A CLINICIANS PERSPECTIVE TO PLAN EVALUATION

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THE PRESENTATION IS A OUTLINE TO THE FINAL PRESENTATION AND MODIFICATIONS AND IMPROVISATION WILL BE DONE PRIOR TO THE COURSE DATES

- A Clinician’s perpective is to achieve the best possible dose delivery to the patient while ensuring the OARs are respected.
- In the process, clinician needs to understand
  - The dose requirement for the treatment
  - The biology and spread patterns of the disease
  - The OAR constraints
  - The basic principles of physics – like dose distributions, beam placements, limitations etc
- The final responsibility of the plan lies with the oncologist, including the appropriate delivery of the planned treatment

APPLIED RADIATION ONCOLOGY

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

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KNOWING WHAT TO CONTOUR

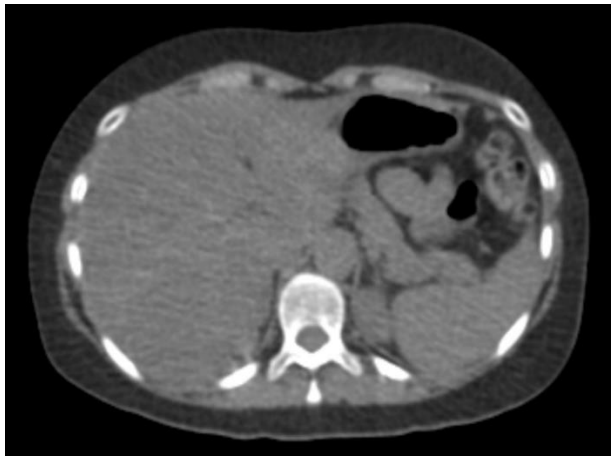
ASPECTS OF CONTOURING

- Accquisition of appropriate diagnostic imaging – CT scan, MRI, PET, PSMA PET etc
- Appropriate treatment planning CT scan – immobilisation, contrast, slice thickness, scan extent
- Appropriate delineation of the GTV using imaging/ preop-prechemo GTV mapping

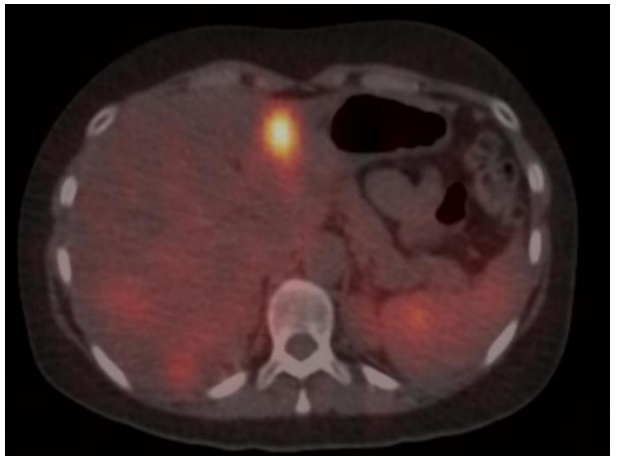
Selection of appropriate window level for contouring -Brain: C35, W100. Bone: C450, W1600. H&N: C35, W350. Parotid: C840 , W370

- Knowing the microscopic extension and locoregional spread pattern of the given malignancy to define the CTV
- Knowing the physiologic motion of the target volume to define the ITV as per motion/ motion restriction
- Accounting for the set up errors – PTV [institutional, use of Van Herk formula]
- Defining the organs at risk with accurate delineation and use of accurate PRV margins

Definitions of volumes in lecture on ICRU 50/62



CT Image



Fused Image

THE EYES SEE AND THE HANDS DO WHAT THE MIND KNOWS !!!

Imaging

- Brain tumours - MRI with contrast/MRSA
- Prostate cancer – PSMA PET for staging, MRI for contouring

GTV to CTV margin

- GBM – 2 cm
- Esophagus – 4 cm craniocaudal, 1 cm radial

ITV

- None for brain tumours
- Significant for target volumes in proximity of bladder and rectum
- Maximum for lower lobe lung, liver tumours

UNIFORMITY OF COLOUR CODING

- These are in different colors for an easy and uniform interpretation.
  - GTV - Dark Red
  - CTV – Light Red
  - ITV – Dark Blue
  - PTV – Light Blue
  - OAR – Dark Green
  - PRV – Light Green
  - Landmarks - Black

- Better to cross check contour if done by someone else and to get your contour reviewed by your colleagues – PRAT/ peer review audit tool
- Check all OARS
- Best to standardise volumes as per protocols
- Constantly update yourself with the new guidelines by means of articles, workshops/conference, online resources like ASTRO/RTOG or NRG oncology/ESTRO

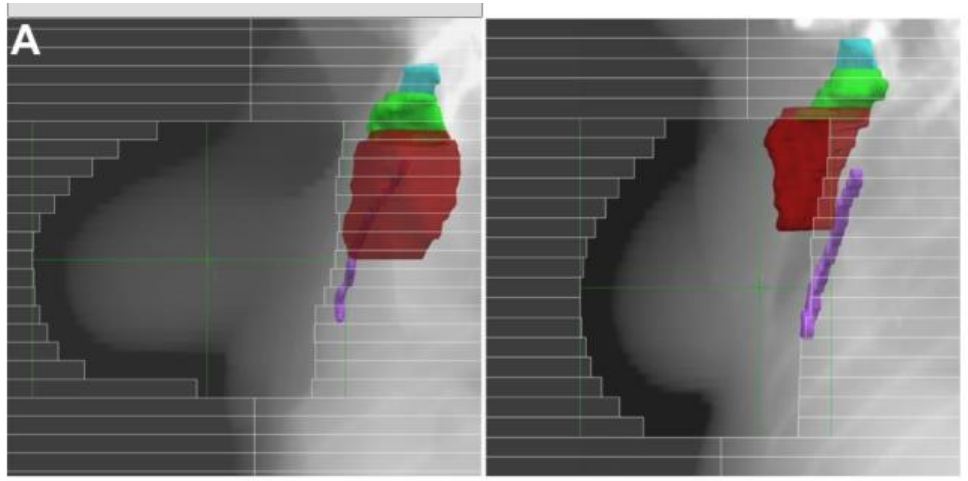
Reasons for Identification of Treated Volume

1. The shape and size of the Treated Volume relative to the PTV is an important optimization parameter.

2. Also, a recurrence within a Treated Volume but outside the PTV may be considered to be a “true”, “in-field” recurrence due to inadequate dose and not a “marginal” recurrence due to inadequate volume.

BEAM ARRRANGEMENTS

- Define importance or priority of target and OARS
- Prefer beams to ensure radiation going to minimal soft tissue
- Plan OARS to be avoided
- Selection of technique best to achieve targets yet keep OAR doses to minimum
- Prefer techniques with less low dose volumes
- Know when to use combination of techniques – complex plans



TECHNIQUE SELECTION

- Keep in mind
- Duration of treatment – palliative patient in pain/ needs anesthesia/ planned with DIBH/ variation of bladder-rectal filling/ general fitness and cooperation of patient
- Position of the patient – comfort

ASSESMENT OF PLAN

Need to understand

- Isodose/isofills/isolines
- Dose volume histograms [DVH] – differential and cumulative
- Dose statics
- Use of all views to see dose wash – axial/coronal/saggital
- Knowing desired PTV coverage, where to accept compromise in coverage versus compromise OAR
- Knowing OAR constrains and evaluation of their doses

Isodose Curves

- **Isodose curves** are the lines joining the points of equal Percentage Depth Dose (PDD)

- If the isodose covering the PTV is within a desired range (95-100%) and OAR doses are acceptable – plan is acceptable
- Isodose curve evaluation should be done in all sections – axial, coronal, saggital

Dose Statistics

- **Volume covered by a dose**
  - Volume of PTV getting a dose of 95% - V95. we could also have V90, V105, V107 to assess coverage and hot spots
- **Dose covering a volume**
  - Dose going to a volume percentage of PTV – D95
- **Minimum dose**
  - Strong correlation between target minimum dose and clinical outcome
  - High percentage of the dose maximum
- **Maximum dose**
  - Useful tool for critical structures, radiation reactions
  - Typically tolerance dose
- **Mean dose**
  - Indicator of dose uniformity within the target volume
  - Should be very close to maximum dose

DOSE FOR TARGET VOLUMES

- Dose should range between 95%-107% of prescribed dose
- Dose inhomogeneity within target volume - +/-1-%
- ICRU 83 report is used for describing IMRT has described $D_{98\%}$, $D_{50\%}$, and $D_{2\%}$. (D_{max}, D_{median} and D_{min})
- Check location and volume of D_{max} in each slice – GLOBAL Dmax value without knowing location and volume is insufficient information

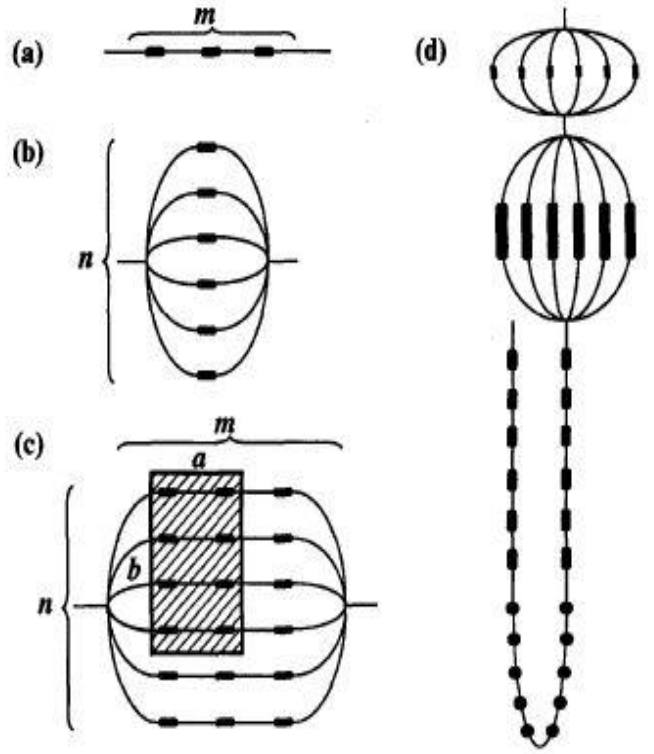
Definitions of terms in presentation on ICRU-83

Organ(s) at Risk (OAR)

- These are normal tissues whose radiation sensitivity may significantly influence the treatment planning and/or prescribed dose.
- These organs receive some dose irrespective of the planning technique
- All OARs have a tolerance dose below which risk of severe side effects is minimal
- OAR's have 3 classes :
  - Class I : Radiation lesions are fatal or result in severe morbidity.
  - Class II : Radiation lesions result in mild to moderate morbidity.
  - Class III : Radiation lesions are mild, transient, and reversible, or result in no significant morbidity.

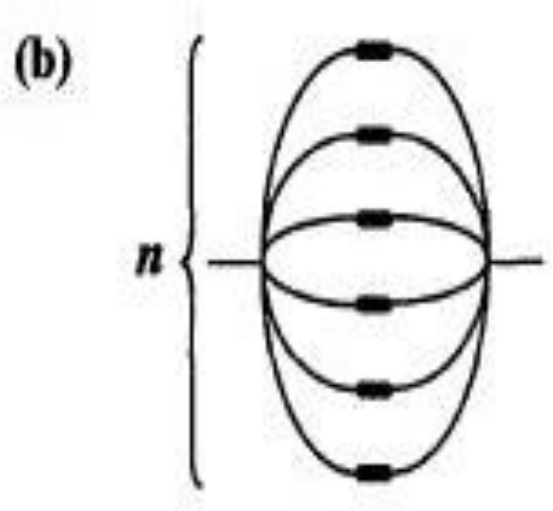
BIOLOGICAL CLASSIFICATION OF OAR'S

- Tissues can be thought of as containing **functional sub-units** (FSUs):
  - E.g. lung alveoli or kidney nephrons;
- The FSUs can be arranged in **serial** or **parallel** architectures;
- In practice, organs will display a mix of serial and parallel characteristics;



- **Serial architecture:** tissue function impaired even if a small volume is irradiated above a certain threshold:
  - Maximum dose constraints are important;

- **Parallel architecture:** function is impaired if a certain proportion of a tissue receives a dose above a given threshold:
  - Mean or dose-volume constraints are important



PARAMETERS FOR OAR'S CONSTRAINTS

- **DVH statistics** should be reviewed against recommended constraints:
  - D_V = the dose received by at least V% if the volume
  - V_D = the volume receiving a dose of at least D Gy/%

- Ideal to evaluate a plan sum of all phases at the outset of the treatment
- The **3D dose distribution** should also be reviewed:
  - The position of isodose contours relative to OARs should be checked, particularly for serial organs.

GUIDELINES FOR DOSE CONSTRAINTS

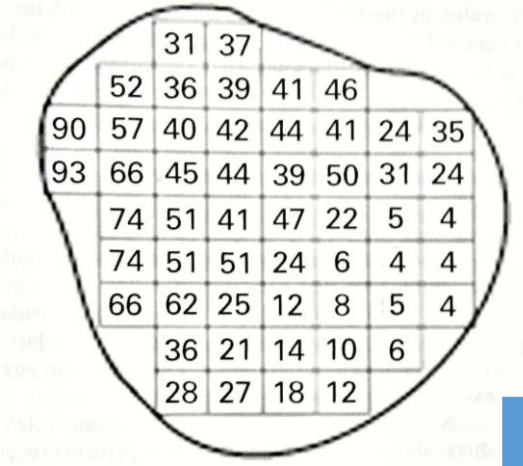
- Details of any prior radiation delivered with target and OAR doses, time since radiation – knowledge of recovery of organs
- The **QUANTEC** data is a useful resource for appropriate constraints;
- **AAPM TG-101** is also useful for hypofractionated regimes;
- BED conversions can be used for alternative fractionations;
- The relative **priority** of constraints is also relevant:
  - Critical thresholds for severe toxicities are likely to take priority.

DOSE VOLUME HISTOGRAM [DVH]

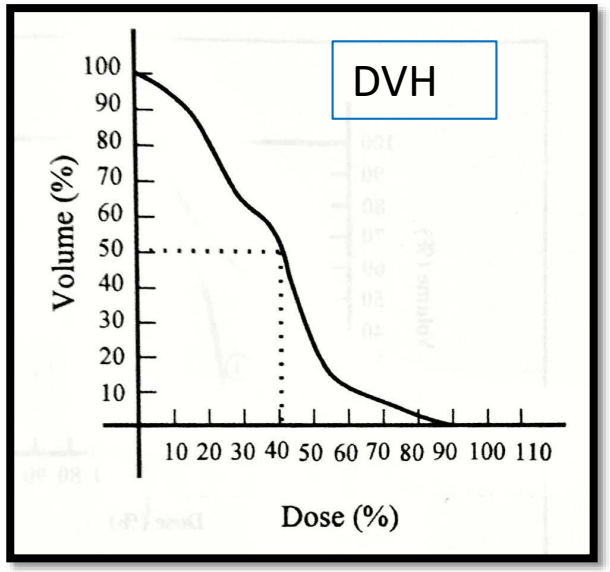
- 3D treatment plan consists of dose distribution information over a 3D matrix of point over the patient's anatomy and a DVH summariezes this information
- Very reliable quantitative evaluation of plan
- Types of DVH
  - Direct (or differential) DVH
  - Cumulative (or integral) DVH

GENERATING DVH

- Each volume is divided into a number of **voxels** (volume elements);
- The dose delivered to each voxel is determined; and
- The number of voxels receiving each dose is tallied.



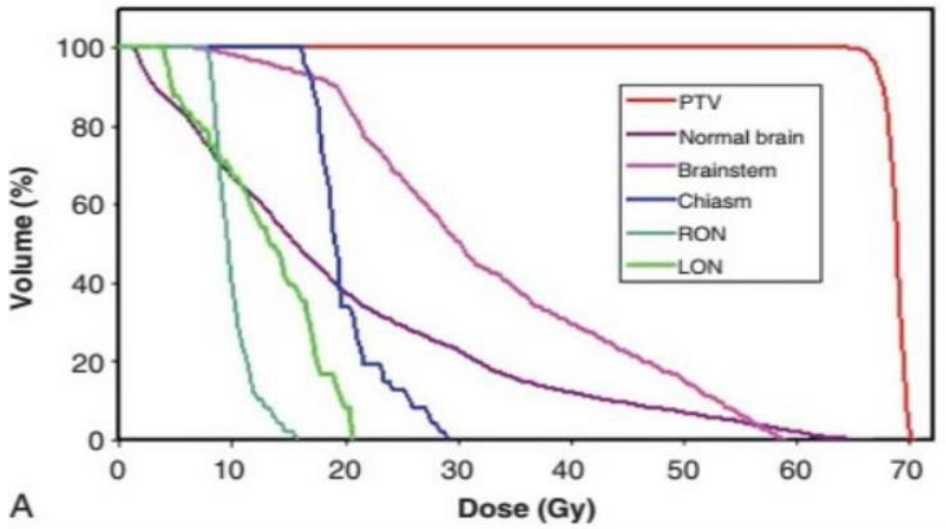
Dose (D) /%	No. voxels receiving a dose ≥ D	Percentage of total no. voxels
100	0	0.0
90	2	3.8
80	2	3.8
70	4	7.5
60	7	13.2
50	13	24.5
40	23	43.4
30	31	58.5
20	39	73.6
10	44	83.0
0	53	100.0



TYPES OF DVH

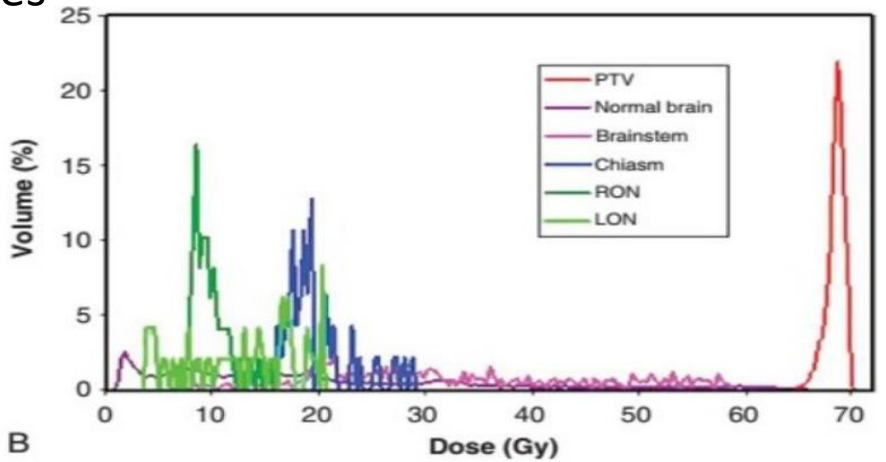
CUMULATIVE DVH

- Illustrates the volume of a structure receiving a given dose or greater
- Useful for indicating whether dose-volume constraints are met



DIFFERENTIAL DVH

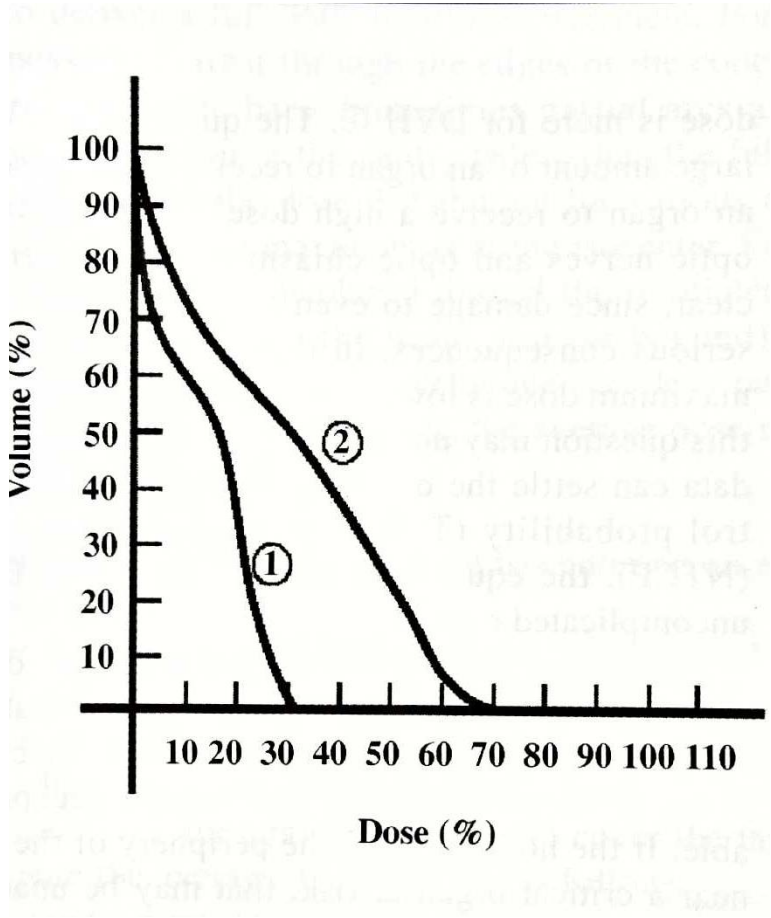
- Illustrates the volume of the a structure receiving a given dose
- Useful for indicating maximum and minimum doses

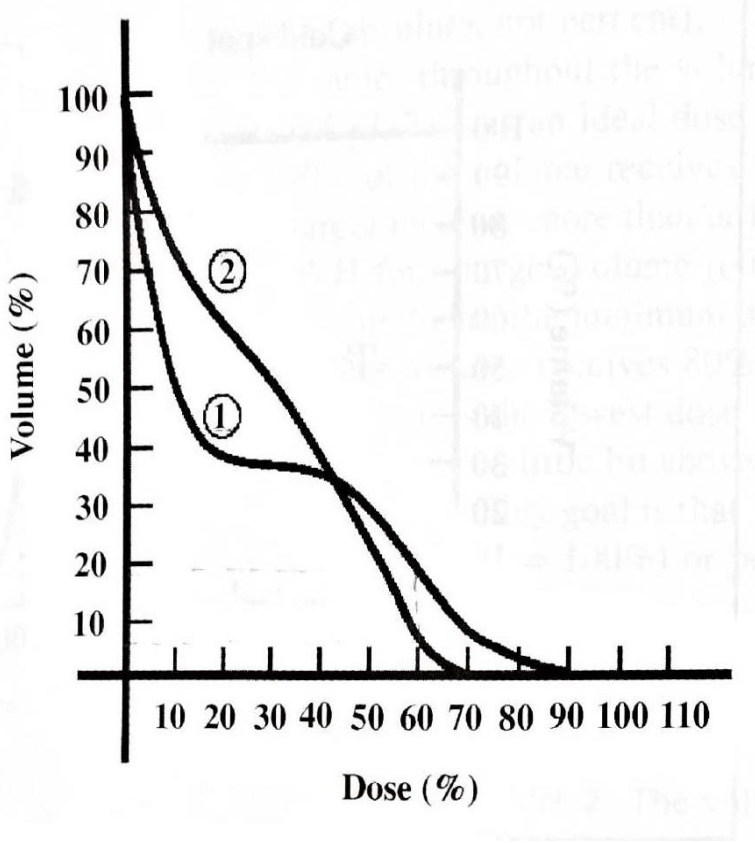


How to Interpret a DVH?

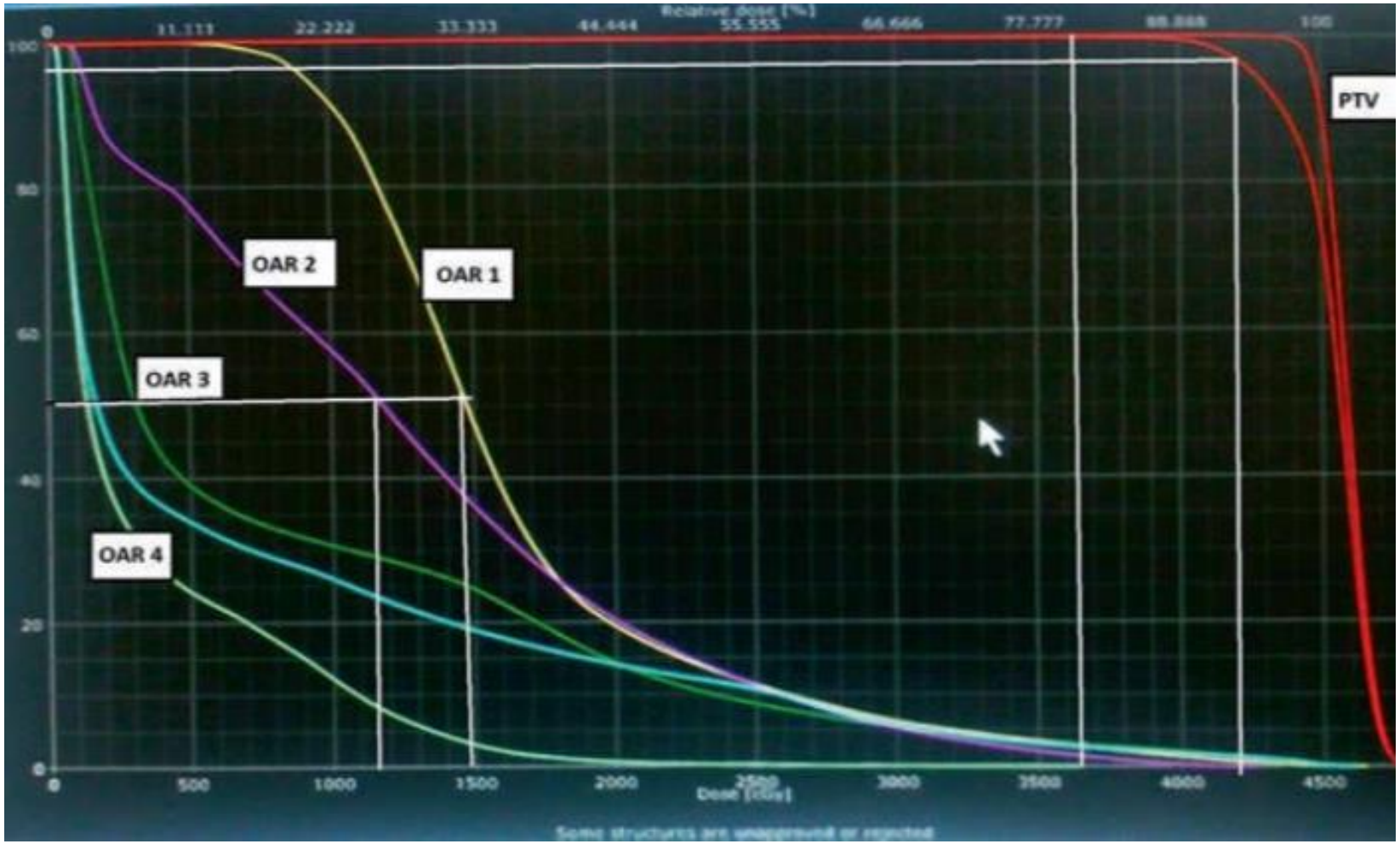
- Whether PTV coverage is adequate?
- Whether OARs are being adequately spared?
- Target volume maximal dose?
- Target volume minimal dose?
- Serial OAR: $D_{nearmax}$
- Parallel OAR: $D_{50\%}$

Interpreting DVH

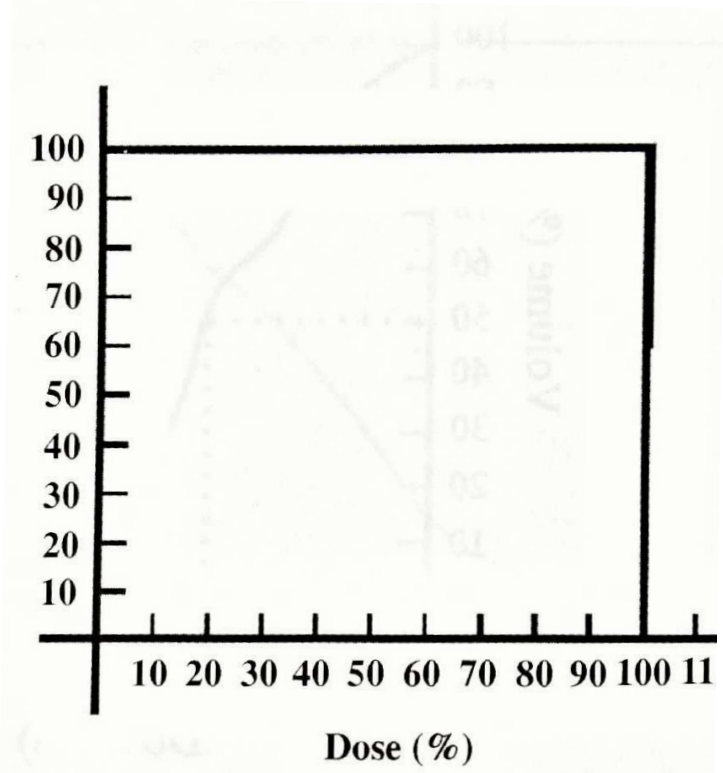




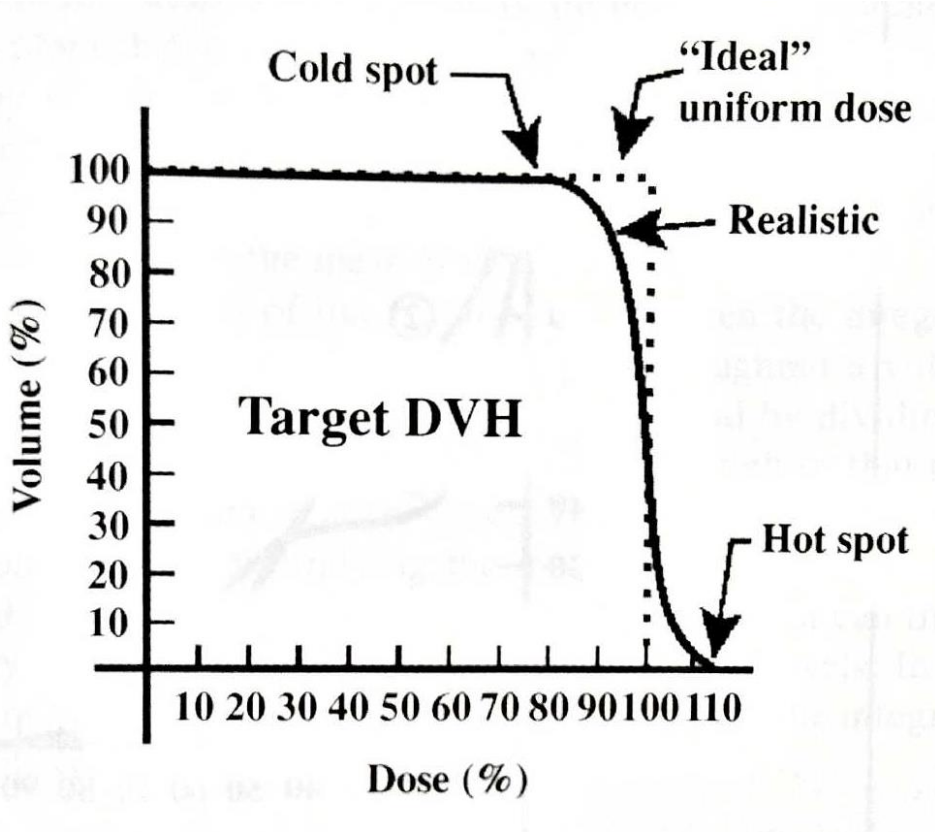
HOW TO INTERPRET A DVH?



TARGET DVH

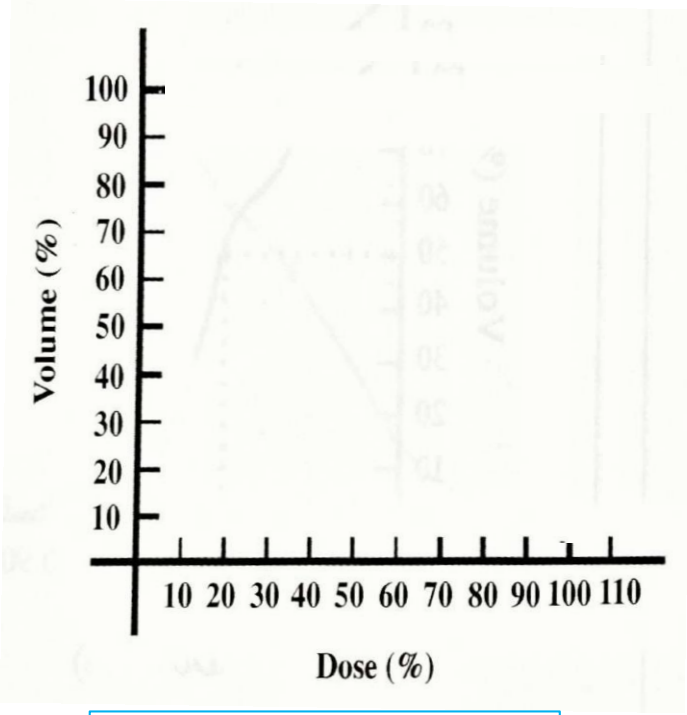


IDEAL

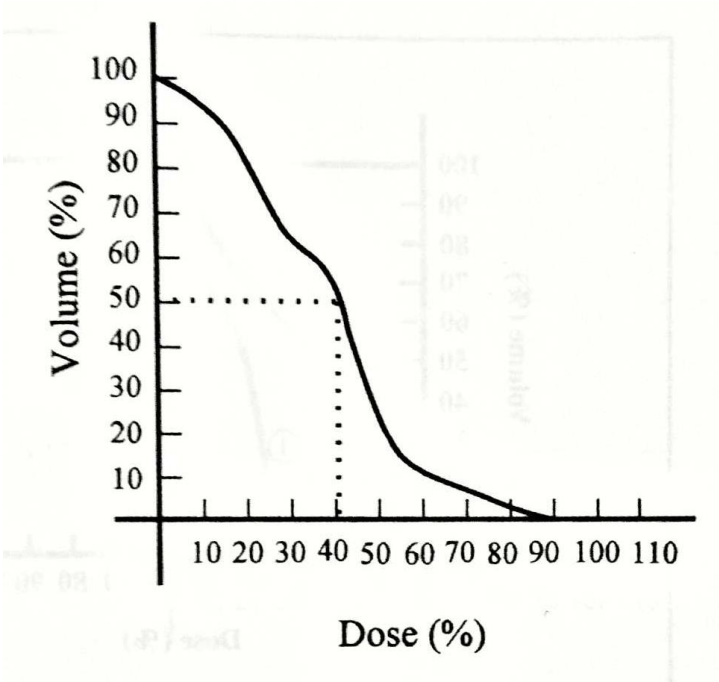


REALISTIC

OARs DVH

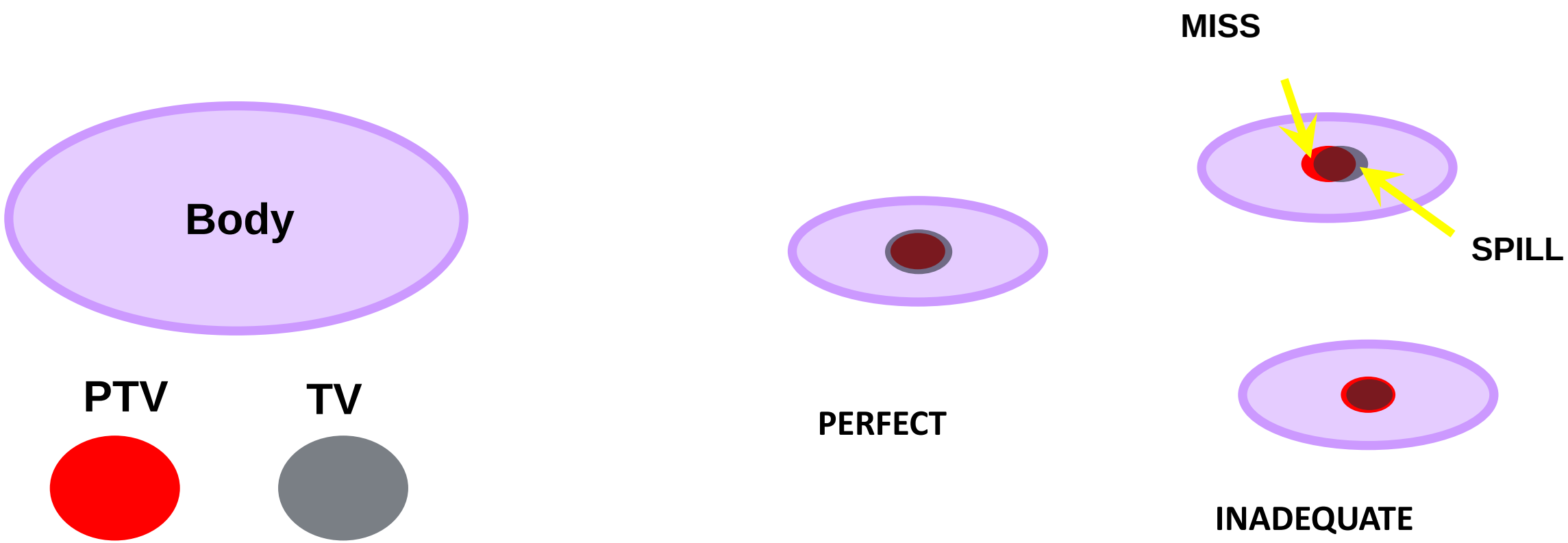


IDEAL



REALISTIC

- COVERAGE FACTOR – VOLUME OF PTV COVERED BY TV/VOLUME OF PTV [overlapping volumes
- IDEAL VALUE IS 1



- CONFORMITY INDEX & HOMOGENEITY INDEX
- They describe quality of a plan
- Definitions in talk in ICRU50 & 62

Homogeneity Index (HI)

- Measure of uniformity within PTV
- Expressed as the ratio D_2/D_{98}
  - **D_2** is the maximum dose received by **at least 2% of the PTV**
  - **D_{98}** is the maximum dose received by **at least 98% of the PTV**
- $D_2 / D_{98} = 5830/5463 = 1.067$
- For a typical 3-D CRT plan, it is around 1.07
- For IMRT it should be ≤ 1.15
- D_5 / D_{95} has also been used

Conformity Index (CI)

- As defined in ICRU 50: **CI = TV / PTV**
- Here the **Treated Volume** (TV) is the volume irradiated by a dose deemed appropriate for the purpose of treatment (typically 100% isodose) or greater.
- Ideally, ***CI* = 1**. A value greater than 1 implies the TV is too large whilst a value less than 1 implies inadequate coverage.

Hot Spots

- **Volume**: In accordance with ICRU 50;
  - There should be no hotspots outside the PTV;
  - Hotspots within the PTV should be <107% of the $D_{prescription}$
- **Location:** Hotspots should be central within the PTV, preferably within the GTV;
- Hotspots at the peripheral of the PTV, especially near OARs, should be avoided.
- However, greater doses may be encouraged for certain techniques:
  - SABR – up to 140%, RCR (2016);
  - APBI – up to 120%, RTOG 0413 (2011);

Cold Spots

- **Volume:** In accordance with ICRU 50, there should be complete coverage of the PTV by the 95% isodose;

- However, this is not always achievable:
  - At the boundary of a lung tumour with air;
  - Due to a compromise with nearby OARs;

- **Location:**
  - There should be no cold spots at the center of the PTV.

Prescription

- Last step of plan evaluation
- Dosimetrist may have edited the prescription: Recheck
- Treatment details must also be specified
  - Type of radiation (Photon/ electron)
  - Energy
  - Delivery technique (3D-CRT/ IMRT/ VMAT)
  - Schedule
- Specify Image guidance and setup verification imaging

Prescription: Immobilization

- Patient immobilization is important for **reproducible** patient **set-up** and for **preventing patients moving** during treatment;

- Appropriate immobilisation is both **site** and **technique dependent:**
  - Highly conformal treatments with nearby critical organs will require more precise immobilization;

- Patient immobilization will **not** prevent **internal organ motion**.

Prescription: Image Verification

- Image verification involves acquiring patient images immediately prior to treatment and comparing these to **reference images** (planning CT or DRRs);

- **Online verification –** the verification and reference images are compared immediately prior to treatment and are used to correct set-up if required;

- **Offline verification** – the verification and reference images are compared following treatment. Any corrections are applied to following fractions.

Prescription: Image Verification

- Image verification can be performed with combinations kV or MV planar or CBCT images;
- Planar imaging provides 2D verification which is quick and delivers less dose than CBCT;
- CBCT is required for 3D verification;
- MV images can be used for portal imaging (imaging with the treatment beam);
- kV images provide better contrast but are more sensitive to metal artifacts;

TAKE HOME

- Follow the CB-CHOP approach
- protocols and consistency is key
- Rechecks and multiple level checks by different individuals are recommended
- Plan revisions may be requested

HOWEVER….

- Have realistic expectations from the plan
- Pushing further can deteriorate the plan, delay treatment
- Foresee maximum possible requests in the first review

- FINAL RESPONSIBILITY FOR A PLAN’S SUITABILITY LIES WITH THE RADIATION ONCOLOGIST