Defining Target Volumes and Organs at Risk: a common language

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Objective:
To introduce target volumes and organ at risk concepts as defined by ICRU

Learning Outcomes:

• Distinguish the various target volume definitions of ICRU Reports (GTV, CTV, and ITV)
• Determine how these elements are part of a global planning target volume (PTV) construction
• Describe the elements that influence the definitive shape and volume of the PTV and OAR
Background concepts

• The process of RT is a teamwork
• In the 2D era, it was not necessary to define volumes
• In the 3D era it is necessary to define volumes accurately
• The RO is the one responsible for the definition of the target volumes, while the organs at risk can be contoured by a RO, trained RTT or dosimetrist.
• There is strong inter-observer variation
• There was a need for a common language
Relation between benefit and complexity/cost with technological advances in radiotherapy

- Complexity
- Time requirements
- QA requirements
- Costs
New technologies
(IMRT  IGRT  SBRT  SRT  arc robotic)

... are able to deliver pre-determined doses of radiation with high precision to limited and irregular volumes, while at the same time limiting the dose to healthy organs according to pre-determined dose-volume constraints.
The process of radiotherapy

1. Clinical evaluation
2. Treatment decision
3. Image acquisition
4. Treatment planning
5. Simulation/verification
6. Treatment delivery
7. Patient evaluation during treatment
8. Final evaluation/Report
9. Patient follow-up
The process of radiotherapy

1. Clinical evaluation
2. Treatment decision
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The process of radiotherapy treatment planning

- Positioning and immobilization
- Image acquisition
- Structure segmentation (volume contouring)
- Beams and dose calculations
- Evaluation and approval of plan
- Virtual simulation
- Data transfer
- Treatment delivery
- Treatment verification
The process of radiotherapy treatment planning

- Positioning and immobilization
- Image acquisition
- **Structure segmentation (volume contouring)**
- Beams and dose calculations
- Evaluation and approval of plan
- Virtual simulation
- Data transfer
- Treatment delivery
- Treatment verification
The process of radiotherapy treatment planning

3D CRT process

- Positioning and immobilization
- Image acquisition
- Structure segmentation
- Treatment planning and evaluation
- Plan validation if necessary
- File transfer and management
- Position verification
- Treatment verification and delivery
In 2D radiotherapy

- Dose is prescribed to a reference point or to an isodose line
- The TPS algorithm calculates dose-distributions on a plane
- The treatment plan is evaluated on a plane (or various planes: “2.5 D”)
- There is no concept of volume
In 3D radiotherapy

- Dose is prescribed to a volume or several volumes
- The TPS algorithm calculates dose-distributions in a volume
- The dose to volumes of healthy organs can be quantified
- The treatment plan is evaluated looking at volumes (BEV)
- or to a quantitative analysis of doses/volumes (DVH)
ICRU 29

“Target volume” & uniform prescription concepts: “2-D era”

1978

- Single slice (or few)
- External contour
- Coplanar beams
- Simple calculations
- Dose prescription to “ICRU reference point”
Prescribing, Recording and Reporting Photon Beam Therapy

The new ICRU Report 83

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Journal of the ICRU

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Prescribing, Recording, and Reporting Photon-Beam Intensity-Modulated Radiation Therapy (IMRT)

2010
GTV

Gross Tumour Volume

Is the gross demonstrable extent and location of the malignant growth.

GTV 1 – primary
GTV 2 – + lymph nodes
GTV clinical and radiological
Difficulties in GTV determination

- Larger lateral and posterior wall extension
- Larger cartilage, extralaryngeal and contralateral side extension
- 
- CT-scan
- FDG-PET
- MRI

Daisne et al., Radiother Oncol 69, 247-250, 2003
GTV on CT

- Use the right window settings
- Use the right contrast and delay
Inter-observer variation in GTV and CTV delineation

Leunens et al., Radiother Oncol 29: 169-175, 1993

Dimopoulouss et al., Radiother Oncol 89: 164-171, 2008
In the post-operative setting ...

Anaplastic meningioma

Post Prostatectomy

Guidelines based on anatomic boundaries or co-registered pre-op MRI?
CTV
Clinical Target Volume

Is a tissue volume that contains a demonstrable GTV and/or subclinical malignant disease that must be eliminated.

This volume must be treated adequately in order to achieve the aim of radical therapy.
Cervical lymph node regions

Surgical levels

RO levels for 3D-CRT

A margin must be added to the CTV to compensate for expected physiologic movements and variations in size, shape and position of the CTV during therapy. Includes the CTV and an “Internal Margin”
PTV
Planning Target Volume

Is a *geometrical concept* used for treatment planning and it is defined to select appropriate beam sizes and beam arrangements, to ensure that the prescribed dose is actually delivered to the CTV.
GTV is the gross tumour volume

CTV is the GTV + subclinical disease

PTV = CTV + patient movements, set-up and beam inaccuracies

These are oncological (clinical) concepts

This is a geometrical concept (for the purpose of planning)
TV
Treated Volume

Is the tissue volume that (according to the approved treatment plan) is planned to receive at least a dose selected and specified by the radiation oncology team as being appropriate to achieve the purpose of treatment e.g. tumour eradication or palliation, within the bound of acceptable complications.
IV

Irradiated Volume

Is the tissue volume that receives a dose that is considered significant in relation to normal tissue tolerance.
Organ at risk (OAR): Organ whose radiation sensitivity is such that the dose received by during treatment may be significant compared to its tolerance.

- OARs may significantly influence treatment planning and/or prescribed dose.
GTV and CTV: NSCLC stage IIIA
PTV
Treated volume
Irradiated volume
ICRU Report 83

- 2010
- 3-D CRT to IMRT
- More availability of CT
- Additional imaging – CT + MRI, PET, PET/CT
- Improved conformality
- Reduced doses to normal tissues
- More detailed dose-volume information on TPS
- Use of dose-volume constraints
- Automated optimization
ICRU 83 – Dose Specification

~= dose to ICRU reference point
The RVR is defined by the difference between the volume enclosed by the external contour of the patient and that of the CTVs and OARs on the slices that have been imaged.

The RVR is of importance in evaluating plans; if not specifically evaluated, there could be unsuspected regions of high absorbed dose within the patient that would otherwise go undetected.
Dose distribution for conventional beam (A) and IMRT (B) treatment of an oropharyngeal tumour. The patient experienced a lip desquamation (dashed arrow) and hair loss in the occipital/posterior area (solid arrow), which are not expected with conventional bilateral opposing beams (Zhen et al., Med. Dos. 27, 155-159, 2002).
3 Clinical Scenarios [A]

- GTV

- CTV = GTV + subclinical

- PTV = CTV + IM + SM
3 Clinical Scenarios [B]

- The IM and the SM have been considered together into a “global“ safety margin
- The PTV is smaller
3 Clinical Scenarios [C]

When an OAR is closer to the GTV, this reduces the width of the acceptable safety margin ...

Thank you!