Delineation and Target concepts

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Disclosures

- None

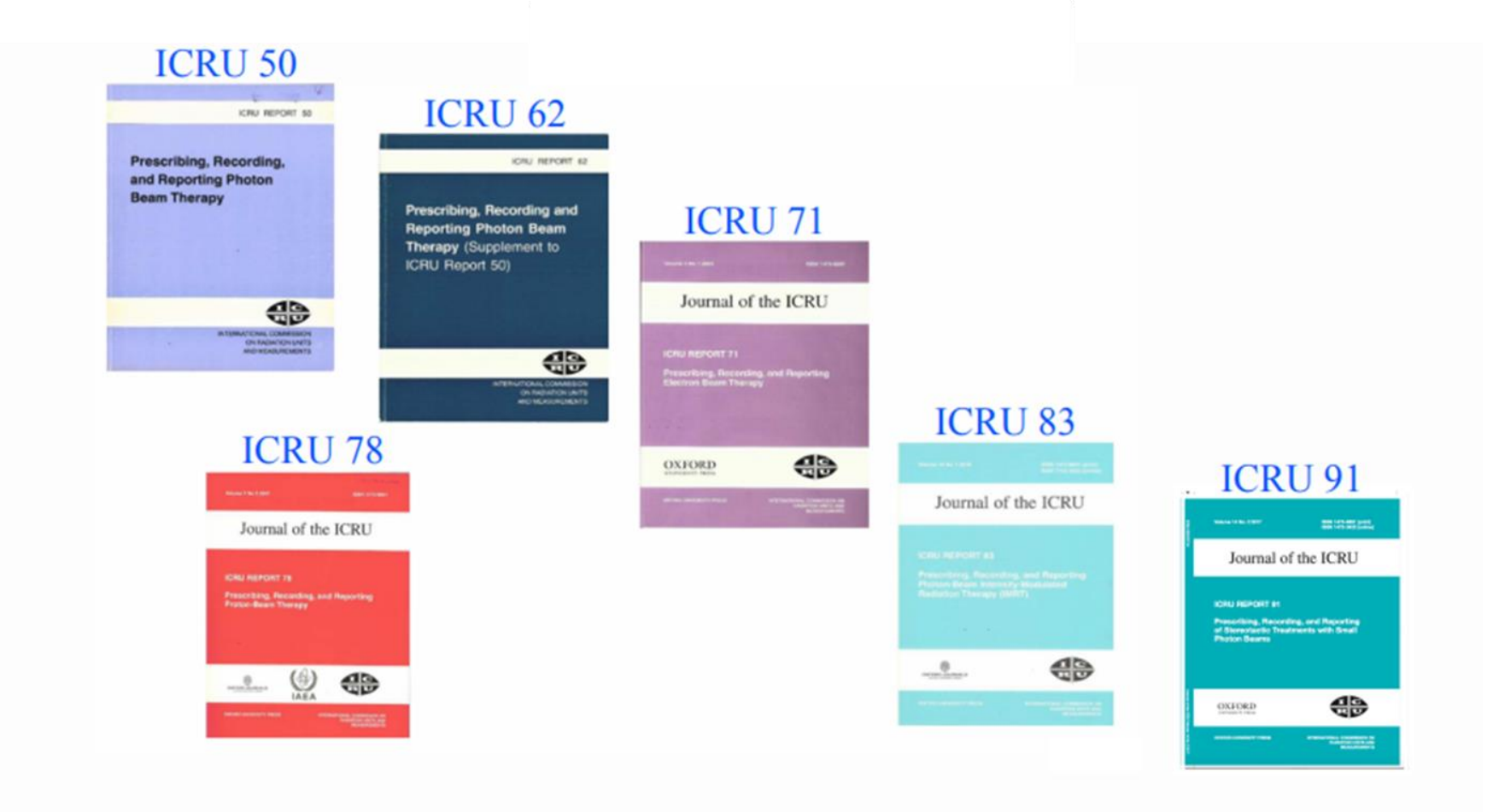
Objectives

- Understand the **concept of target volumes** in radiation oncology.
- Learn the definitions: **GTV, CTV, PTV, and OAR**.
- Explore **the process of contouring and its clinical importance**.

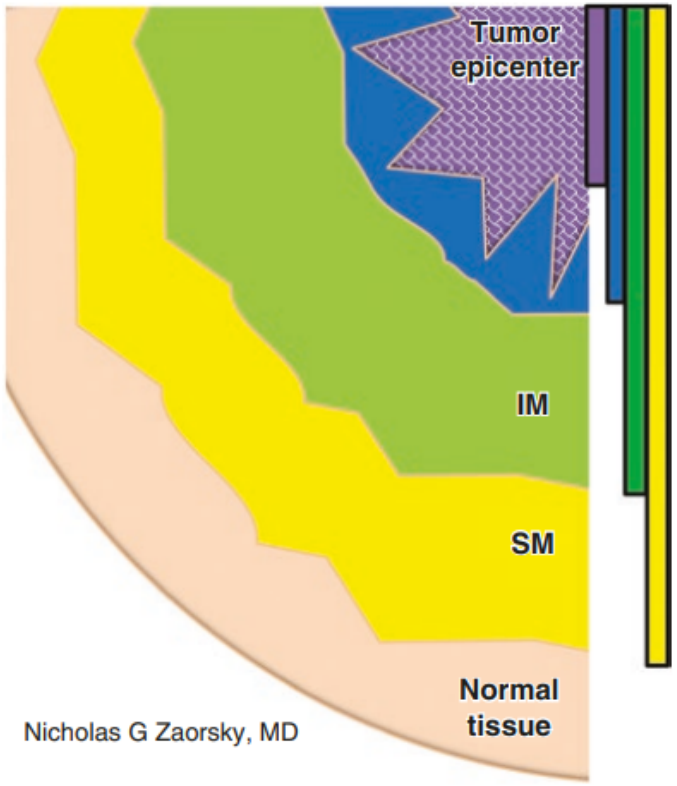
Introduction-Why accurate delineation matters ?

- **Precision in Radiotherapy** : Accurate delineation ensures the tumor receives the prescribed dose while sparing healthy tissues to minimize side effects.
- **Consequences of Errors** : Errors in delineation can cause underdosing of tumors reducing efficacy or overdosing normal tissues increasing toxicity.
- **Standards and Protocols** : ICRU guidelines and advanced imaging technologies standardize delineation to ensure treatment consistency and safety.
- **Hierarchical Volume Definition** : Delineation involves defining volumes accounting for visible disease, microscopic spread, motion, and setup uncertainties.

Historical definitions



Target Volume_ Overview



GTV: gross tumor volume

- All tumor that can be seen on a scan
- For reference, a 1 cm tumor has about 10^9 billion cells

CTV: clinical target volume

- The volume that has to be treated to achieve cure or palliation
- Should be defined before choosing a treatment modality
- Includes "crablike" extensions of the cancer, which contain:
  - microscopic cancer cells that cannot be seen on a scan
  - "Elective" lymph nodes that we think the cancer spread to
- CTV = GTV + a margin of where we think microscopic disease is located

IM: internal margin

- Variations in size, shape, and position of CTV relative to anatomic reference points (e.g. from breathing)

ITV: internal target volume

- Volume that encompasses movement of the CTV and the IM
- ITV = CTV + IM

SM: setup margin

- Uncertainties in patient positioning and alignment of therapeutic beams during treatment planning, and all treatment sessions

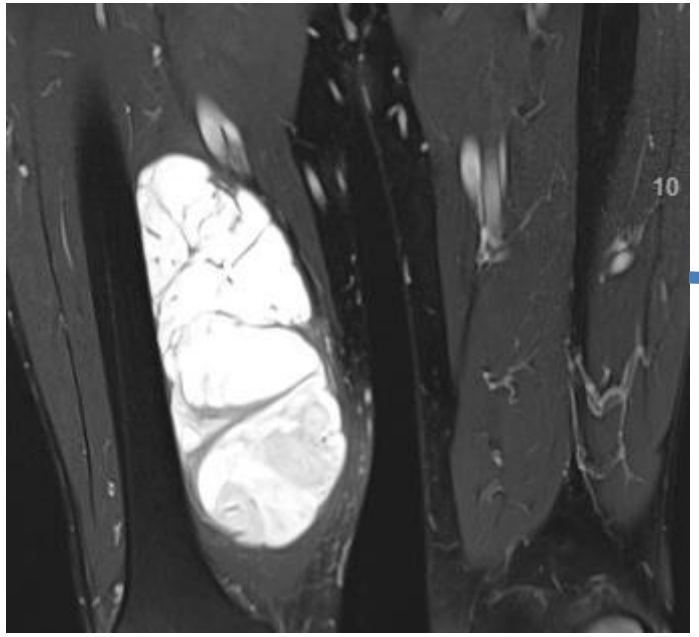
PTV: planning target volume

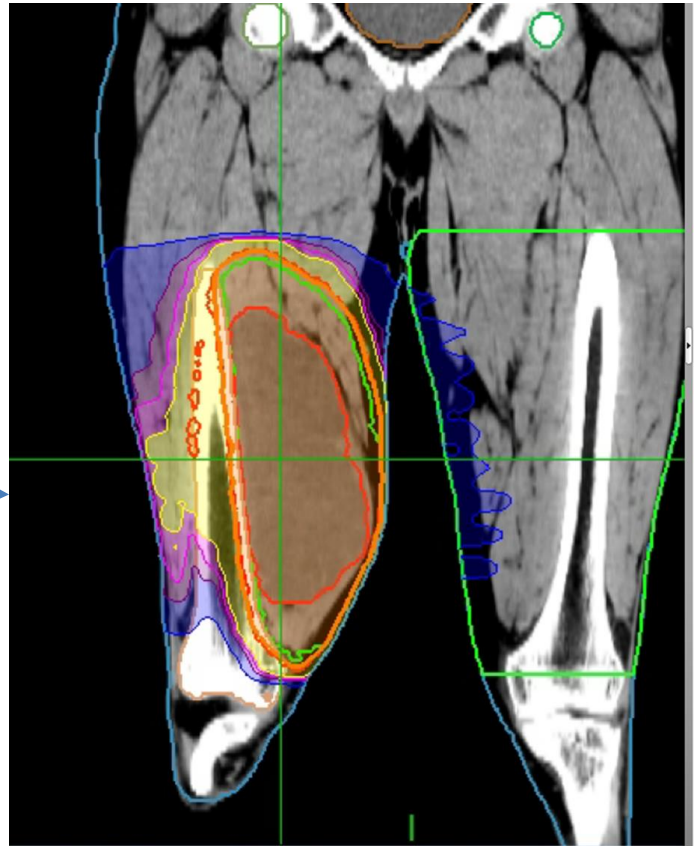
- Volume that encompasses movement of the CTV, the IM, and errors in setup / position of the patient and penumbra
- PTV = CTV + IM + SM

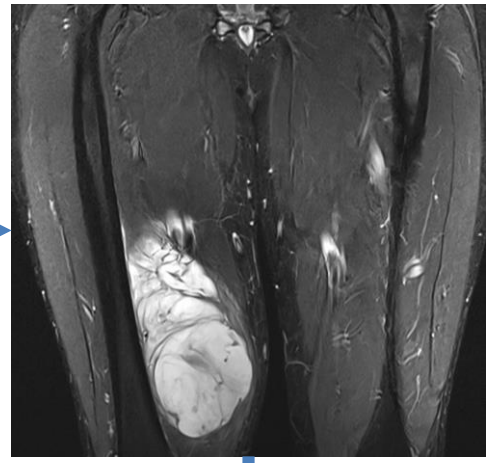
Hitorical Evolution of volume definitions

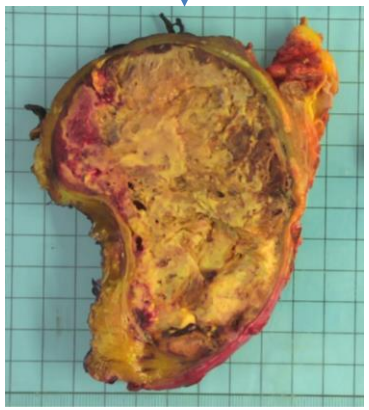
- **Initial Volume Standardization** : The 1978 ICRU report first distinguished between target and treated volumes, initiating volume standardization in radiotherapy.
- **Introduction of GTV, CTV, PTV** : ICRU Report 50 (1993) introduced Gross Tumor Volume, Clinical Target Volume, and Planning Target Volume for clearer dose specifications.
- **Refinement with ITV and PRV** : ICRU Report 62 (1999) added Internal Target Volume and Planning Organ at Risk Volume to address motion and conformal techniques.
- **Adaptation for IMRT** : ICRU Report 83 (2010) adapted volume definitions for intensity-modulated radiation therapy, recommending volume-based dose prescriptions

Example









GTV – Gross Tumor Volume

- **Definition of GTV** : GTV includes all visible tumor tissue and involved lymph : nodes identified via clinical exams and imaging.
- **Importance of Accurate Delineation** : Precise GTV delineation impacts the size and shape of Clinical and Planning Target Volumes, essential for effective treatment.
- **Challenges in GTV Definition** : Despite imaging advances, inter-observer variability poses challenges in consistently defining GTV boundaries.
- **Planning Without Visible Tumor** : When no tumor is visible post-surgery, treatment planning starts with **Clinical Target Volume** instead of GTV.

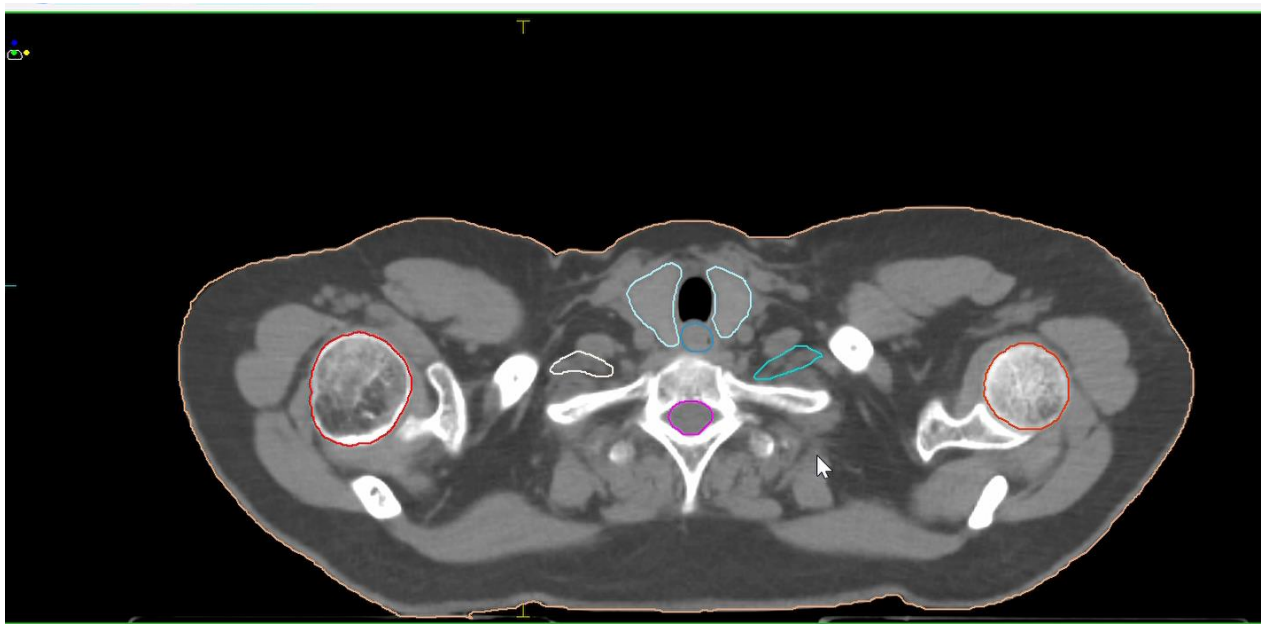
CTV – Clinical Target Volume

- **Definition of CTV** : CTV includes the gross tumor volume and surrounding areas at risk for microscopic disease spread.
- **CTV Margin Determination** : CTV margins are determined using clinical judgment based on pathological data and tumor failure patterns.
- **Margin Size Variation** : CTV margins vary by tumor type and location, generally from 5 mm to 20 mm, depending on cancer type.
- Importance of Accurate Delineation Accurate CTV delineation balances tumor control with minimizing damage to healthy tissue

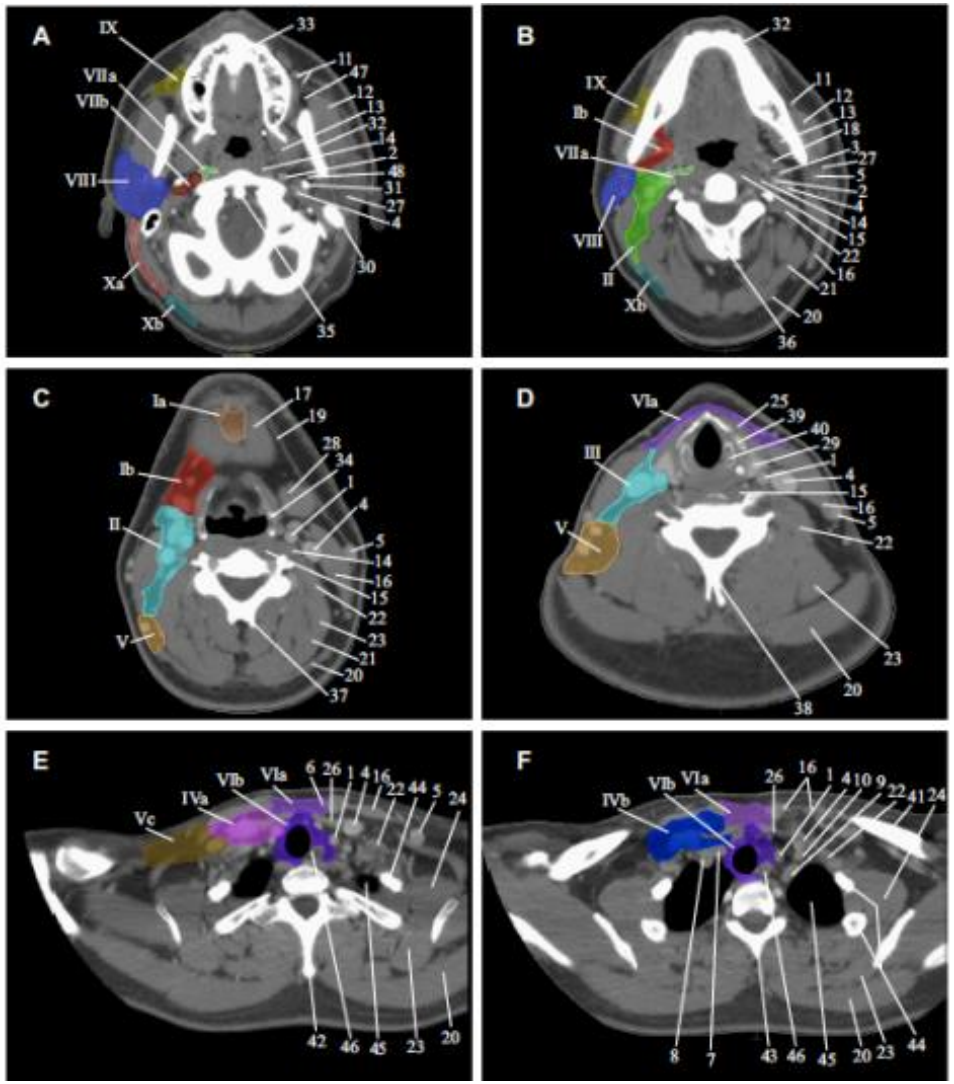
Volume definition

CTV T = CTV Chest wall R

CTV N = nL4+nL2+IP+IMC



Volume definition CTV N

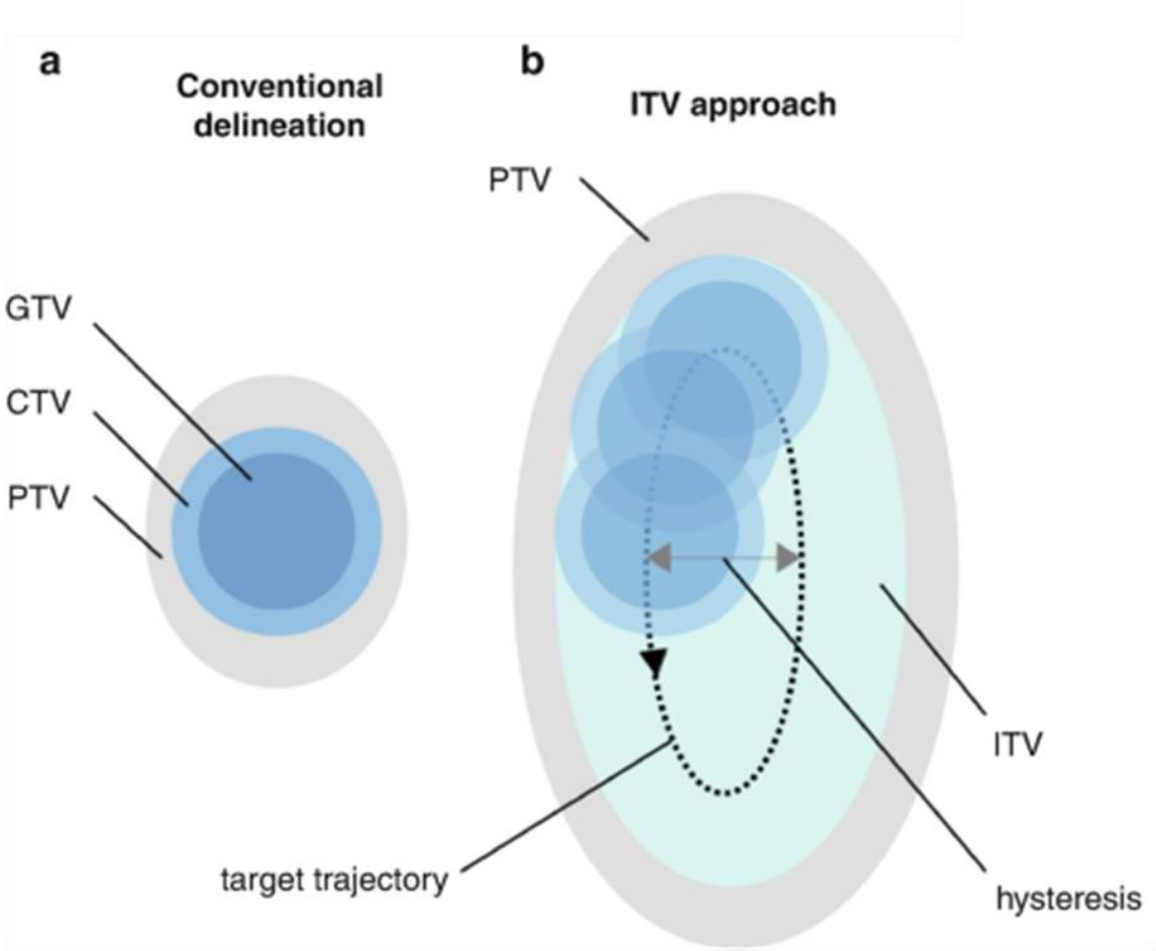


Gregoire et al. 2013

ITV-Internal Target Volume

- **Purpose of ITV** : ITV accounts for physiological changes in tumor shape and position during treatment, ensuring consistent coverage.
- **Physiological Variations** : Respiratory motion, cardiac activity, and organ filling cause tumor displacement up to 15 mm, influencing ITV design.
- **Imaging Techniques** : Four-dimensional CT (4DCT) captures tumor motion over time to accurately define the ITV for treatment planning.

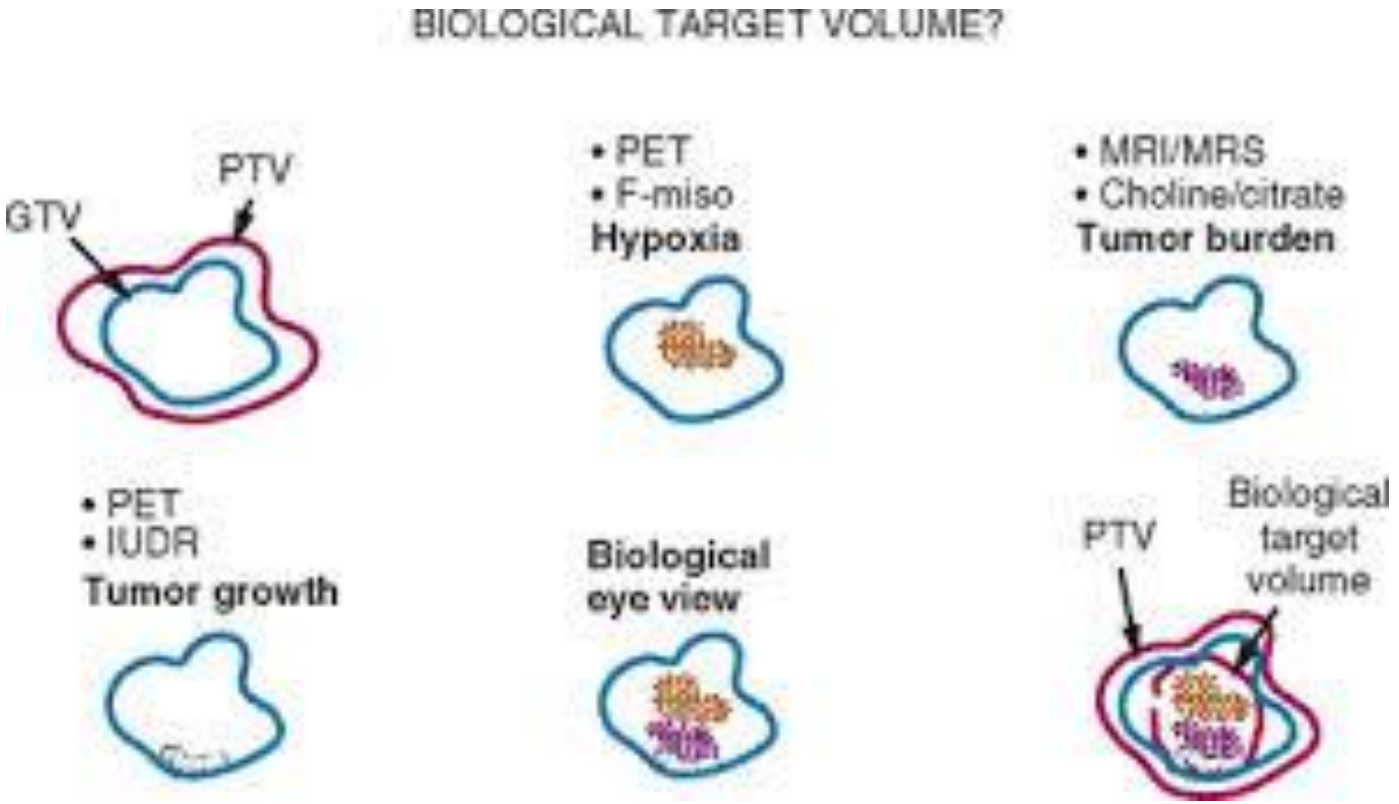
ITV


a
Conventional delineation
b
ITV approach
PTV
GTV
CTV
PTV
ITV
target trajectory
hysteresis

BTV-Biological target Volume

- **Concept of BTV** : BTV integrates functional and metabolic imaging like PET to delineate biologically active tumor regions for targeted therapy.
- **BTV Definition Methods** : Methods include fixed SUV thresholds, percentage of SUVmax, and advanced algorithms such as PERCIST for defining BTV.
- **Challenges in BTV** : Challenges include variability in techniques and spatial mismatches with conventional tumor volumes affecting accuracy.
- **Benefits of PET Integration** : Integrating PET improves delineation accuracy and reduces inter-observer variability, supporting personalized treatment.

BTV


BIOLOGICAL TARGET VOLUME?
GTV
PTV
• PET
• F-miso
Hypoxia
• MRI/MRS
• Choline/citrate
Tumor burden
• PET
• IUDR
Tumor growth
Biological
eye view
PTV
Biological
target
volume

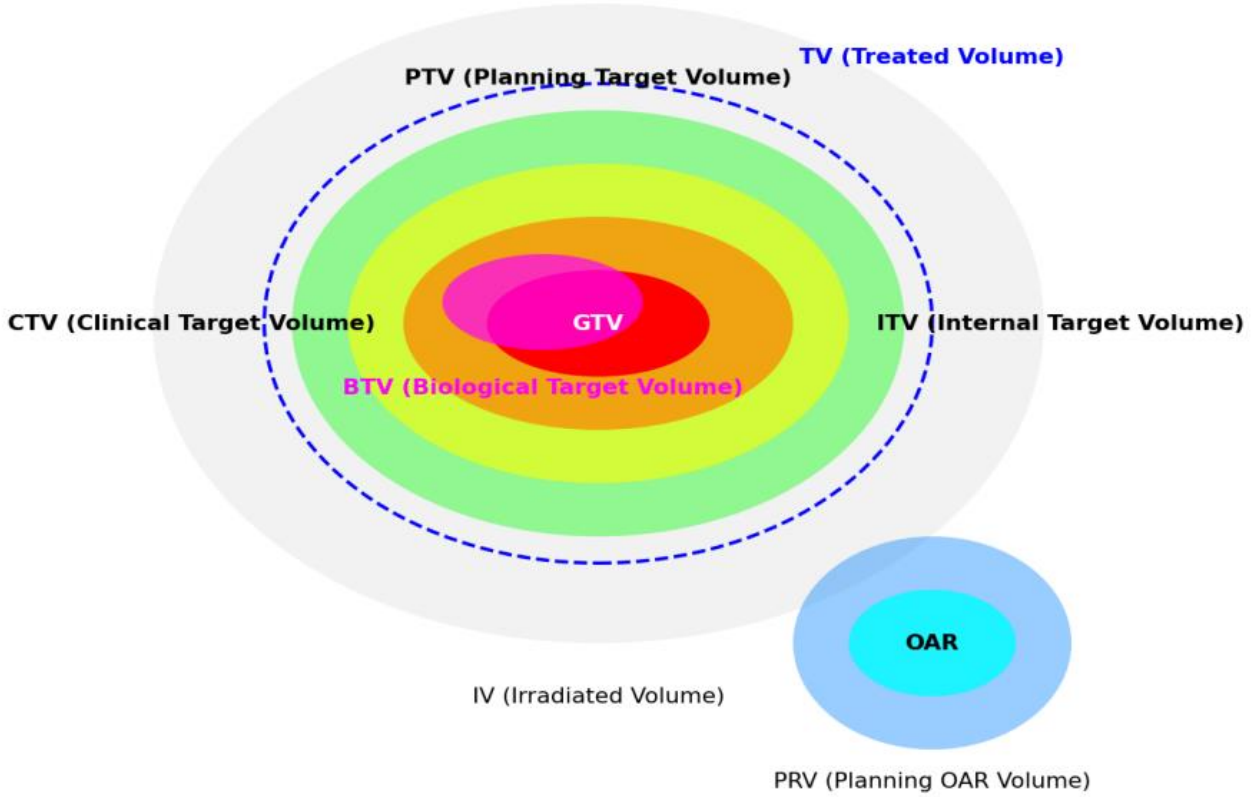
PTV – Planning Target Volume

- Definitions and purpose :
  - PTV ensures prescribed dose coverage of the CTV despite setup and treatment uncertainties.
- Margin Calculation Formula
  - The van Herk formula calculates margins using systematic and random error components for dose accuracy.
- Margin Variability factors
  - PTV margins depend on anatomical sites and advanced imaging for smaller, precise treatment margins.

Conclusions : references tables

VOLUME TYPE	DEFINITION	KEY CONSIDERATIONS
GTV	Visible tumor on imaging	No margin; direct imaging
CTV	GTV + microscopic disease margin	5–20 mm based on tumor type
ITV	CTV + internal margin for motion	Accounts for respiration and organ filling
PTV	CTV/ITV + setup and uncertainty margins	Van Herk formula: $M = 2.5\Sigma + 0.7\sigma$
BTV	Functional/metabolic imaging-based volume	PET SUV thresholds or advanced algorithms
TV	Volume receiving prescribed dose	Defined by 95% isodose line

Target Volume Concepts – Overview



Prasanth et al 2025