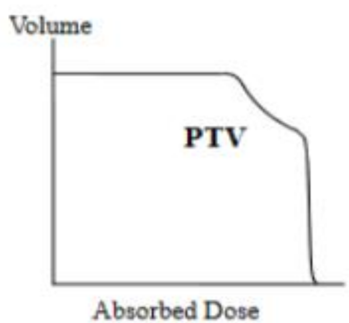


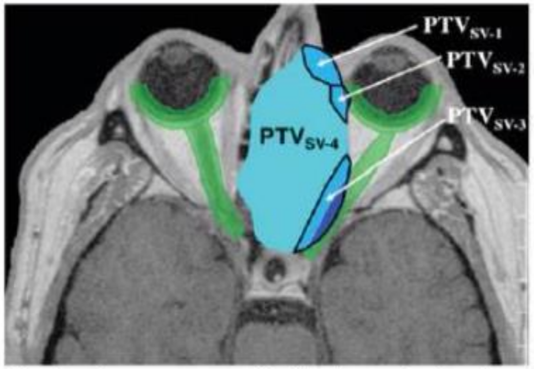
Basics of plan evaluation – junction volume



$$PTV = PTV_{SV-1} + PTV_{SV-2}$$







Planning aims

PTV
- median dose (D_{50} %): 70.0 Gy
- near-min dose (D_{98} %): ≥ 66.5 Gy
- near-max dose (D_2 %): ≤ 74.9 Gy

Optic nerves
- near-max dose (D_2 %): ≤ 60.0 Gy

Retina
- near-max dose (D_2 %): ≤ 50.0 Gy

Modification to planning aims

PTV
- PTV$_{SV-1}$
  - near-max dose (D_2 %): ≤ 74.9 Gy
  - near-min dose (D_{98} %): ≥ 66.5 Gy
- PTV$_{SV-2}$
  - near-max dose (D_2 %): ≤ 50.0 Gy
  - near-min dose (D_{98} %): ≥ 49.0 Gy
- PTV$_{SV-3}$
  - near-max dose (D_2 %): ≤ 60.0 Gy
  - near-min dose (D_{98} %): ≥ 58.0 Gy
- PTV$_{SV-4}$
  - median dose (D_{50} %): 70.0 Gy
  - near-max dose (D_2 %): ≤ 74.9 Gy
  - near-min dose (D_{98} %): ≥ 66.5 Gy

PRV optic nerves
- near-max dose (D_2 %): ≤ 60.0 Gy

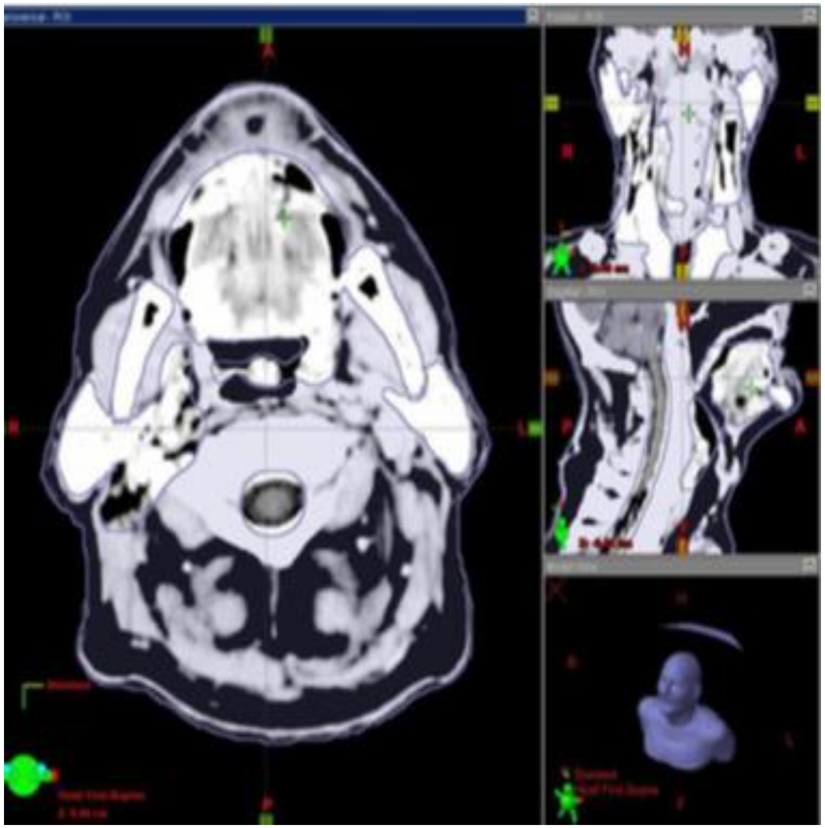
PRV retina
- near-max dose (D_2 %): ≤ 50.0 Gy

Accept under dosage in one of the Subvolumes

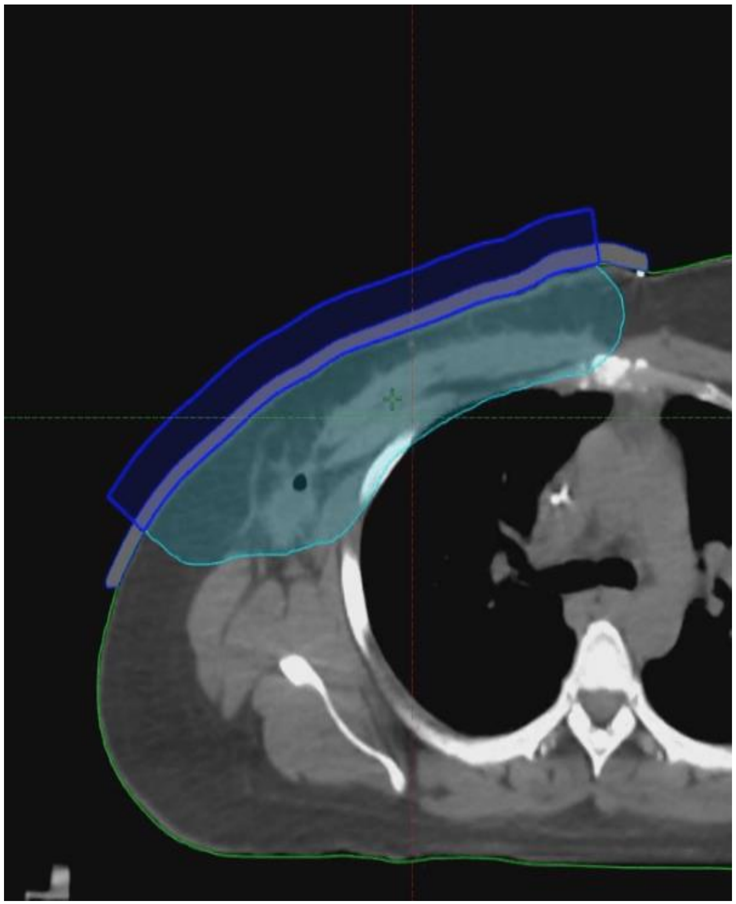
Basics of plan evaluation – junction volume

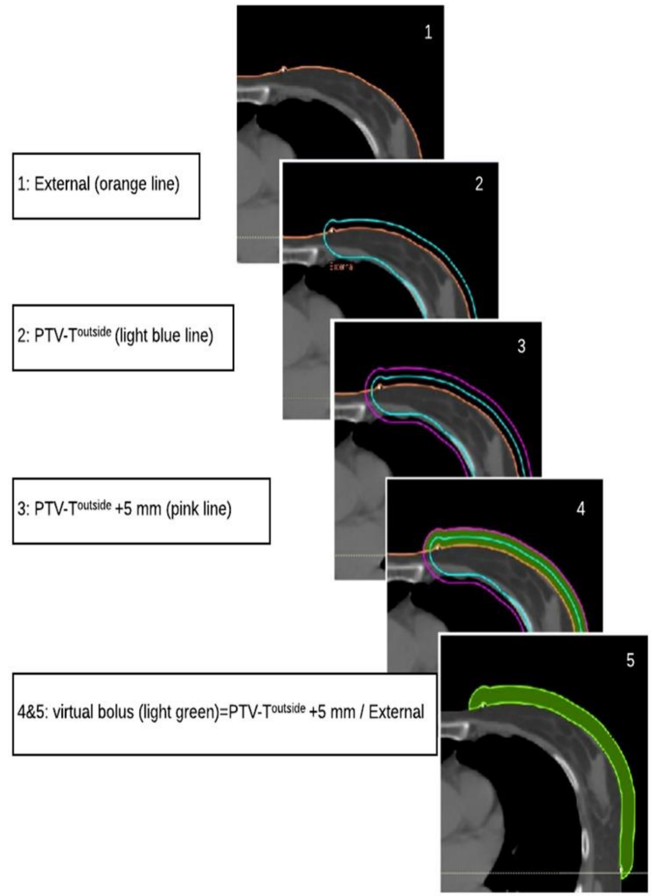
1. For plan optimization, additional dose may be dumped in RVR.

2. High absorbed dose in RVR



Basics of plan evaluation – FLASH vs BOLUS



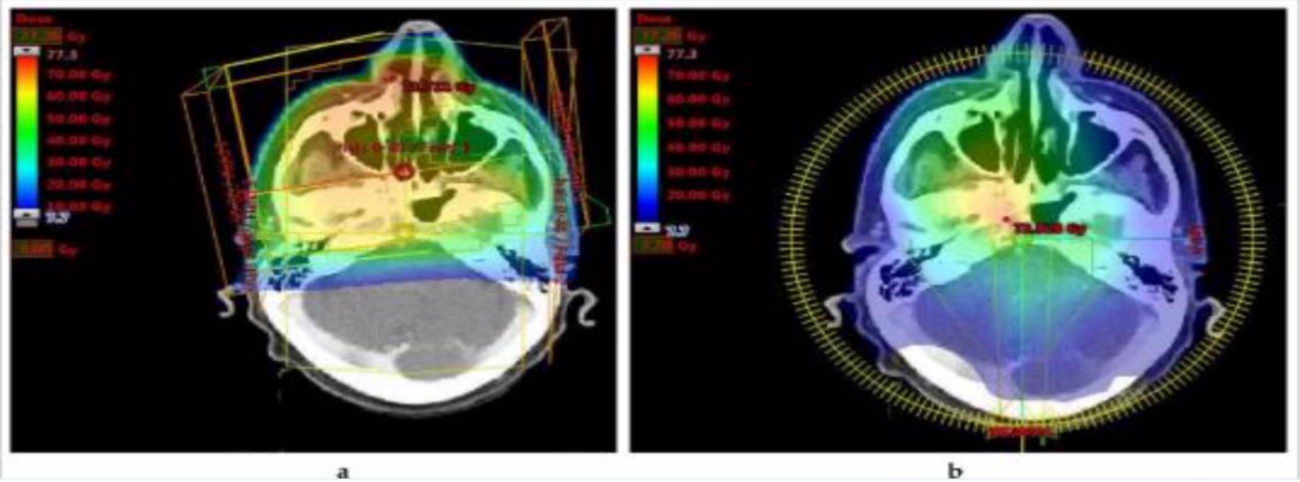


Basics of plan evaluation – dose displaying

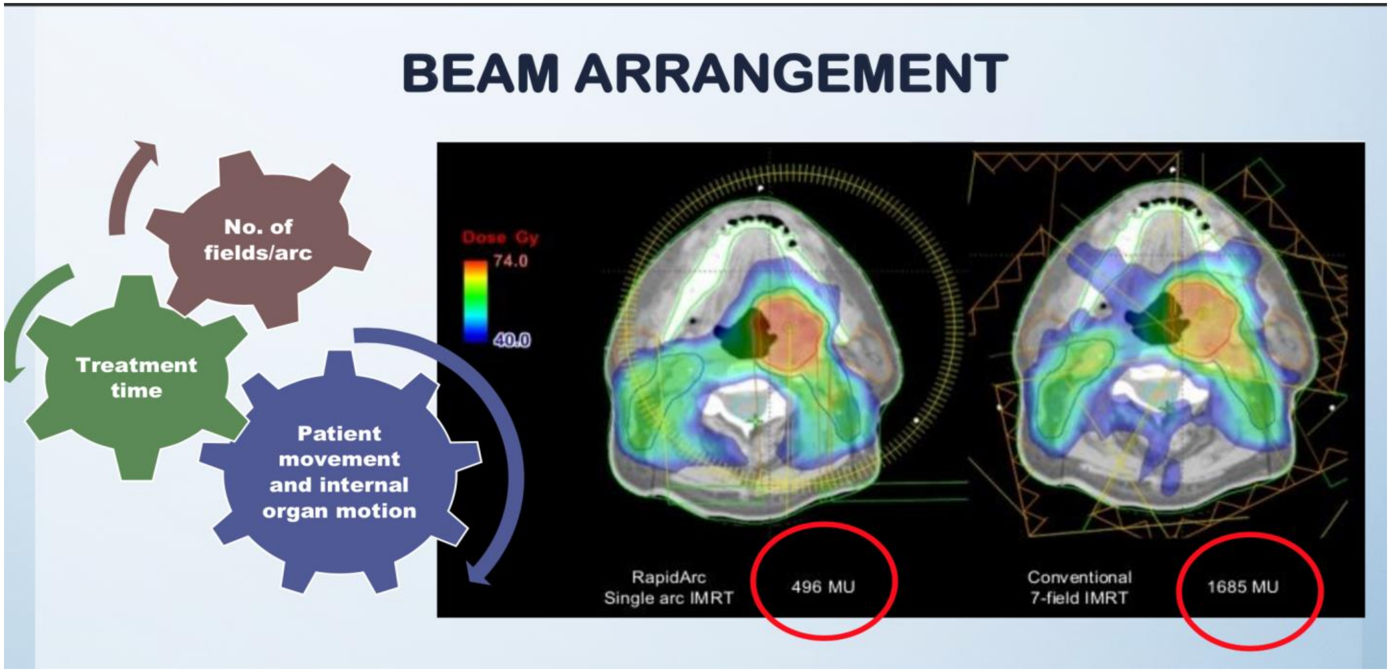
1. Isodose Contours: Set of closed contours linking voxels of equal dose
2. Color Wash: The coding of CT and Dose in the same voxel through the modulation of both intensity (CT) and color (Dose)
3. Isodose Surfaces: The Shaded surface (pseudo 3D) representation of the particular dose level and selected VOI

Basics of plan evaluation – Low dose bath

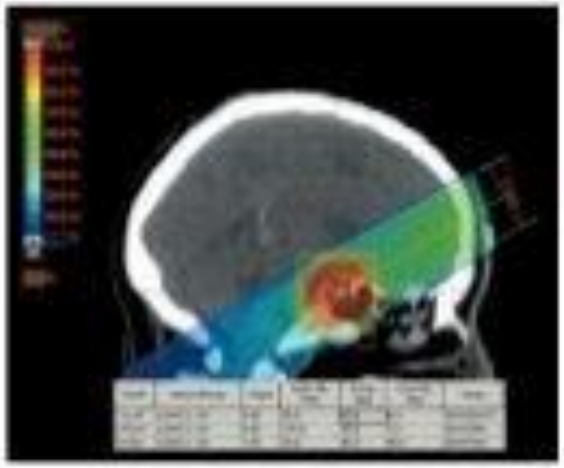
Figure 1. A comparison between a three-dimensional conformal radiotherapy (3DCRT) plan and a volumetric modulated arc therapy (VMAT) plan for a head and neck tumour. Notice the larger volume of the posterior fossa receiving a low dose bath in the VMAT plan. (**a**) 3DCRT; (**b**) VMAT.

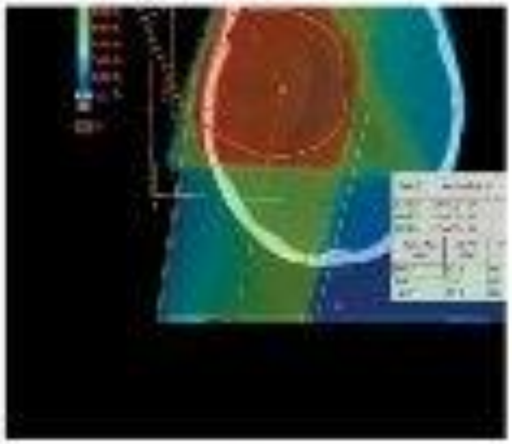


Basics of plan evaluation – Beam arrangements

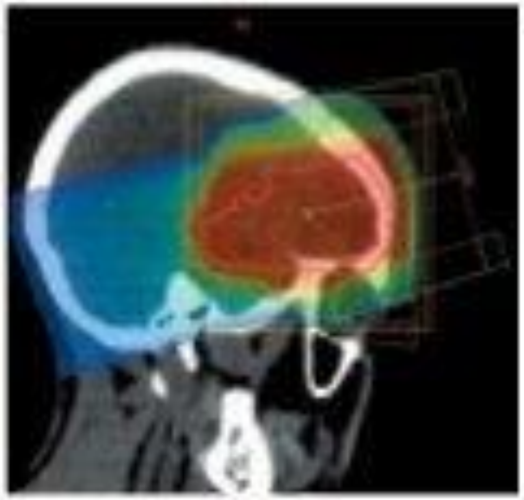


Basics of plan evaluation – BEAM exit point





Patient positioning: A neutral head position with the patient supine is easily reproducible. Noncoplanar beams can be used to avoid entry and exit dose to organs at risk (OAR).



Basics of plan evaluation – standardizing names

Standardizing Normal Tissue Contouring for Radiation Therapy Treatment Planning: An ASTRO Consensus Paper

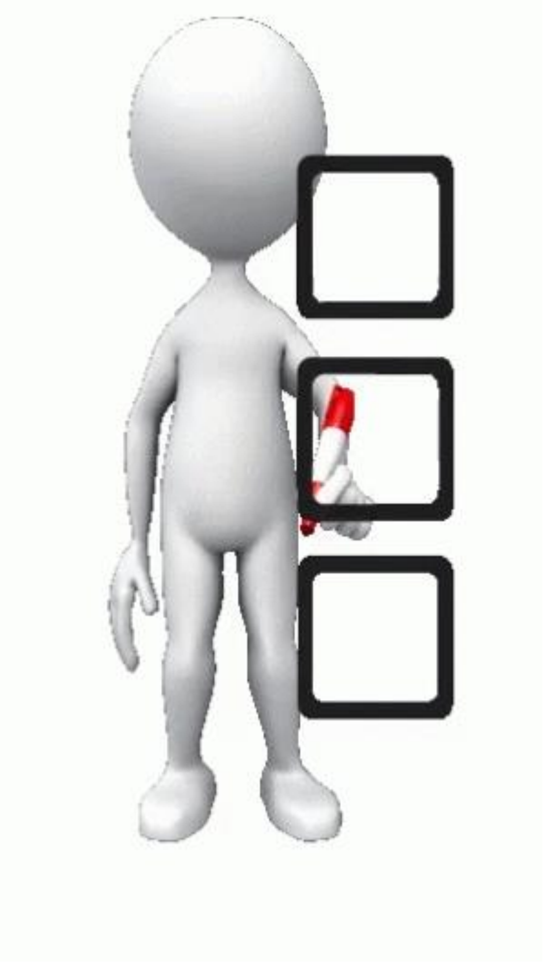
Jean L. Wright, MD,[a] Sue S. Yom, MD, PhD, MAS,[b] Musaddiq J. Awan, MD,[c] Samantha Dawes, CMD,[d] Benjamin Fischer-Valuck, MD,[e] Randi Kudner, MA,[d] Raymond Mailhot Vega, MD, MPH,[f] George Rodrigues, MD, PhD[g]

a. Johns Hopkins University, Baltimore, MD.
b. University of California, San Francisco, CA
c. University Hospitals of Cleveland and Case Western Reserve University, Cleveland, OH
d. American Society for Radiation Oncology, Arlington, VA
e. Washington University School of Medicine, St. Louis, MO
f. Perlmutter Cancer Center Department of Radiation Oncology, New York University, New York, NY
g. London Health Sciences Centre, London, ON, Canada

This document was prepared for the American Society for Radiation Oncology (ASTRO) Clinical Affairs and Quality Council as part of an ongoing quality initiative with the goal of enabling members to consistently deliver the highest quality and value care to cancer patients.

H&N		
Treated Organ	**Recommended**	**Consider**
Face, Parotid	Brainstem Eye_L/R Lens_L/R Lips Parotid_L/R SpinalCord	Bone_Mandible Cavity_Oral Cochlea Glnd_Lacrimal_L/R Glnd_Submand_L/R Joint_TM_L/R Lobe_Temporal _L/R
Orbit	Brain Brainstem Eye_L/R Glnd_Lacrimal_L/R Lens_L/R OpticNrv_L/R OpticChiasm Parotid_L/R	Cochlea_L/R Lobe_Temporal _L/R Pituitary Retina

Basics of plan evaluation – check list



TRAIN YOUR BRAIN TO DECREASE THE DOSES TO DARS STRACTURES BUT NOT AT THE COST OF PTV

RESTRAIN YOURSELF FROM GIVING STRICT CONSTRAIN OTHERWISE TUMOR WILL SUSTAIN.

kanhu