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

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KNOWING WHAT TO CONTOUR
ASPECTS OF CONTOURING

• Acquisition 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

• 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
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 ARRANGEMENTS

• 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
ASSESSMENT 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/sagittal
• 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, sagittal
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_{\text{max}}, D_{\text{median}} and D_{\text{min}})
- Check location and volume of D_{\text{max}} in each slice – GLOBAL D_{\text{max}} value without knowing location and volume is insufficient information
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:
  ▪ $D_V = \text{the dose received by at least V}\% \text{ if the volume}$
  ▪ $V_D = \text{the volume receiving a dose of at least D Gy/\%}$

• 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 summarizes 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.

<table>
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<th>Dose (D) /%</th>
<th>No. voxels receiving a dose $\geq$ D</th>
<th>Percent age of total no. voxels</th>
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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 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: $D_{\text{nearmax}}$
- 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 $\leq 1.15$

- $D_5 / D_{95}$ has also been used
Conformity Index (CI)

- As defined in ICRU 50: \( \text{CI} = \frac{\text{TV}}{\text{PTV}} \)

- 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, \( \text{CI} = 1 \). 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 $D_{\text{prescription}}$

- **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