Target Volumes In Radiotherapy And Their Inter-relationship

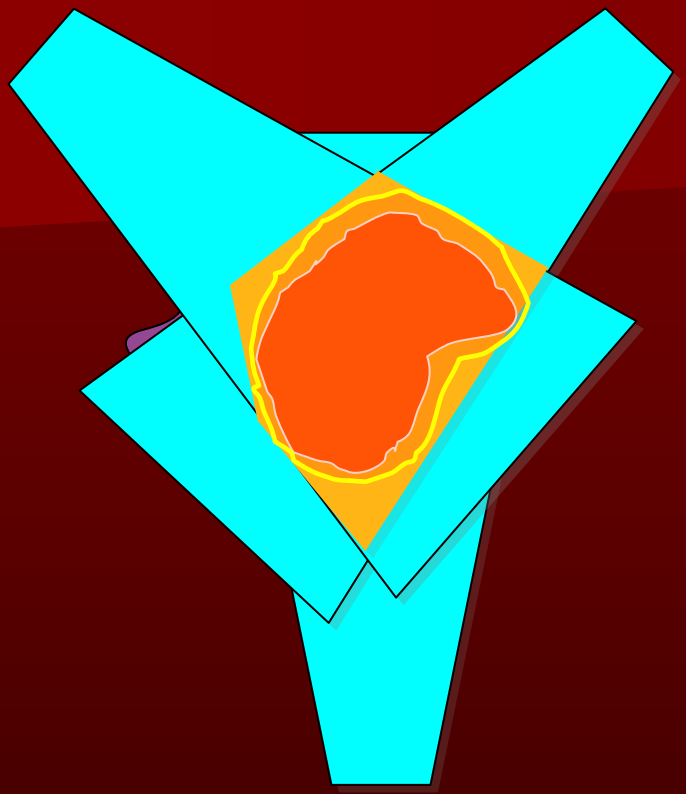
Dr Kirti Srivastava

Assoc. Professor

Department of Radiotherapy

CSMMU (King George's Medical University) Lucknow

Ideal Situation



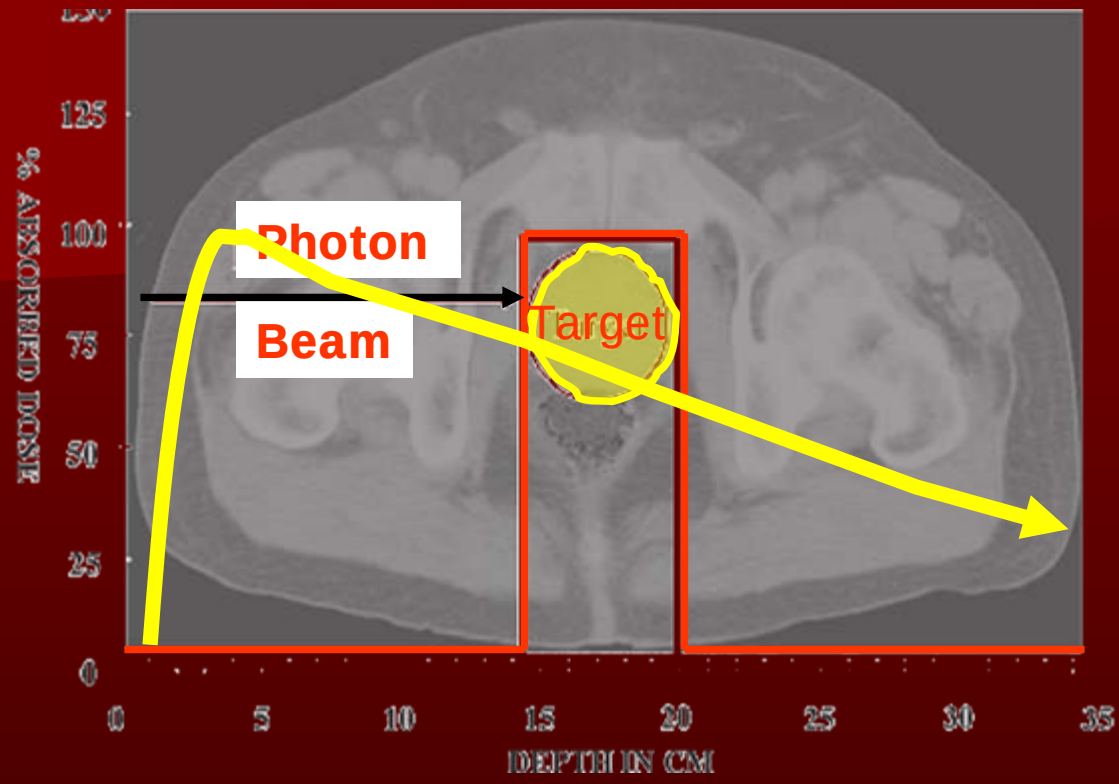
Limitations of available Radiation Technique

Dose variation can reach upto 10 or even 20%within the target volume

Dose difference as small as 5% may be important for tumor response

Such 5% uncertainty can easily be introduced by different method of reporting

Prescribed dose = Recorded Dose = Reported Dose



- Nature of the photon beam is the biggest impediment
  - Has an entrance dose.
  - Has an exit dose.
  - Follows the inverse square law.

Need to have some criteria for

- Prescribing
- Recording
- Reporting

ICRU

Since ICRU 50 (1993)

- Improvement in staging & imaging procedures
- Improvement in delivery of precision RT

- Advances in our understanding of normal tissue response

Need of an update

ICRU 62 (1999, ***COMPANION VOL TO ICRU 50)***

ICRU 62

- Detailed recommendations on different margins to account for Anatomical & Geometrical variations & uncertainties
- Introduction to conformity index
- How to classify different types of organs at risk
- Introduction of PRV= planning organ at risk vol

Levels of Reporting

- LEVEL I : Simple enough to allow reporting in all centers

ICRU "reference point", PTV, Min & Max Doses

- LEVEL II : More complete & relevant information

Full 3D calculations with heterogeneity ,report PTV, PRV,..Volumes & dose distributions (eg. RTOG)

- LEVEL III : Developmental / special techniques

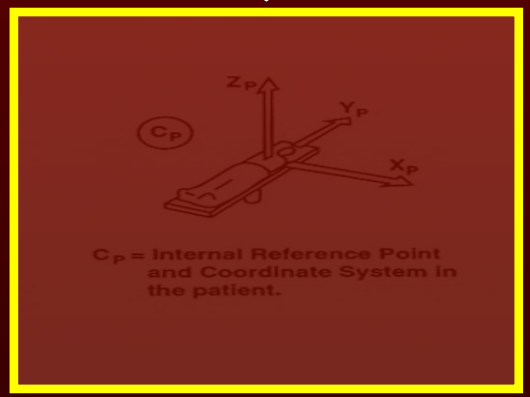
Currently undefined methods for dose reporting (eg. BNCT ,IMRT)

Reference Points

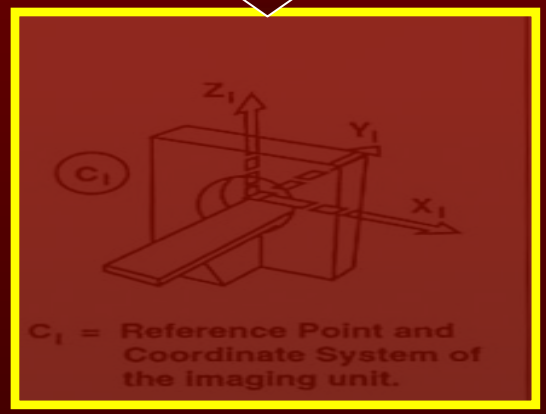
- Internal Reference points-
  - Anatomical Land Marks
    - Bony structures, gas filled cavities
- External Reference point-
  - Skin Markings
  - Tattoos
  - Markings on face masks etc.

Co-ordinate systems

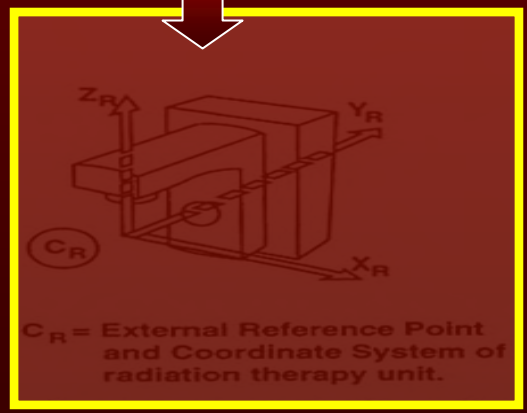
- Related to the patient
  - Related to internal and External ref. points



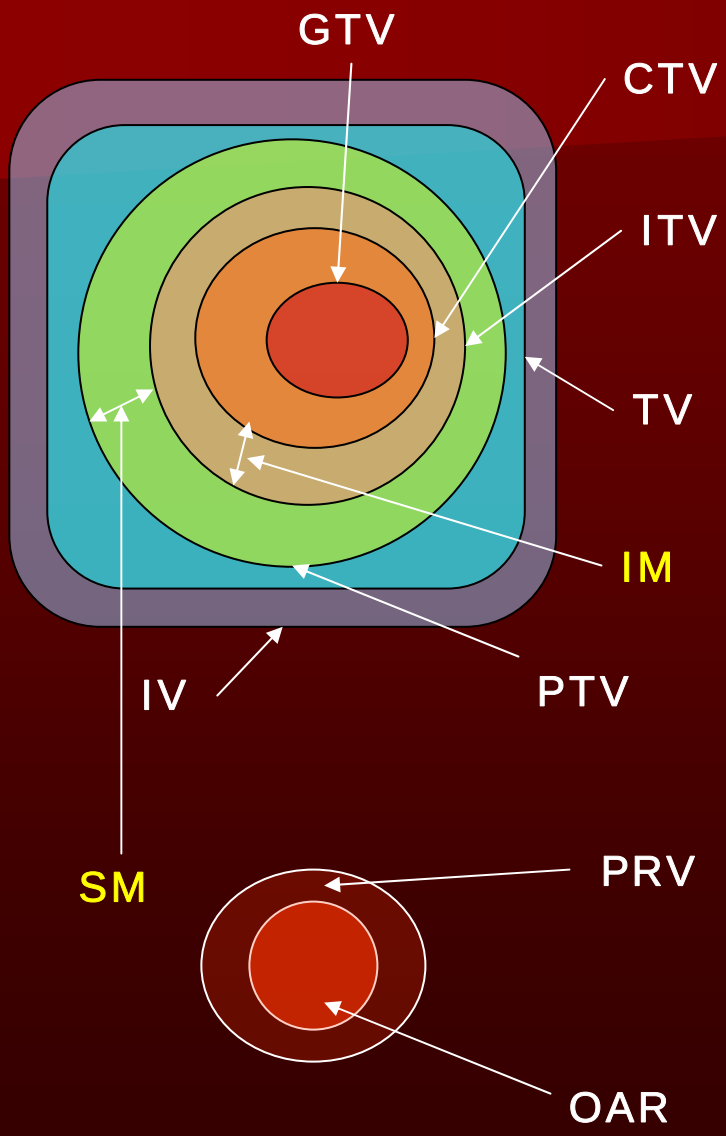
- Related to imaging machine



- Related to Tt Machine
  - With respect to the gantry, Collimator



ICRU 62- Volume Definitions



GTV, CTV } Known / suspected tumor vol.

OAR → Normal tissue

PTV, TV, IV } Purely geometric concept do not correspond to tissue or organ borders

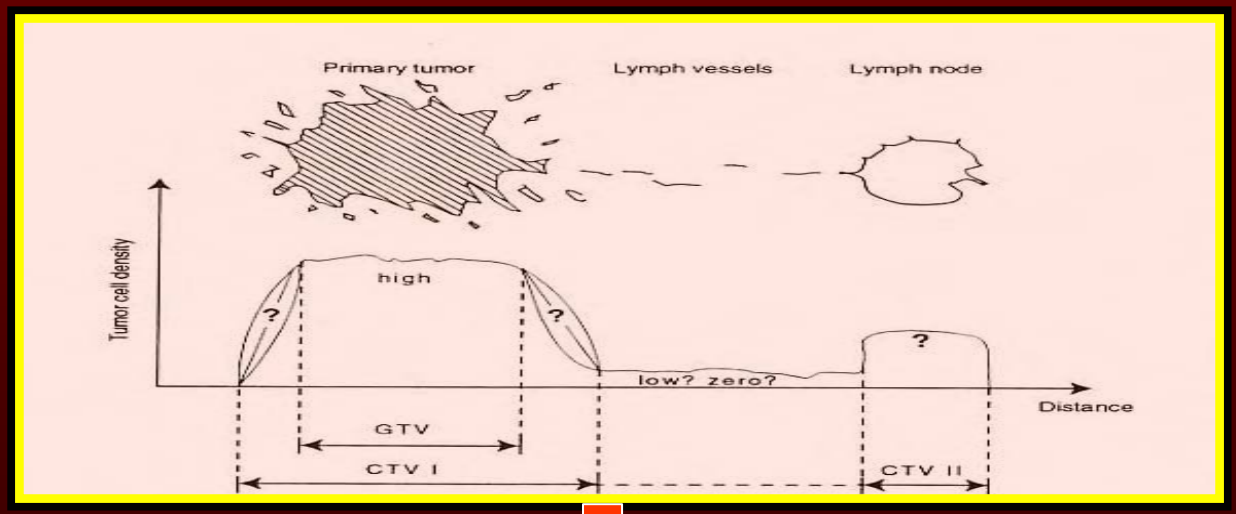
GTV

- Cannot be defined after Surgery
- Can be determined by – clinical examination, imaging techniques
  i.e. X-ray, CT, MRI, PET
- It may differ with the use of different modalities, or with same modality inter observer variation may be significant
- An adequate dose must be delivered to whole GTV for local control in Radical treatment
- Regression of GTV may be used as predictor of response

Gross Tumor Volume (GTV) is the gross demonstrable extent and location of the malignant disease

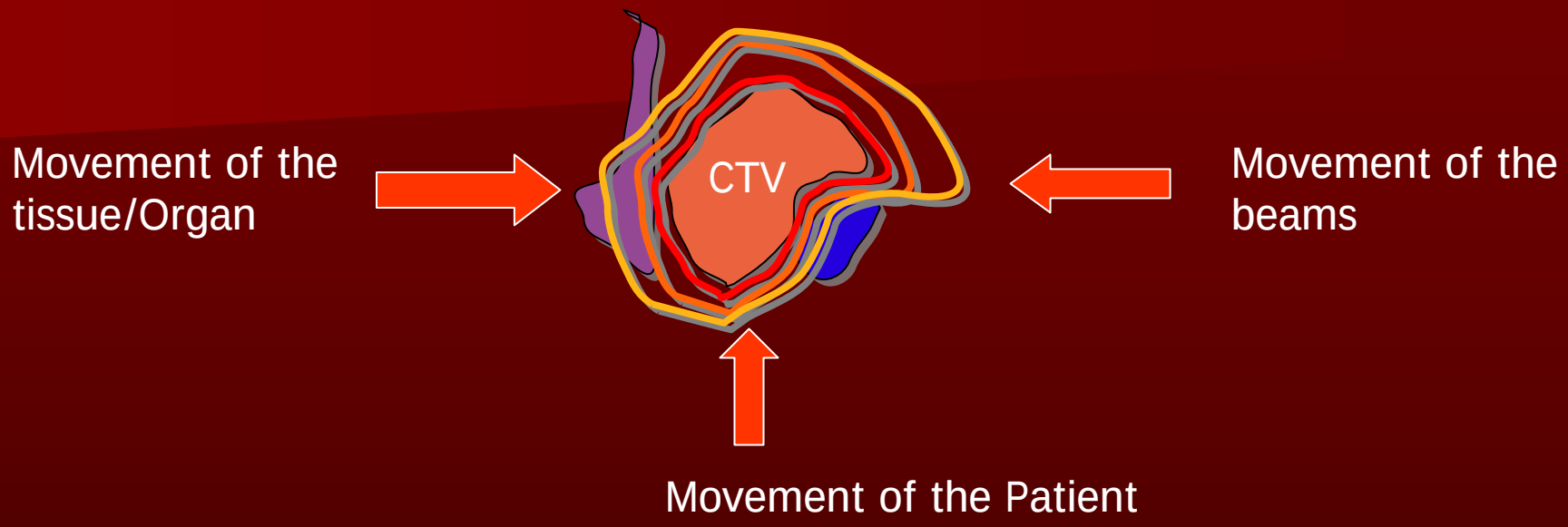
CTV

- A purely clinical/ anatomical concept
- Can also extend to the regional LN having sub clinical disease
- Significant research effort in imaging will impact CTV
- Today however little is understood about combining information from MRI, PET, MRS……
- Pathologists are always right !



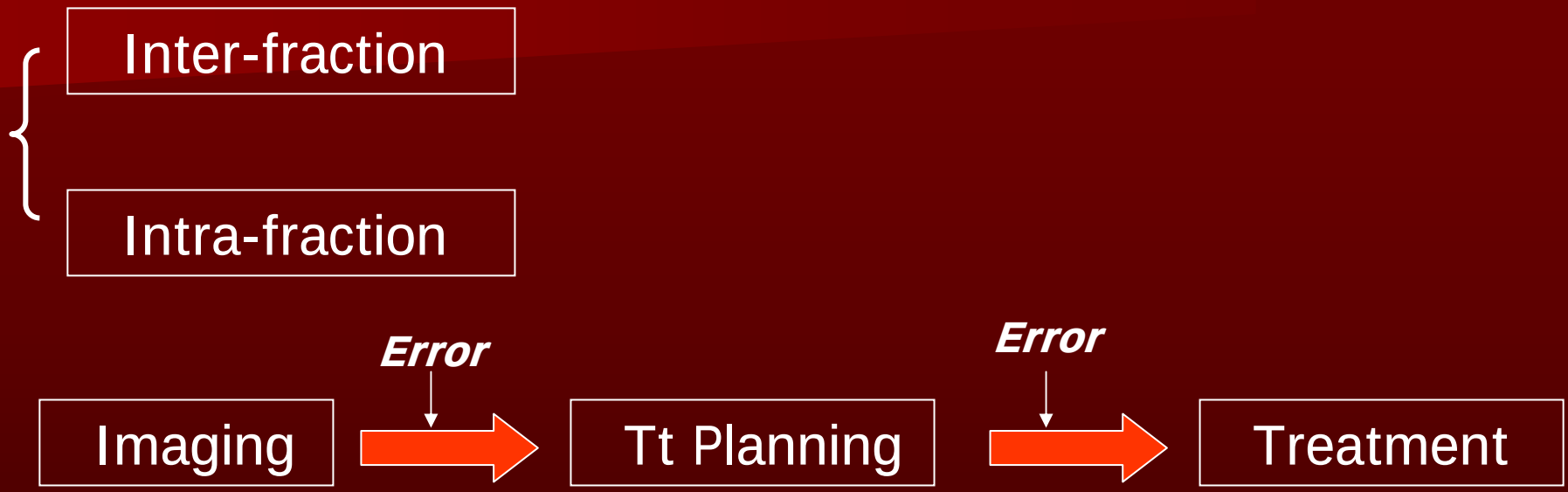
Clinical Target Vol (CTV) Is a tissue volume that contains a demonstrable GTV and/or sub clinical malignant disease that needs elimination to achieve the aim of radical therapy

PTV

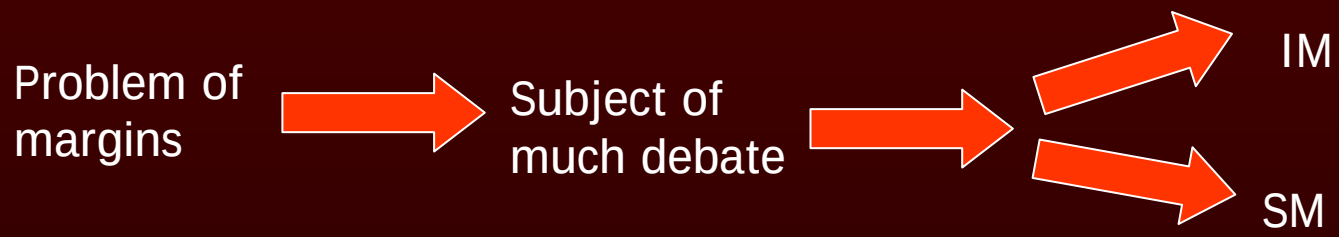


The Planning target volume (PTV) is a geometrical concept used for treatment planning & it is defined to select appropriate beam sizes & beam arrangements to ensure that the prescribed dose is actually delivered to CTV

PTV Contd.....



PTV may take into account either all uncertainties or most of them (2 SD) eg variations due to deep breath



PTV Contd.....

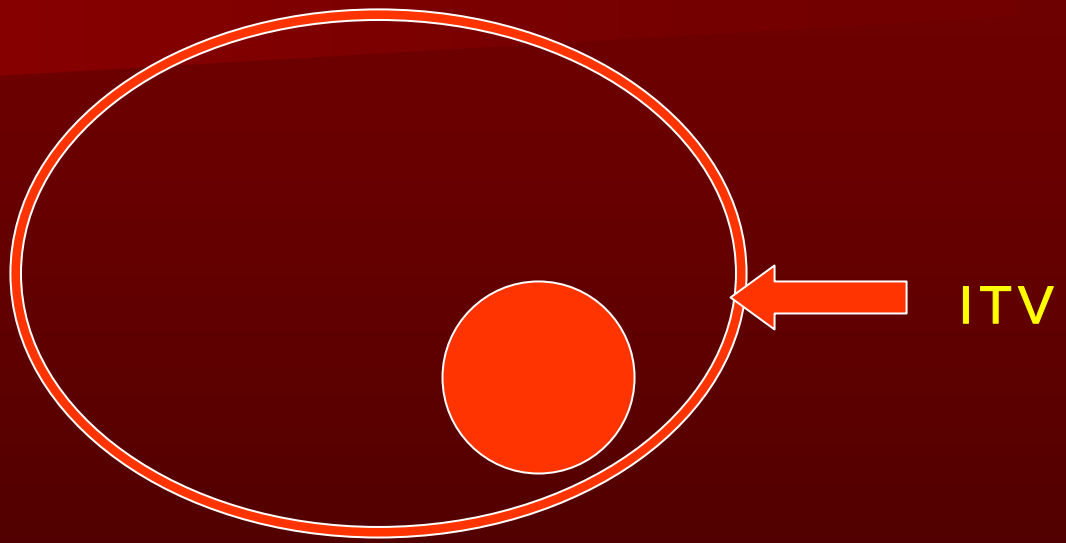
Category	Intra #		Inter #	
	Random	Systematic	Random	Systematic
Variation of CTV in Size	Circulation, Respiration, Peristalsis	Circulation	Degree of Bladder filling, bowel gas	Tumor reduction
In Position relative to a fixed point in the patient	"	Change in Tt position (Prone, Supine)	"	Wt loss
Variation in Position of the patient in relation to the beam	Pt movement	––	Daily setup	Technical error

Internal Margin (IM)

- Eg: Respiration , Filling of bladder, filling of rectum, swallowing, heart beat, bowel movements
- Cannot be easily controlled
- Do not depend on external uncertainities in beam geometry
- Could depend on patients day to day setup.
- Organ movement is directly appreciated by serial (inter#) or dynamic (intra#) imaging i.e. MRI, Fluoroscopy, 4D CT etc
- Limited tools exist to date to aid in margin definition for internal movement

CTV + IM = ITV (Internal target volume)

Margin to compensate for expected physiological movements in size shape and position of CTV during Tt in relation to internal ref point


ITV

Set up Margin (SM)

In reference to external Co-ordinate system

- Uncertainties depend upon :
  - Pt Positioning
  - Mechanical uncertainities of the equipment i.e. sagging of the gantry, collimators, couch etc.
  - Dosimetric uncertainities
  - Transfer setup errors
  - Human factors

To account for uncertainties in patient positioning & alignment of the beams during planning & through out the treatment.

Treated Volume

- The aim of Quality assurance procedures is to ensure that actual TV corresponds to the PTV
- Proper delineation of TV is important to interpret the causes of in-field Vs marginal recurrences as well as normal tissue complications seen outside the PTV but with in the TV

eg. The dose at ICRU ref point is 60 Gy
Dose variation with in PTV = +7% to -5%
Treated volume will be enclosed by 57Gy (95% of 60GY)
isodose curve

Volume of the tumor and surrounding normal tissue that is included in the isodose surface representing the irradiation dose proposed for the treatment.

Conformity Index

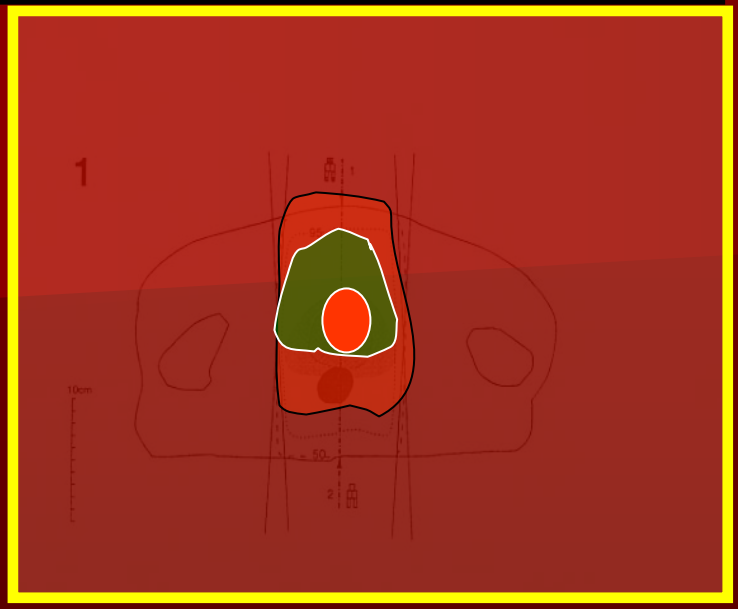
- It is the quotient of TV & PTV and is defined only when TV completely encloses the PTV & is used as the part of the optimization procedure

Irradiated Volume (IV)

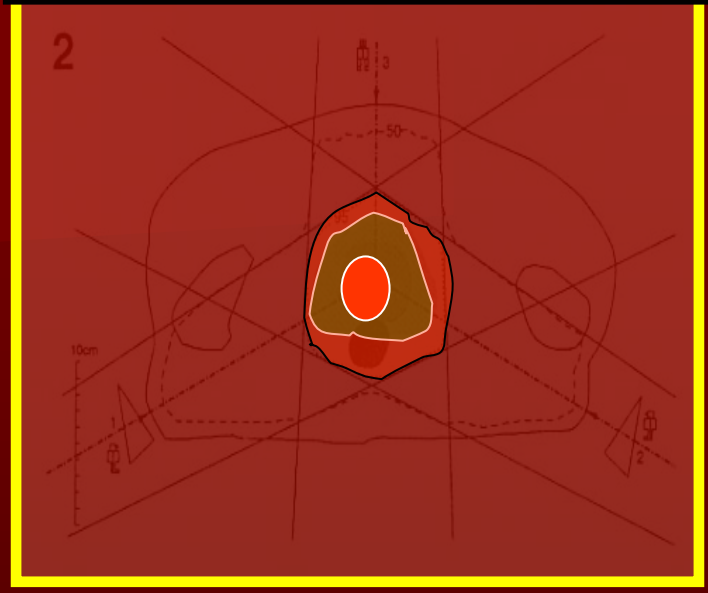
Irradiated Volume: Volume included in an isodose surface with a possible biological impact on the normal tissue encompassed in this volume. Choice of isodose depends on the biological end point in mind.

Use of conformal therapy / MLC can decrease both TV & IV

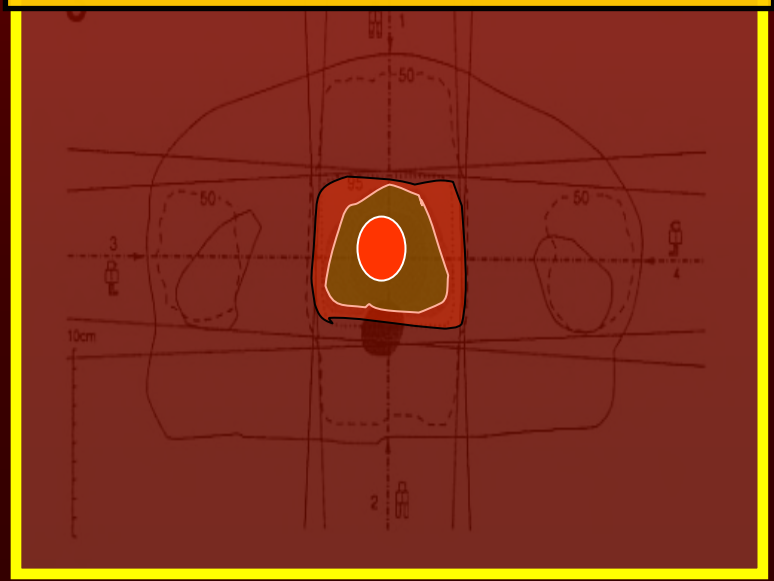
Treatment by AP/PA fields



Treatment by three fields



Treatment by 4 field box Technique

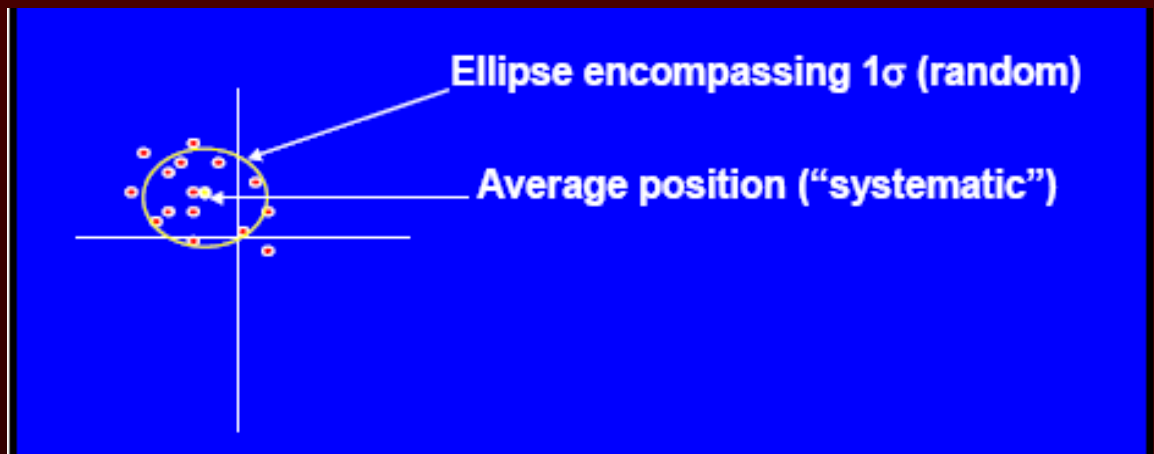


=TV (95% isodose)

= PTV

Systematic Error/ Random Error

- Patient position about a single axis can be classified as a random variable
- There is generally an average “ systematic “ value and a random variation about this average.
- “Systematic”- the average offset of the target from the planned position
- Random – the variation per setup about the average observed position
- Sources of Systematic errors have been attributed to differences in table sag, laser calibration, and mechanical calibration between different rooms (CT, simulator, accelerator)



Influence of technology on setup verification

- Portal films- high dose and time consuming, but provide increased information over skin marks
- EPIDs- improved image quality and reduced dose: availability of digital enhancement and alignment tools
- In-room diagnostic X-Ray and CT- improved target visualization

Modern developments will provide a framework to better understand the impact and setup variation to facilitate robust treatment planning

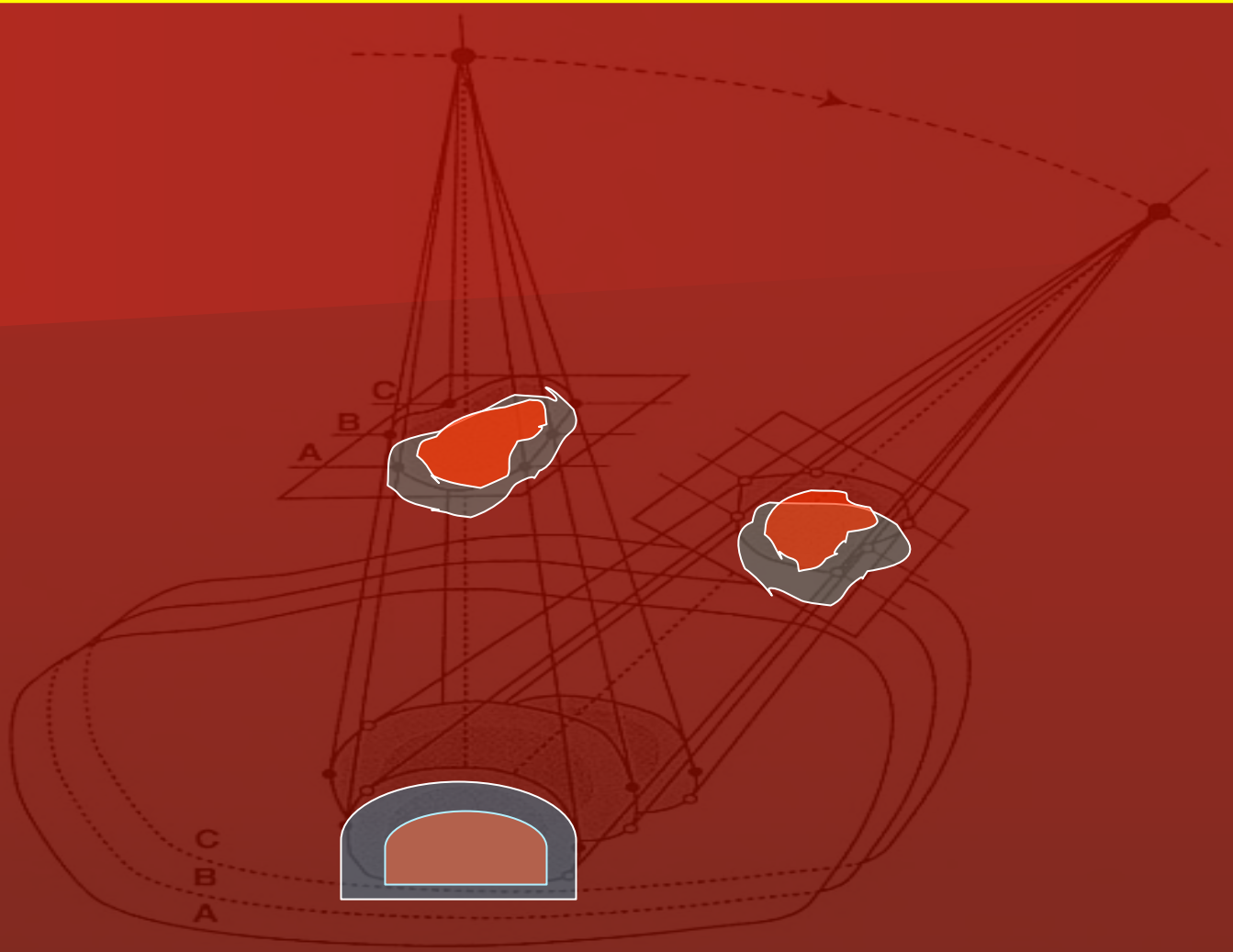
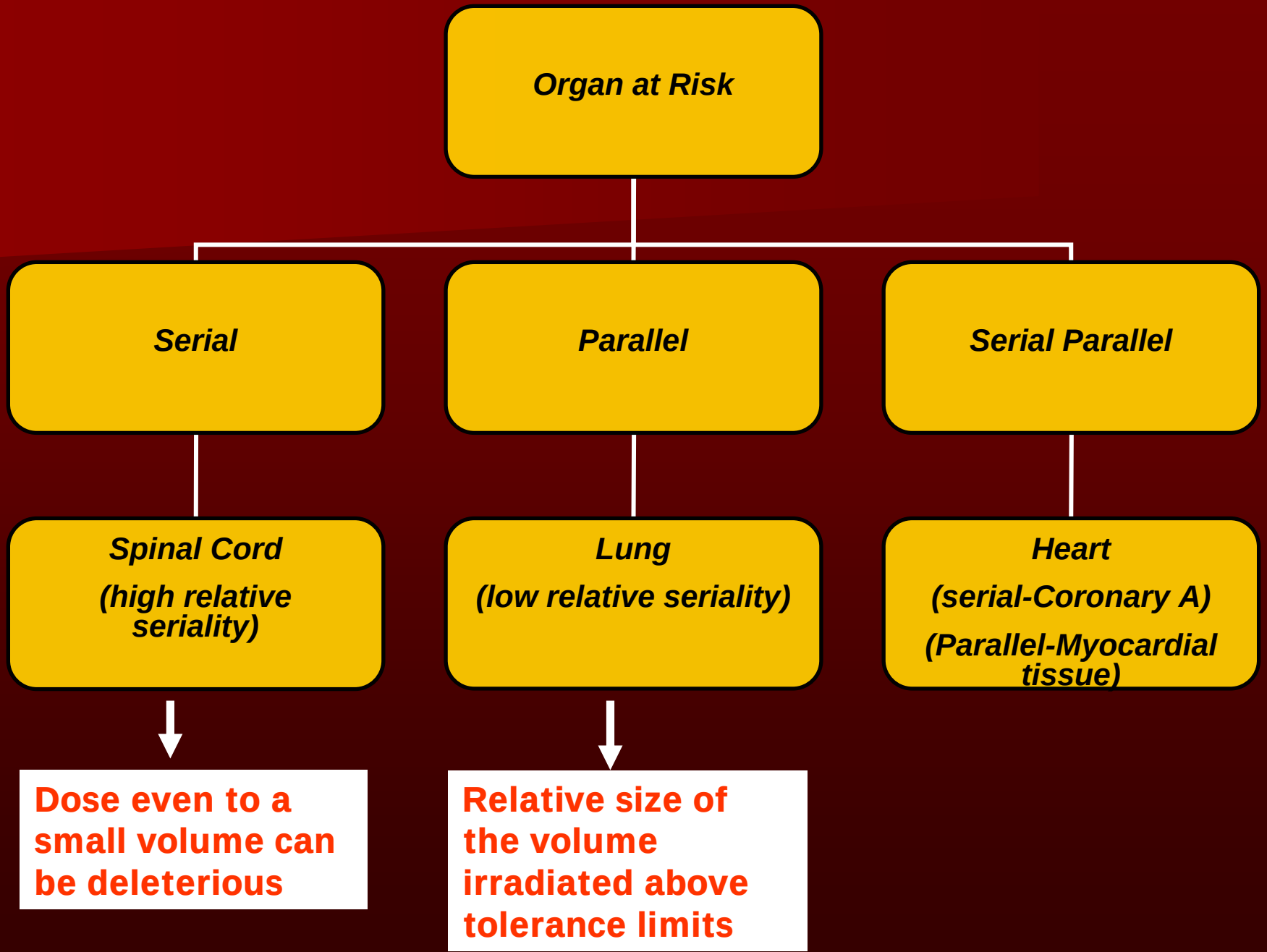
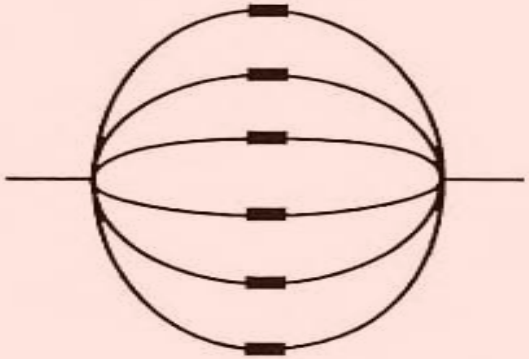


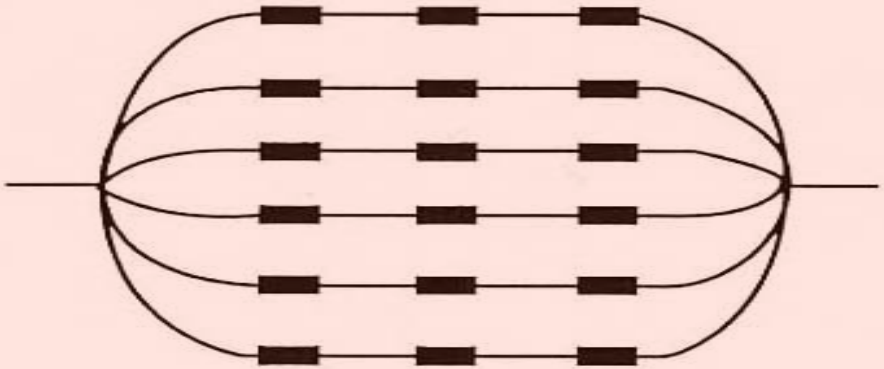
Fig. 2.15. Illustration of Beam's Eye View (BEV) for two isocentric beams. The CTV and PTV are indicated (light red, and light blue, respectively in the three body sections). The projections of the CTV and PTV on the two planes perpendicular to the beam axis are shown. Closed circles and open circles are used to illustrate the projection geometries.


Organ at Risk
Serial
Parallel
Serial Parallel
Spinal Cord
(high relative seriality)
Lung
(low relative seriality)
Heart
(serial-Coronary A)
(Parallel-Myocardial tissue)
Dose even to a small volume can be deleterious
Relative size of the volume irradiated above tolerance limits

Serial eg Spinal cord

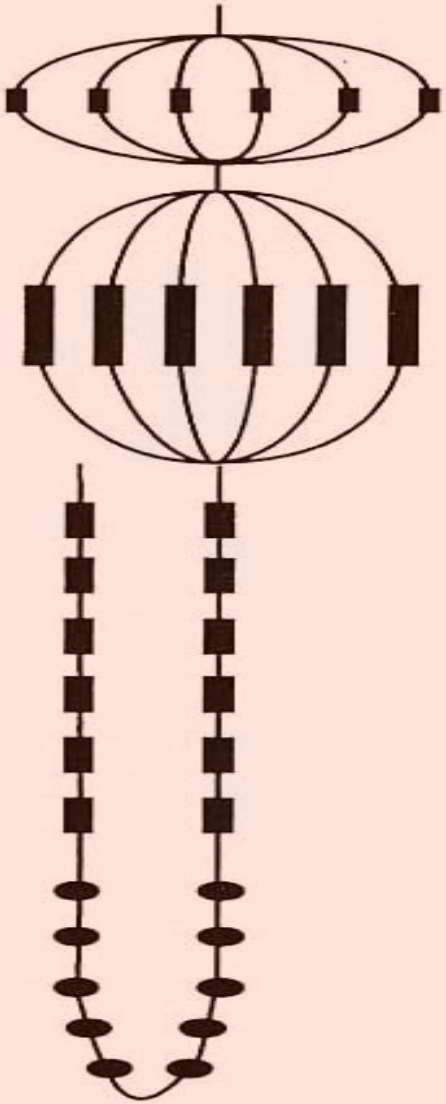


Parallel eg Lung



Serial Parallel eg Myocardium

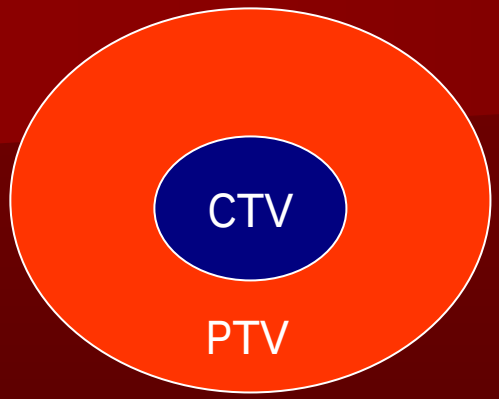
(d)

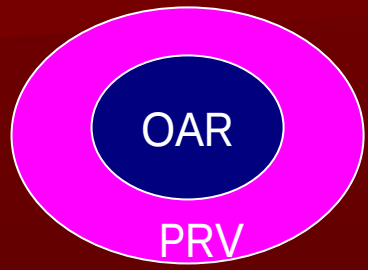


Parallel, Serial

eg Nephron

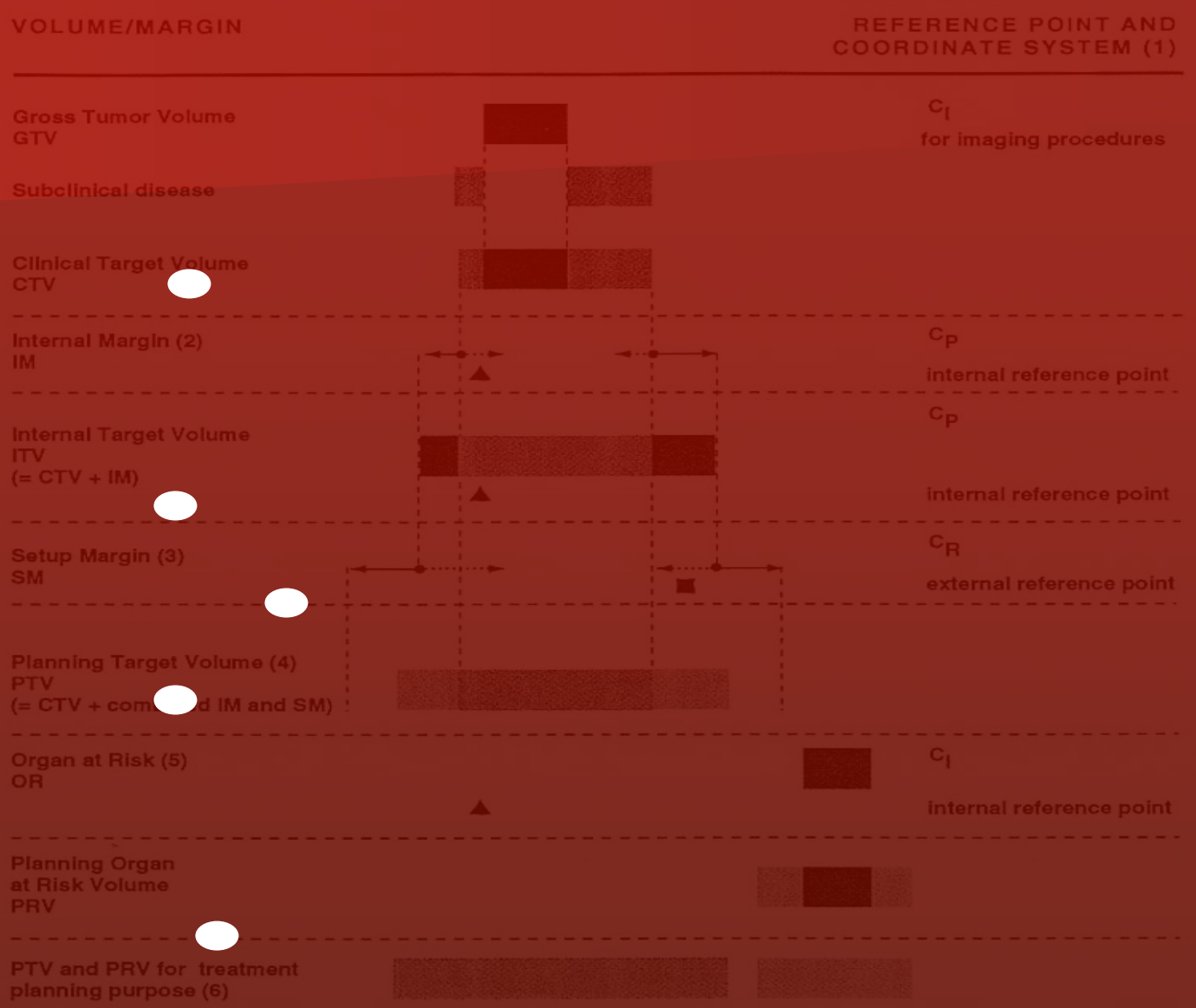
Planning Organ at Risk Volume (PRV)



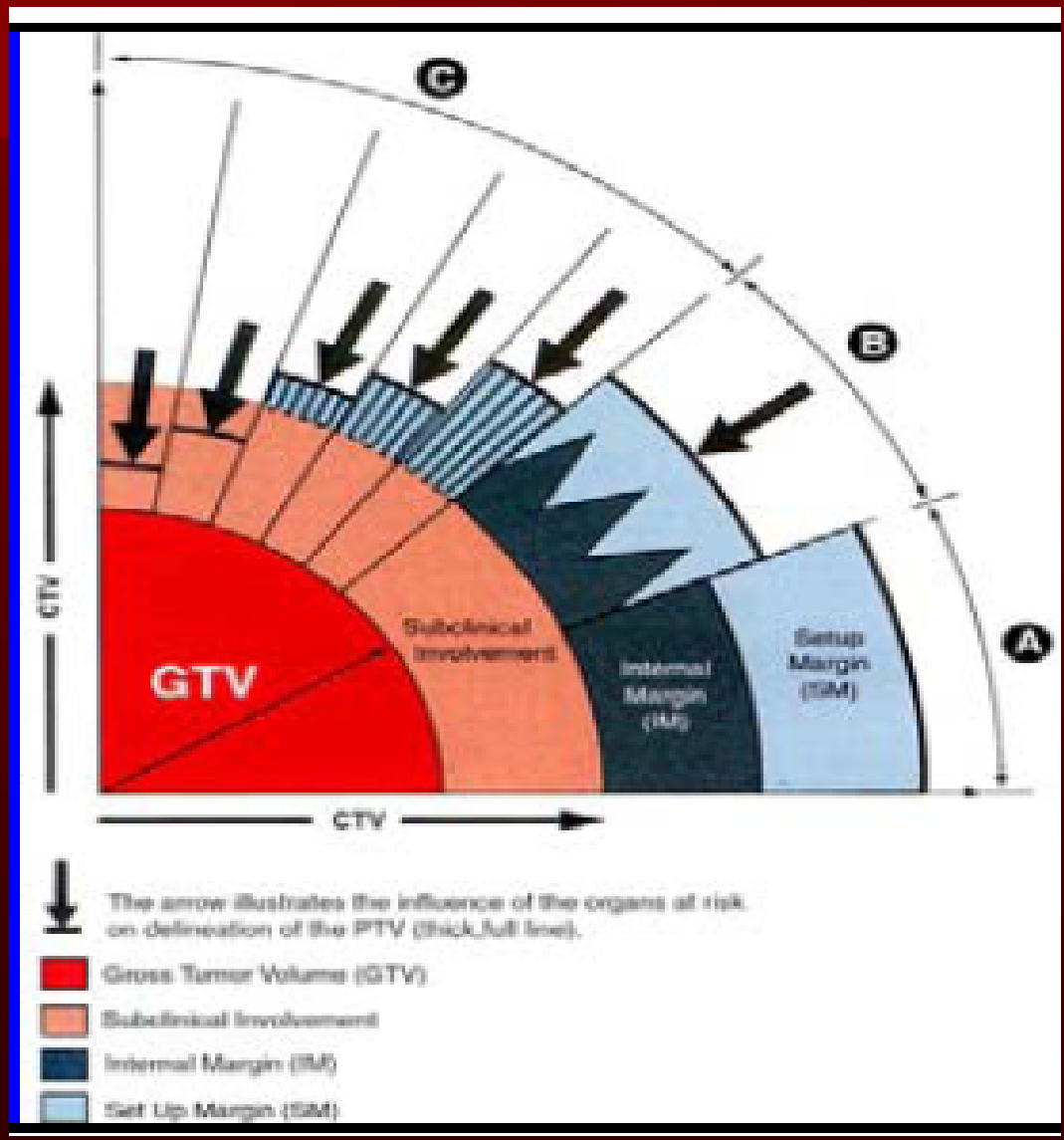


Like PTV any movement of the organ at risk during treatment as well as any uncertainties in the setup during the whole treatment course must be considered. An integrated margin must be added to OAR like PTV

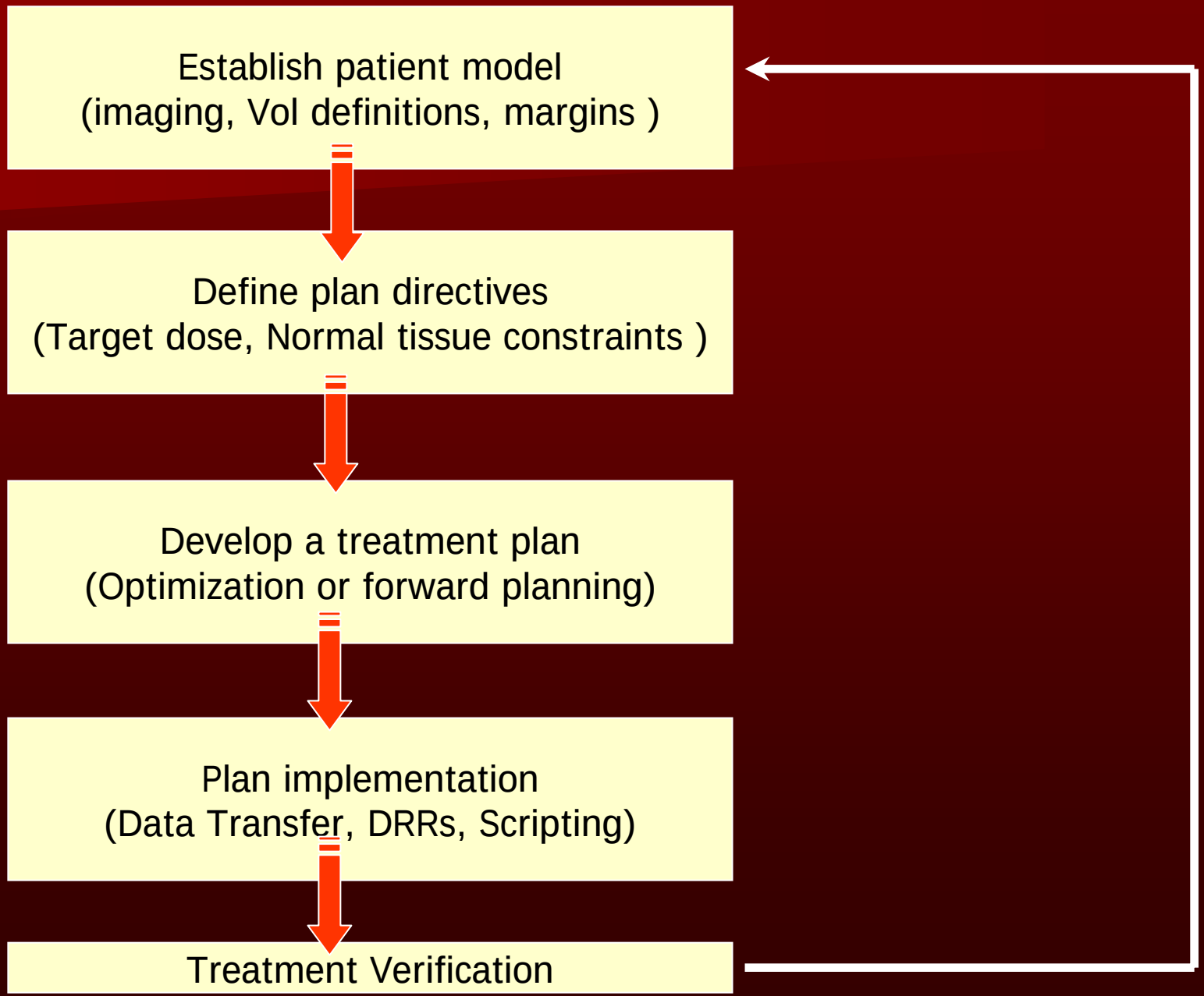
- Described by including the size of the combined margins of the OAR in different directions
- PTV & PRV may overlap


VOLUME/MARGIN
REFERENCE POINT AND COORDINATE SYSTEM (1)
Gross Tumor Volume
GTV
Subclinical disease
Clinical Target Volume
CTV
Internal Margin (2)
IM
Internal Target Volume
ITV
(= CTV + IM)
Setup Margin (3)
SM
Planning Target Volume (4)
PTV
(= CTV + combined IM and SM)
Organ at Risk (5)
OR
Planning Organ
at Risk Volume
PRV
PTV and PRV for treatment
planning purpose (6)
C_I
for imaging procedures
C_P
internal reference point
C_P
internal reference point
C_R
external reference point
C_I
internal reference point

Graphics


C
B
A
CTV
GTV
Subclinical involvement
Internal Margin (IM)
Setup Margin (SM)
CTV
The arrow illustrates the influence of the organs at risk on delineation of the PTV (thick full line).
Gross Tumor Volume (GTV)
Subclinical Involvement
Internal Margin (IM)
Set Up Margin (SM)

The “process” of Radiotherapy



3 Important factors that can attribute to inadequate dose delivery

- Inappropriate target definition.
- Physical limitation dictated by close proximity to normal tissue.
- Day to day field placement errors.

Local tumor recurrence

Recommendations for recording & reporting volumes

- Description of GTV & CTV
- Information concerning the treatment itself – PTV, TV, IV, PRV
- Delineation of the PTV is most important
- Different margins that were added or combined
- OAR that were considered when defining the PTV should be clearly defined

Recommendations for recording & reporting volumes Contd.....

- ICRU 62 requires a reference point that is in the PTV and furthermore in a region of low dose gradient
- While potentially achievable in comfortable radiotherapy, IMRT via fluence optimization presents significant difficulty
- Even if the 3D dose distribution provides a homogenous dose region , it is likely that the individual beams project steep dose gradients through the reference location

Dose reporting for OAR

- As shown, the delivered dose to normal tissue adjacent to the tumor may vary significantly from that planned
- Neither PRV nor OR dose Vol histograms are clearly representative of expected risk (esp for parallel Organs)


Thank You