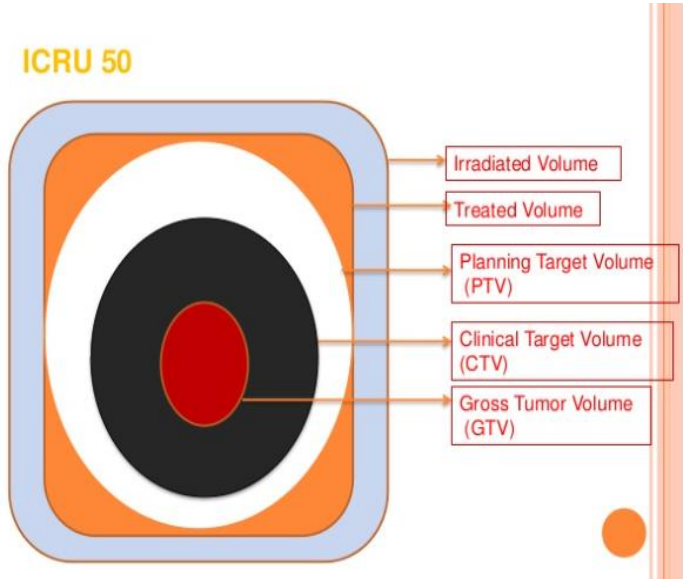
Overview of 3DCRT Planning: Focus on ICRU 50 & 62



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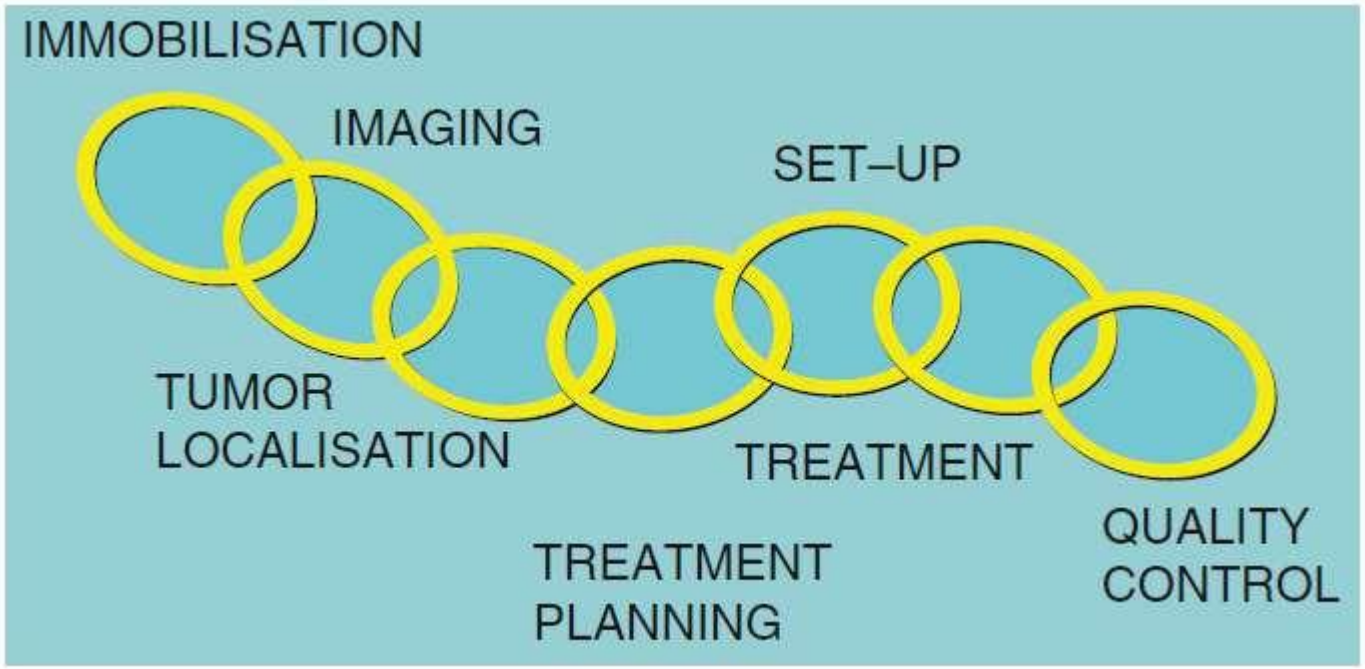
sterling Hospitals
Because life matters

STEPS IN RADIOTHERAPY



- When delivering a radiotherapy treatment, parameters such as volume and dose have to be specified for different purposes: prescription, recording, and reporting.

- It is important that clear, well defined and unambigous concepts and parameters are used for reporting purposes to ensure a common language between different centers.

ICRU

ICRU 50

- originally known as the International X-Ray Unit Committee
- later named International Committee for Radiological Units
- Conceived at the First International Congress of Radiology (ICR) in London in 1925 and officially came into being at ICR-2 in Stockholm in 1928
- Initially meetings were held every 3 years at ICR congresses with one physicist and one radiologist from each participating country

ICRU 50

- In the late 1950s the ICRU started publishing reports on an irregular basis - on average two to three a year.

- In 2001 the publication cycle was regularised and reports are now published bi-annually under the banner "Journal of the ICRU”

- **Principal objective of ICRU** Is to develop concepts, definitions and recommendations for the use of quantities and their units for ionizing radiation and its interaction with matter, in particular with respect to the biological effects induced by radiation

Principal objective of ICRU ICRU 50

The development of internationally accepted recommendations regarding:

- (1) quantities & units of radiation & radioactivity

- (2) procedures suitable for the measurement and application of these quantities in diagnostic radiology, radiation therapy, radiation biology, nuclear medicine, radiation protection, and industrial and environmental activities

- (3) physical data needed in the application of these procedures, the use of which assures uniformity in reporting.

Purpose

- To enable the radiation oncologist to maintain a consistent treatment policy and improve it in the light of experience
- To enable the radiation oncologist to compare the results of treatment with those of departmental colleagues
- To enable other radiation oncologists to benefit from the department's experience
- To compare with other centres

History of ICRU

ICRU 50

ICRU Report No: 29 (1978)

"Dose specification for reporting external beam therapy in photons and electrons

ICRU Report – 50 (1993)

Supersedes and updates Report 29

Prescribing, Recording, and Reporting photon beam therapy

ICRU Report – 62 (1999) Supplement to ICRU Report No: 50

ICRU Report – 83 (2010)

Prescribing, Recording, and Reporting Photon-beam IMRT

ICRU 50

- Even though published in the 2D era, it attempted to address spatial uncertainties by pointing out that the size and shape of a target volume may change during the course of a treatment and that one should take into account the following parameters when describing the target volume-

- 1. expected movements (e.g., caused by breathing) of those tissues that contain the target volume relative to anatomic reference points (e.g., skin markings, suprasternal notch),

- 2.expected variation in shape and size of the target volume during a course of treatment (e.g., urinary bladder, stomach)

- 3.inaccuracies or variations in treatment setup during the course of treatment.

Defined by ICRU 29

ICRU 29

- Target Volume
- Treatment Volume
- Irradiated Volume
- Organs at Risk
- Hot Spot

ICRU 29

Target volume

- Volume containing those tissues that are to be irradiated to a specified absorbed dose according to a specified time- dose pattern

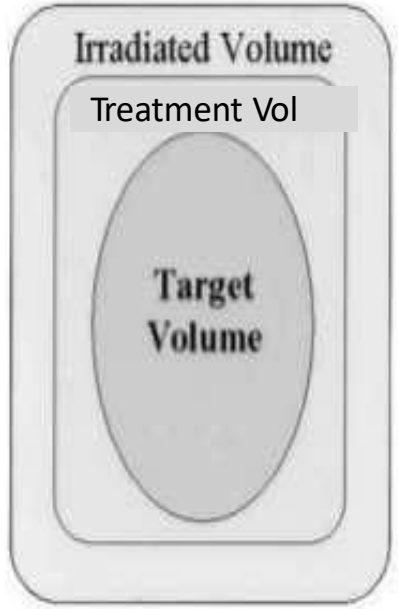
ICRU 29

- Treatment volume –

  volume enclosed by the isodose surface representing the minimal target dose

- Irradiated volume –

  volume that receives a dose considered significant in relation to normal tissue tolerance (e.g., 50% isodose surface)



ICRU 29

- Defined organs at risk (OAR) as radiosensitive organs in or near the target volume whose presence influences treatment planning and/or prescribed dose.

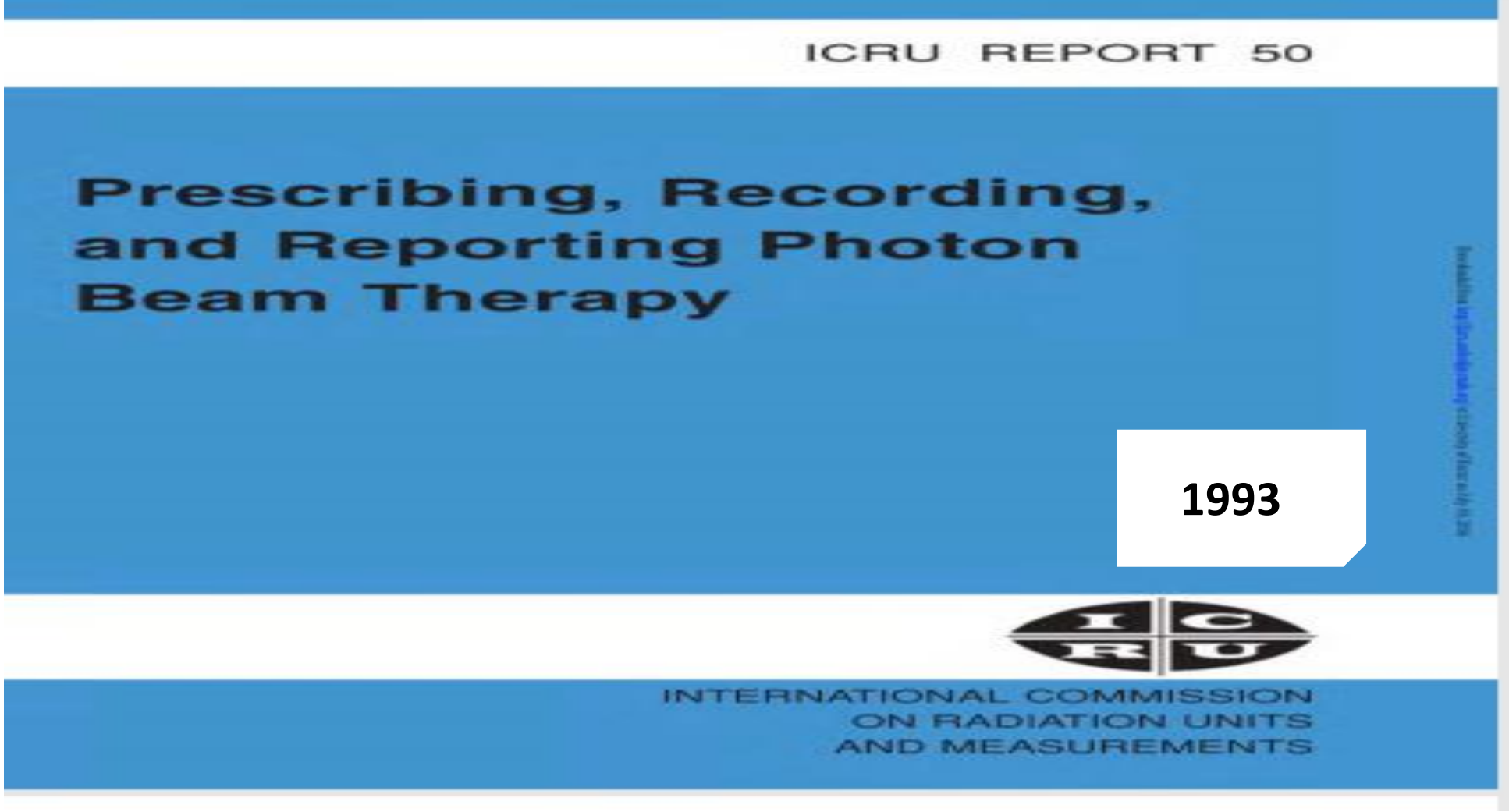
- Hot spot - Tissues outside the target area that received a dose higher than 100% of the specified target dose, and was considered clinically meaningful only if the corresponding isodose curve enclosed an area of at least 2 cm^2 in a section.

ICRU 29

DRAWBACK

- However, the report did not address the issues of coordinate systems (e.g., patient vs. treatment machine), and no attempt was made to define and explicitly separate the margins for the different types of uncertainties.

- ICRU Report 29 recommendations were well suited for the technology of the 1970s and 1980s,using a conventional simulator to generate a planning radiograph for designing beam portals based on bony and soft tissue landmarks.



- In 1993, the ICRU updated its recommendations for specifying dose/volume in Report 50, and were well suited for conformal therapy

ICRU Report - 50 Prescribing, Recording, and Reporting Photon Beam Therapy

ICRU 50

When delivering a radiotherapy tretament, parameters such as volume and dose have to be specified for different purposes: prescription, recording, and reporting. The aims are –

- To have a consistent treatment policy and improve it in the light of experience
- To be able to compare the results of treatment with those of departmental colleagues
- Other radiation oncologists should be able to benefit from the department's experience
- The results to be meaningfully compared with those of other centers, without having access to the complete data

ICRU 50

- Radical treatment of Malignant disease:-
  - To achieve permanent tumor control
  - Volumes to be treated is tumor and the expected subclinical disease.

- Palliative treatment of Malignant disease
  - To decrease symptoms
  - May include all or only part of the tumor

*Non malignant disease - may or may not include all of the affected tissues eg irradiation of dermatoses

ICRU 50

DESCRIBED VOLUMES

- Gross target volume
- Clinical target volume

Defined prior to T/t planning

- Planning target volume
- Organs at risk

During T/t planning

- Treated volume
- Irradiated volume

Depends on the T/t technique

ICRU 50

GROSS TUMOR VOLUME (GTV)

Definition

Gross demonstrable extent and location of the malignant growth.

- It consists of :
  - Primary tumor(GTV primary)
  - Metastatic lymphadenopathy(GTV nodal)
  - Other metastasis(GTV M)

- If the tumor has been removed prior to radiotherapy then no GTV can be defined.

ICRU 50

Determination of shape,size and location of the GTV

- Clinical examination

(Inspection, palpation, endoscopy)

- Various imaging techniques
- X-ray,CT
- USG
- MRI
- Radionucleotide methods like PET

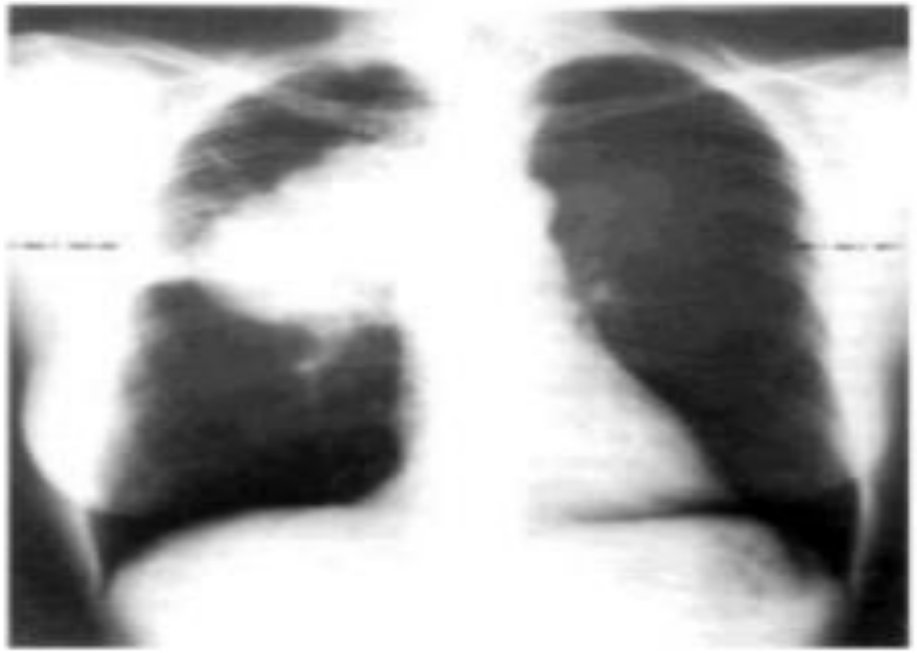
- Reasons to describe GTV accurately
- Staging of the tumor according to the TNM.
- To define area requiring adequate dose delivery for treatment
- Regression of GTV used as predictive of tumor response

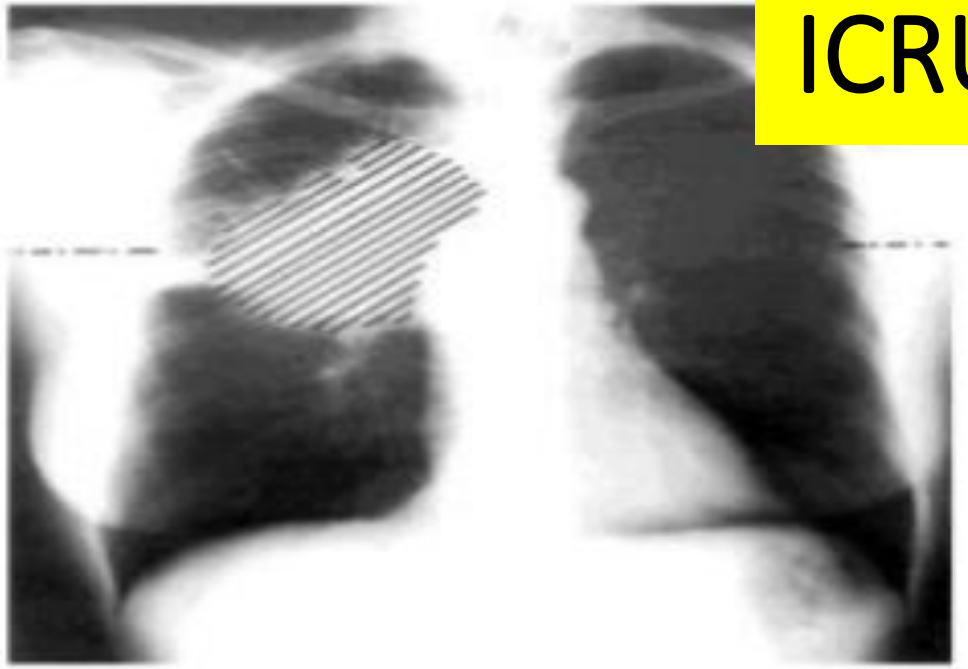
ICRU 50

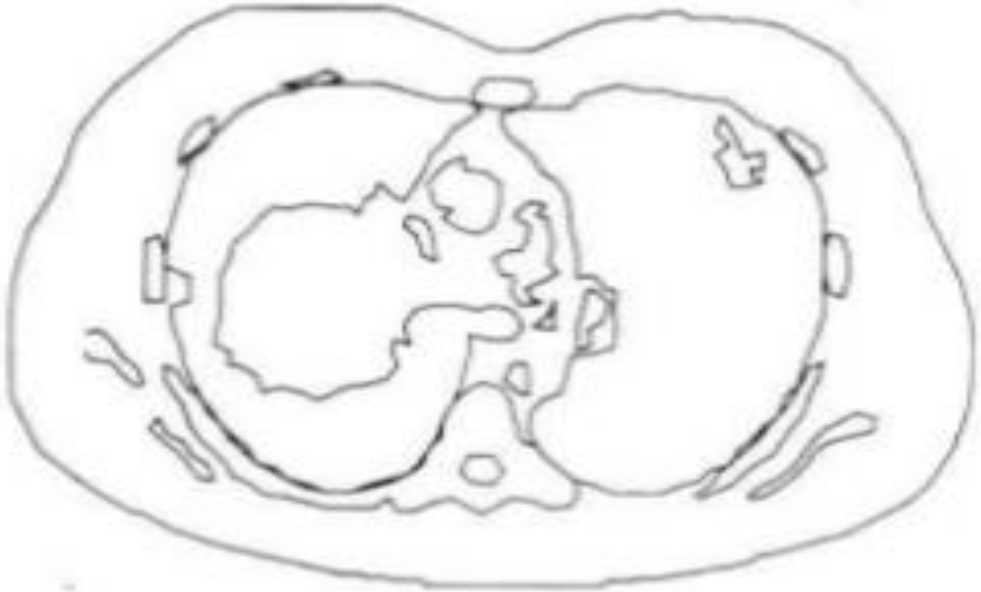
- Corresponds to those parts of the malignant growth where the tumor density is largest.

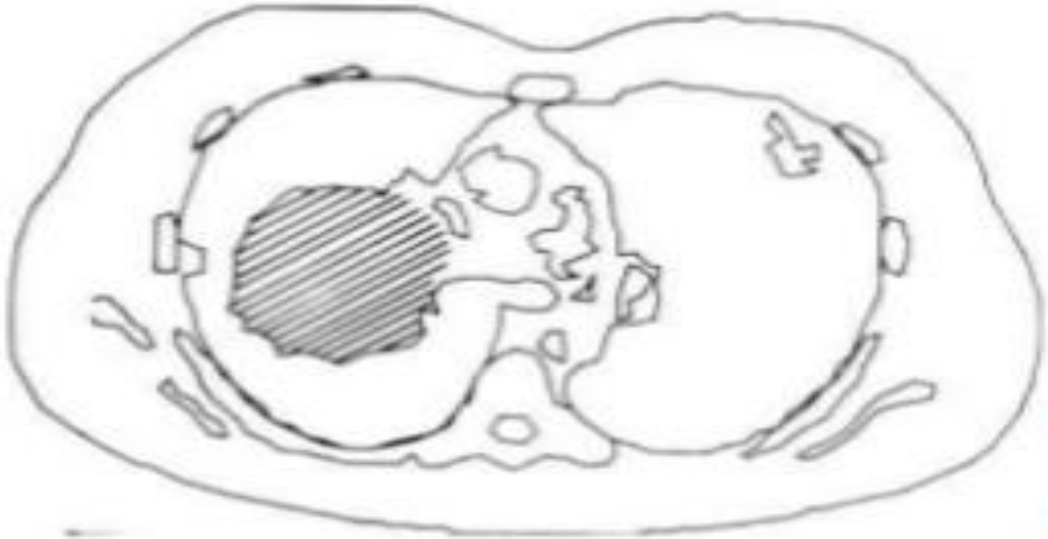
- If the tumor has been removed prior to radiotherapy then no GTV can be defined.

ICRU 50









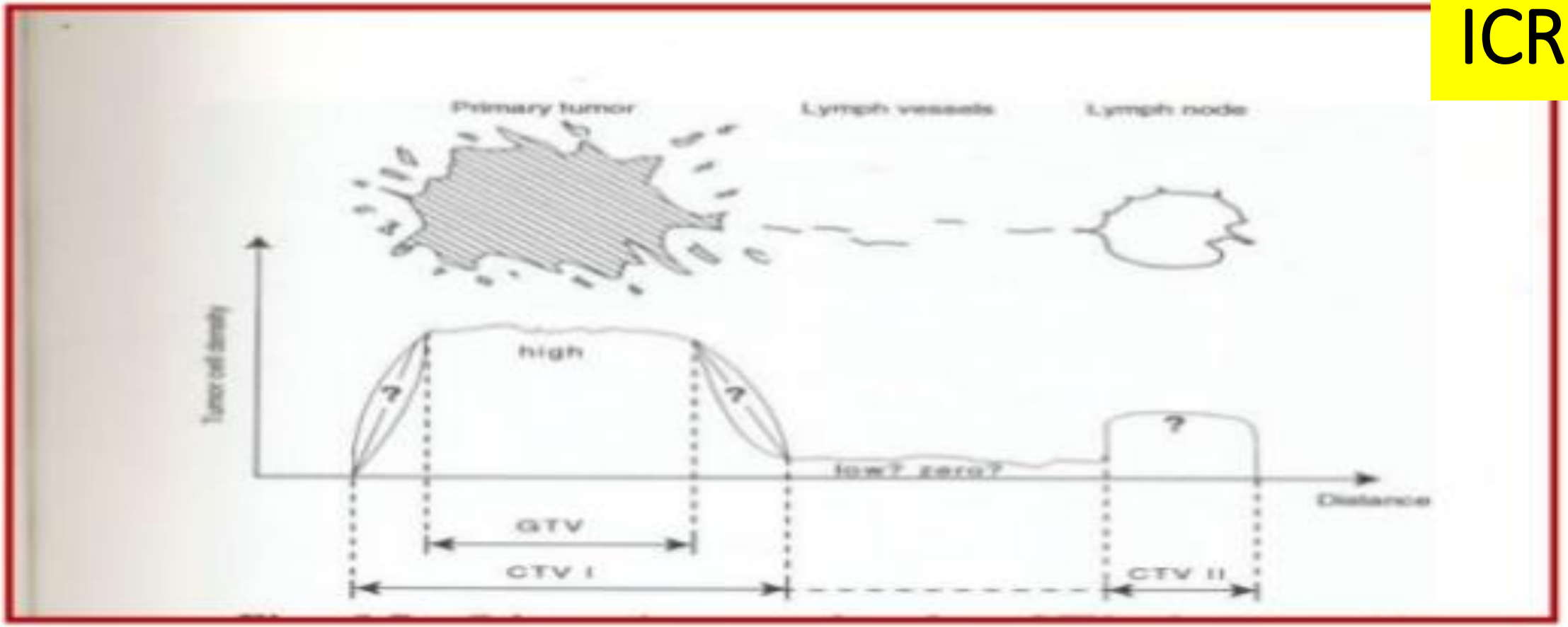
CLINICAL TARGET VOLUME CTV

ICRU 50

- Tissue volume that contains a GTV and/or subclinical microscopic disease, which has to be eliminated

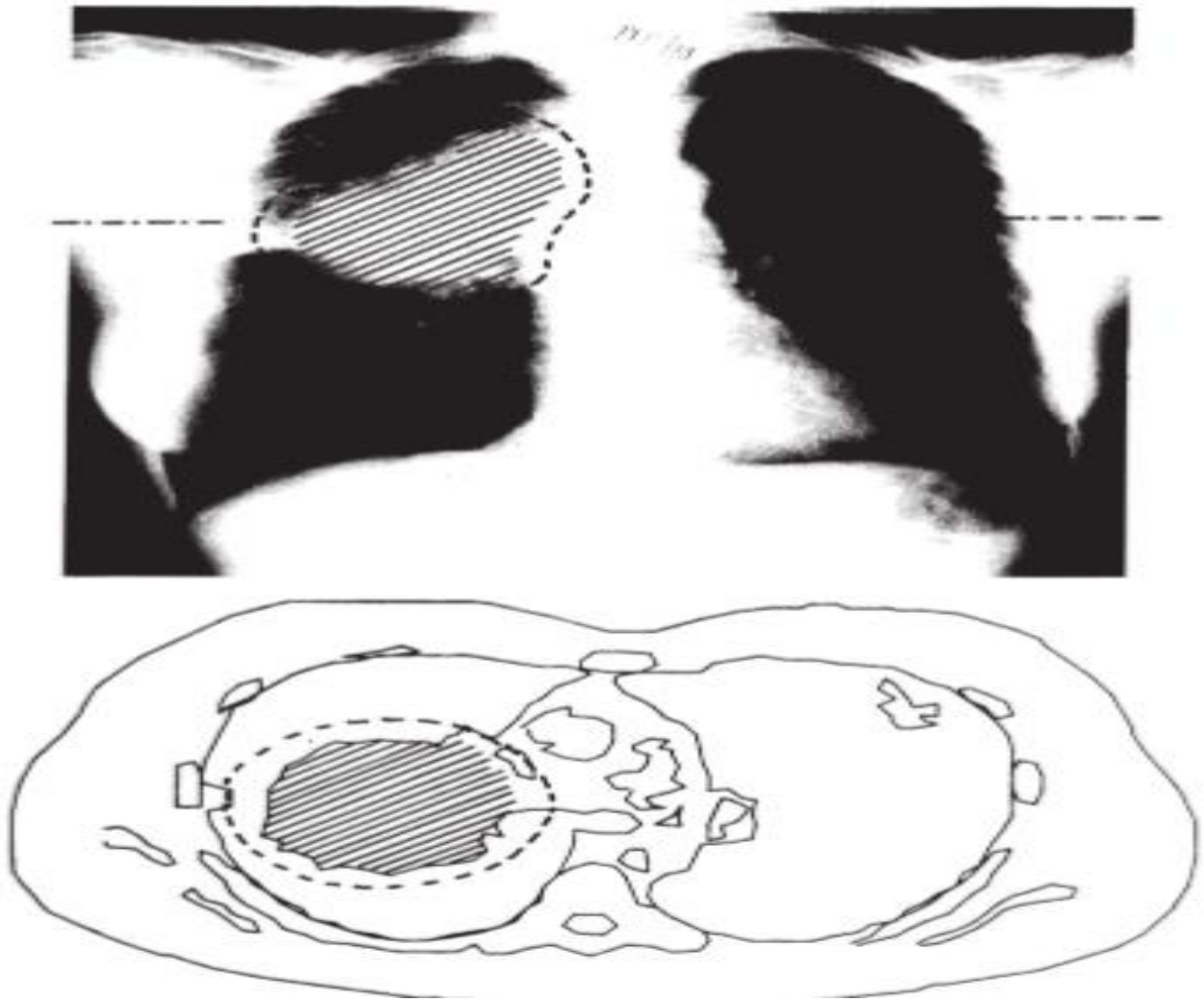
  - In specifying the CTV, the physician must not only consider microextensions of the disease near the GTV, but also the natural avenues of spread for the particular disease and site, including lymph node, perivascular, and perineural extensions

ICRU 50



2 types of Subclinical extension:-

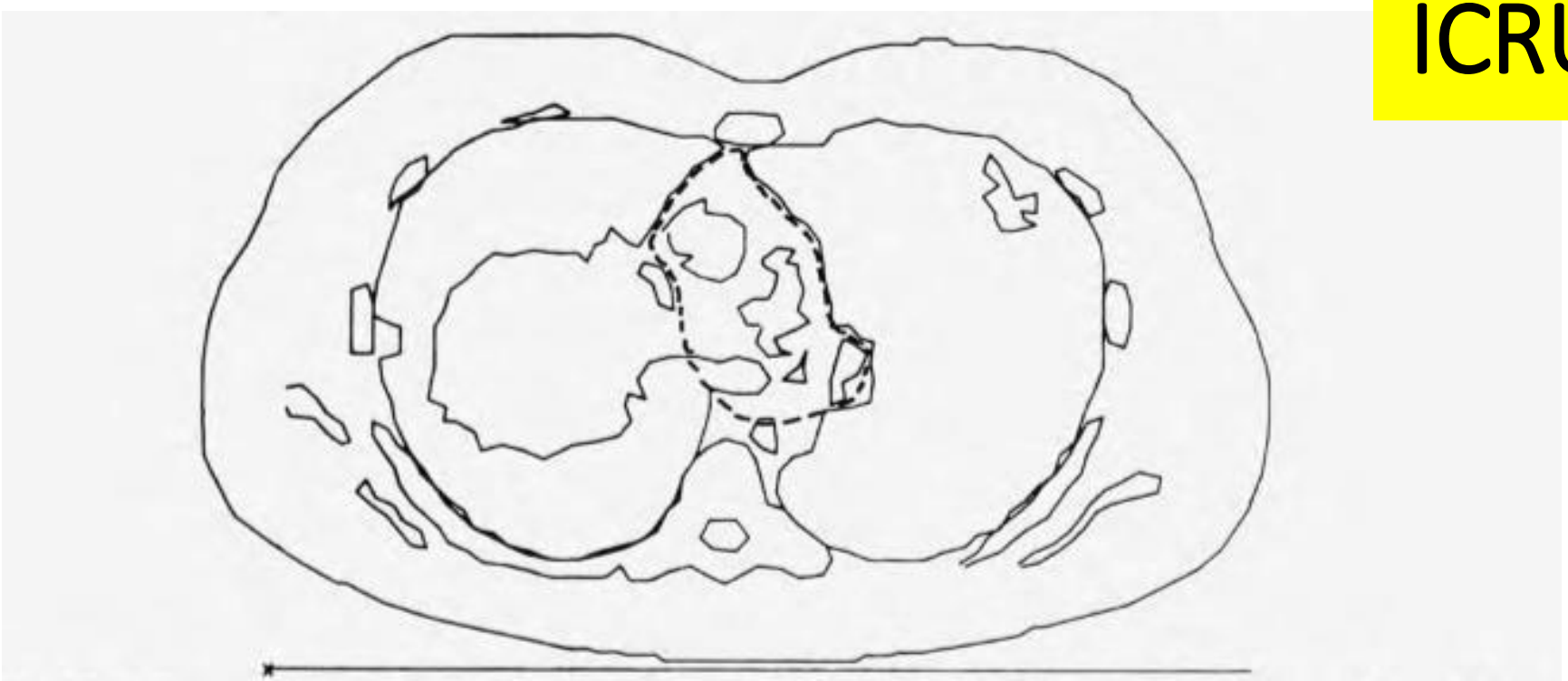
- Around the GTV-CTV I
- At a distance (Regional lymph nodes)-CTV II



ICRU 50

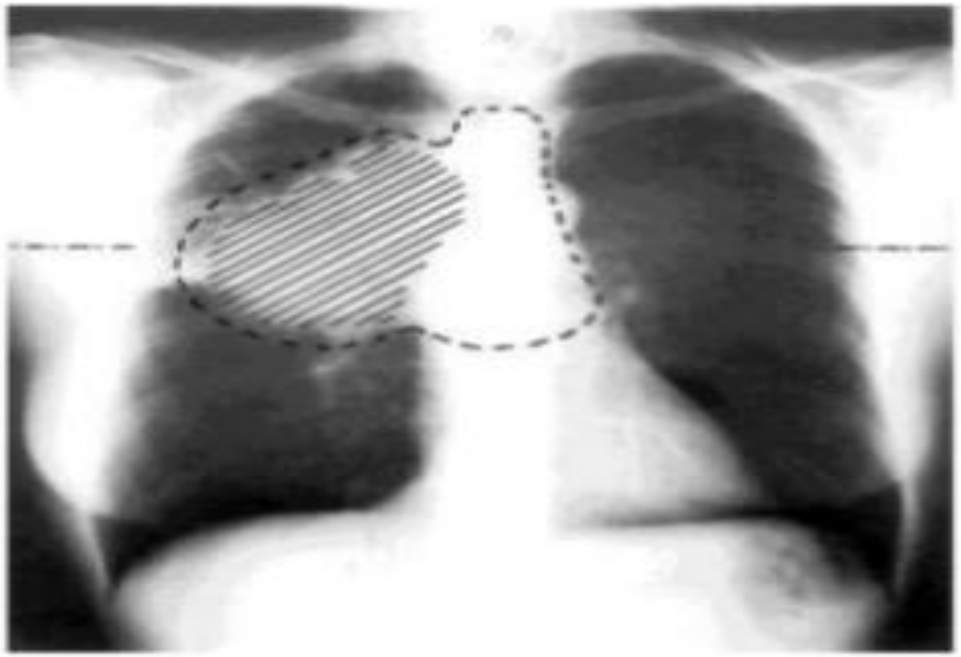
Local subclinical involvement around GTV - CTV I

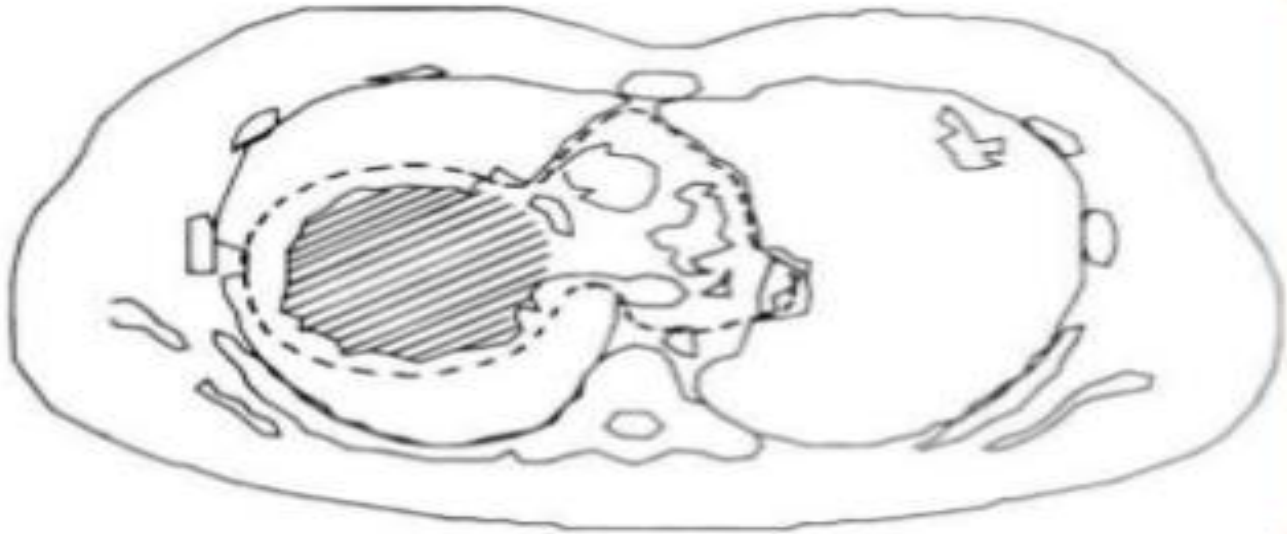
ICRU 50



Mediastinal lymph nodes and medial part of contralateral hilar region - CTV II

ICRU 50



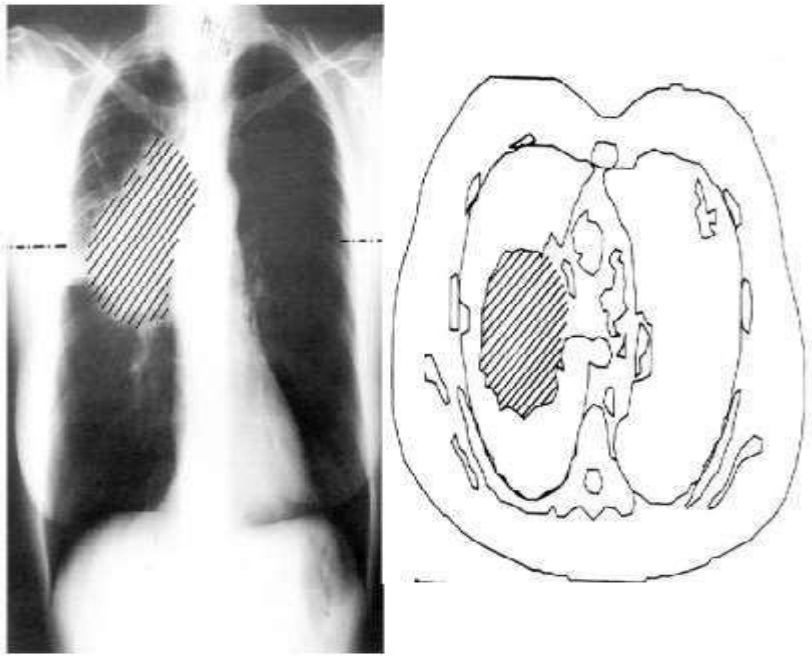


Combined CTV I + CTV II

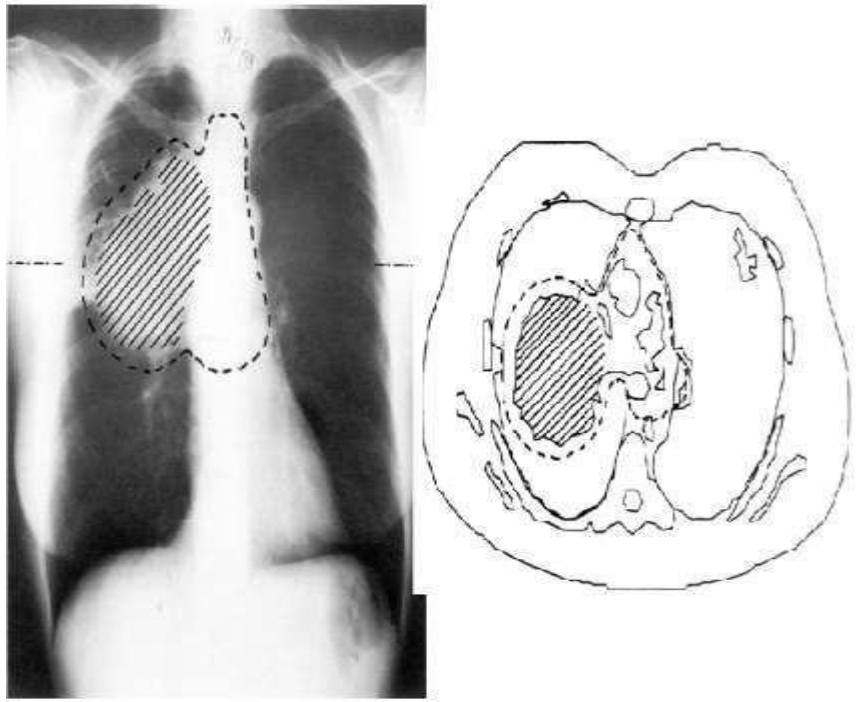
ICRU 50

The delineation of GTV and CTV are based on purely anatomic-topographic and biological considerations without regard to technical factors of treatment.

GTV



CTV



Importance of CTV

ICRU 50

- If different doses are prescribed, this implies the definition of different CTV for different dose level. Eg. boost therapy

- If there is change in size, shape and location of CTV during treatment there may be need or replanning

Planning Target Volume (PTV)

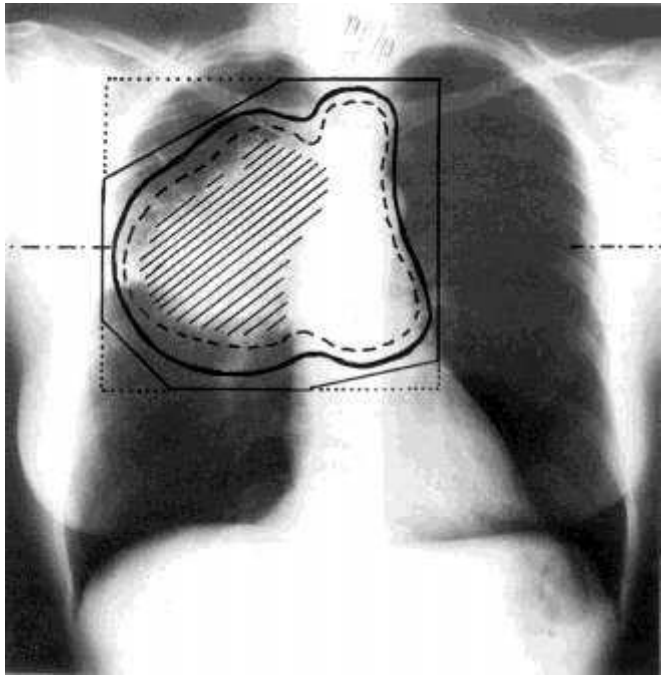
ICRU 50

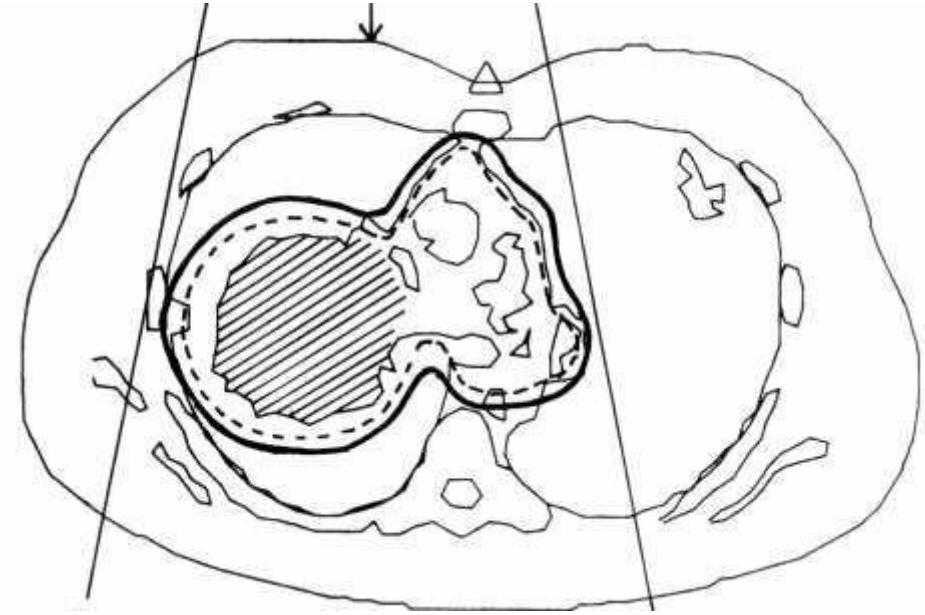
- The PTV is a geometrical concept, and it is defined to select appropriate beam sizes and beam arrangements, taking into consideration the net effect of all the possible geometrical variations and inaccuracies in order to ensure that the prescribed dose is actually delivered to the CTV

- Affected by:
  - Size and shape of the GTV & CTV
  - Effects of internal motions of organs and the tumor
  - Treatment technique (beam orientation and patient fixation, daily setup errors)
  - Intrafractional errors (During a single session)
  - Interfractional errors (From one session to another)

PTV

ICRU 50



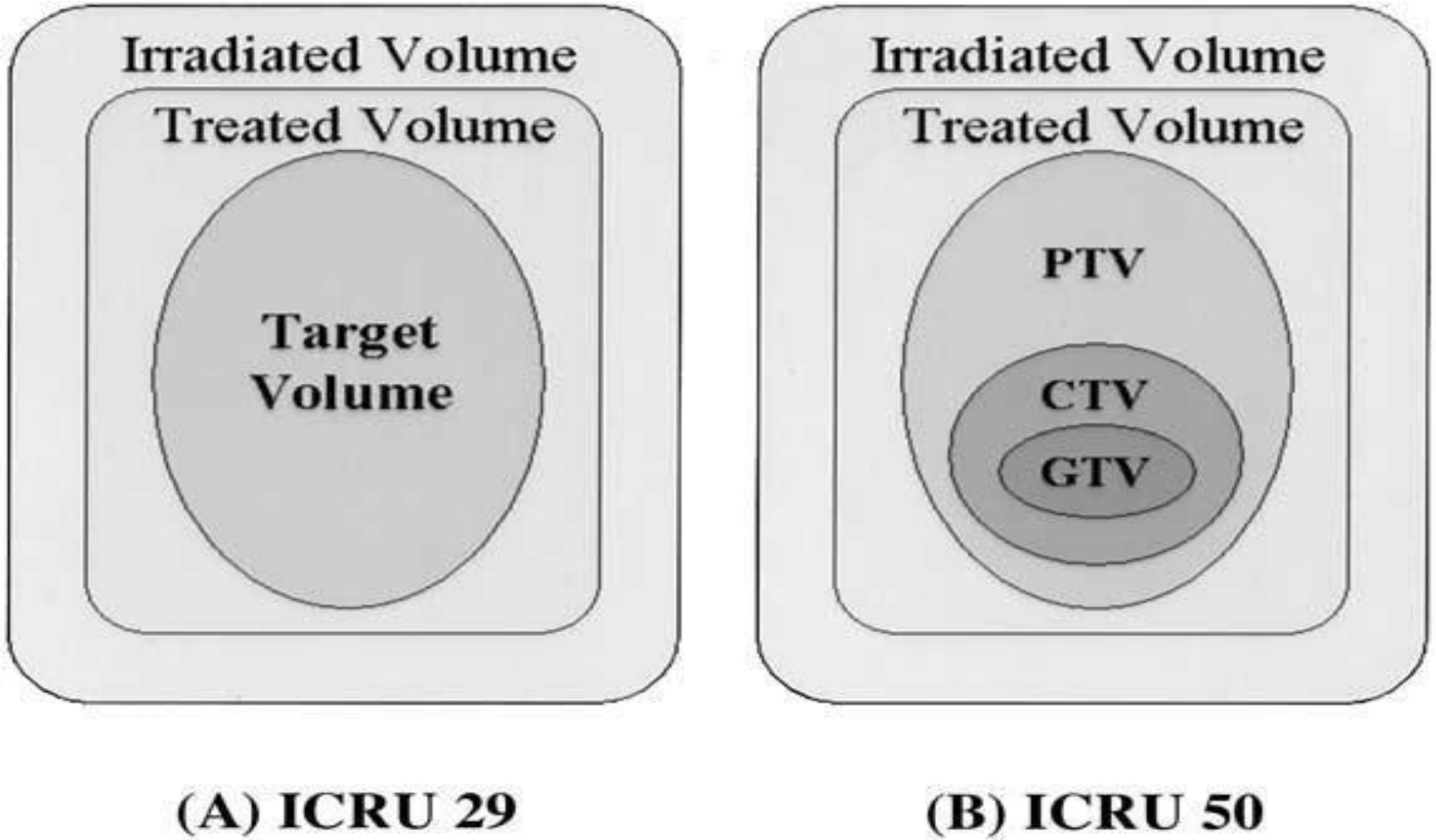


ICRU 50

- Multiple PTVs may be defined for a patient's radiation therapy treatment

- For example, it is common practice to plan a higher dose to the PTV enclosing the GTV, and a lower dose to the PTV containing the CTV

- Such planning volumes are typically subscripted using the dose level prescribed; for example, PTVs for 66 Gy and 54 Gy can be represented as PTV_{66} and PTV_{54}



(A) ICRU 29

(B) ICRU 50

PTV (ICRU 50) synonymous - Target Volume (ICRU 29)

ICRU 50

- Depending on clinical situtation and chosen technique PTV could be very similar to CTV

- Eg
- Small skin tumors, pitutary tumors

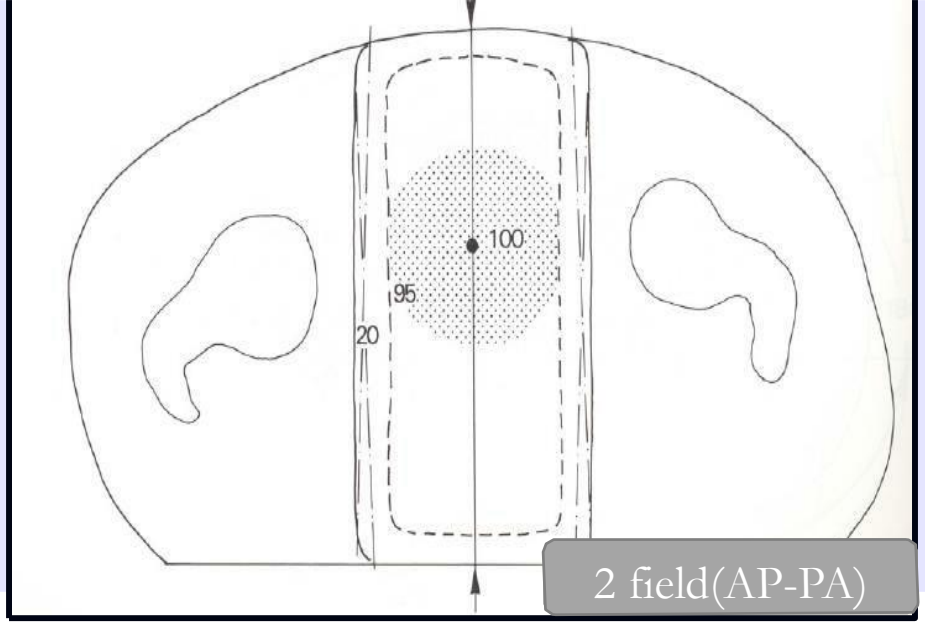
- Larger - Eg Lung tumors.

ICRU 50

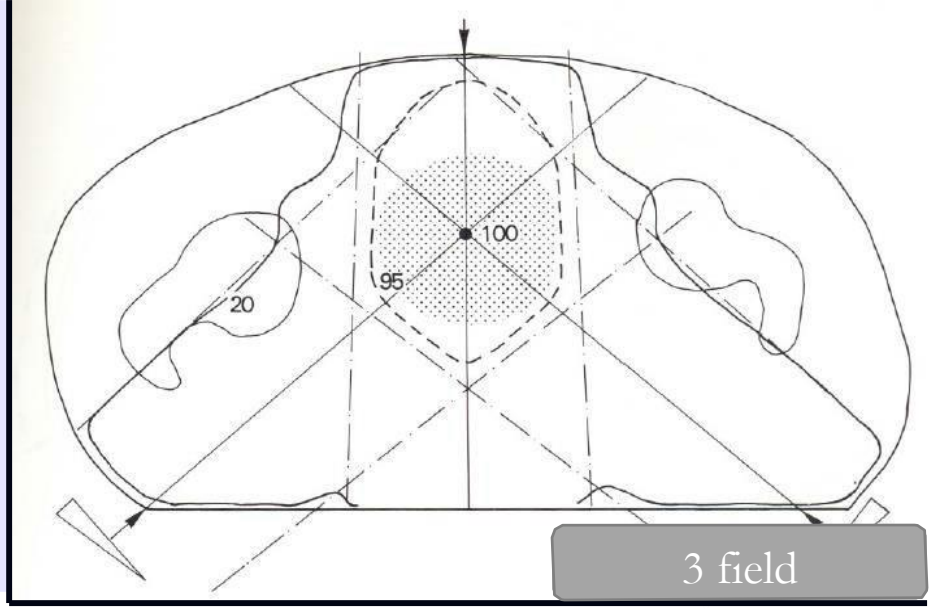
TREATED VOLUME

Definition:-

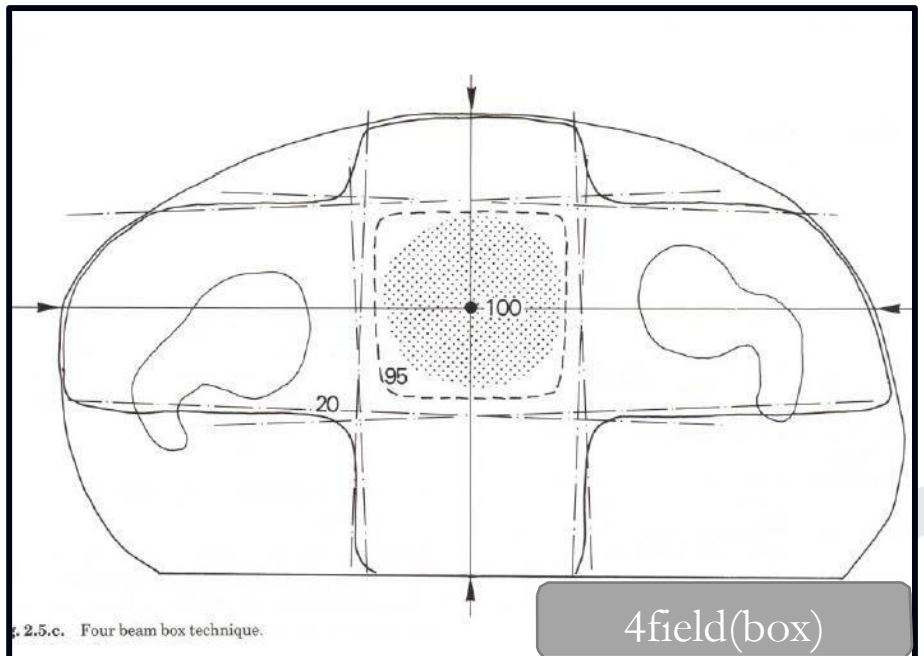
- It is the volume enclosed by an isodose surface that is selected and specified by the radiation oncologist as being appropriate to achieve the purpose of treatment (palliation or cure).
- Usually taken as the volume enclosed by the 95% isodose curve.
- Ideally dose should be delivered only to the PTV but due to limitations in the radiation treatment technique.



2 field(AP-PA)



3 field



g. 2.5.c. Four beam box technique.

4field(box)

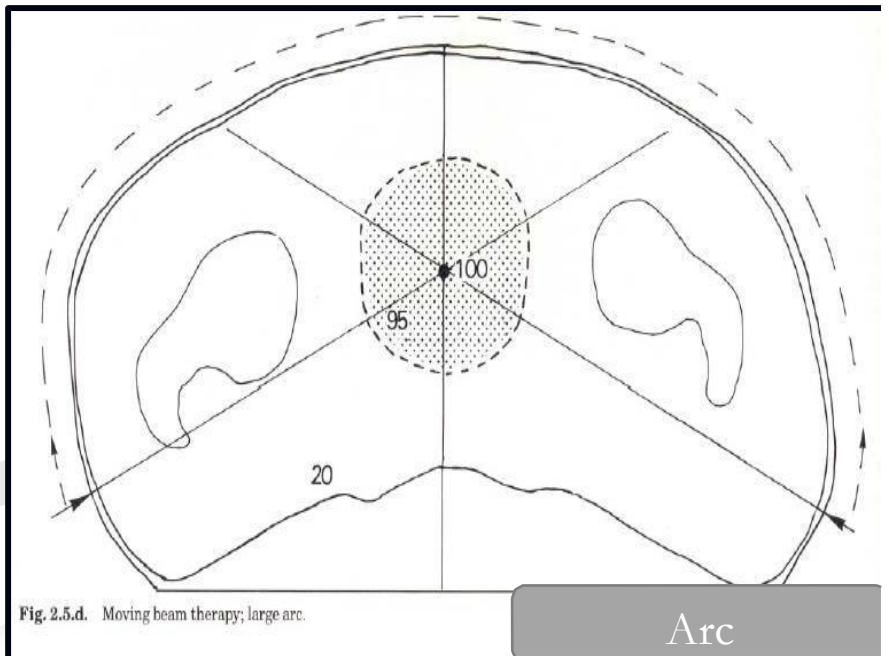


Fig. 2.5.d. Moving beam therapy; large arc.

Arc

ICRU 50

Reasons for identification of Treated Volume are :

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

2. 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.

IRRADIATED VOLUME (IRV)

ICRU 50

- It is the volume that receives a dose considered significant in relation to normal tissue tolerance
- Usually taken as the volume enclosed by the 50% isodose curve.
- It depends on the treatment technique used

ICRU 50

- ICRU Report 50 retained the definition of the two dose volumes defined in ICRU Report 29

- changing the treatment volume name to treated volume, and refining the definition-- *volume enclosed by an isodose surface, selected and specified by the radiation oncologist as being appropriate to achieve the purpose of treatment* (e.g., tumor eradication, palliation

- irradiated volume as that *tissue volume that receives a dose that is considered significant in relation to normal tissue tolerance.*

ICRU 50

- The hot spot definition was modified

- volume outside the PTV that received a dose
  larger than 100% of the specified PTV dose.
  considered clinically meaningful only if the minimum diameter exceeded 15 mm (note: previously it had been 2 cm^2).

- However, if the hot spot occurs in a small organ, such as the optic nerve, a dimension smaller than the recommended 15 mm should be considered.

ORGANS AT RISK (OAR)

ICRU 50

- These are normal tissues whose radiation sensitivity may significantly influence the treatment planning and/or prescribed dose.

- They may be divided into 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.

ICRU 50

Dose Homogenity

- When the dose to a given volume has been prescribed, then the corresponding delivered dose should be as homogeneous as possible
- Some heterogeneity has to be accepted due to obvious technical reasons - should be kept within +7% and -5% of prescribed dose
- If such a degree of homogeneity cannot be achieved, it is the responsibility of the radiation oncologist to decide whether this can be accepted or not.

ICRU REFERENCE POINT

ICRU 50

- It has to be selected according to the following general criteria :
- The dose at the point should be clinically relevant.
- The point should be easy to define in a clear and unambiguous way.
- The point should be selected so that the dose should be accurately determined.
- The point should be in a region where there is no steep dose gradient.

ICRU 50

- Located firstly at the center or in the central parts, of the PTV and secondly on or near the central axis of the beam
- Sometimes not in the centre of PTV then the place where the tumor density is at its maximum
- The dose at the ICRU Reference Point is the ICRU Reference Dose

D_{max} & Hot spot

ICRU 50

- One can identify the maximum dose within the PTV, and the maximum dose at tissue outside the PTV - Hot Spot
- In most cases, high dose to a volume with smallest diameter <15mm is not clinically meaningful in terms of normal tissue tolerance
- However, maximum dose assessment is important for organs at risk with small dimension (<15mm) such as optic nerve

Minimum Dose (D_{min})

ICRU 50

- The minimum dose is the smallest dose in a defined volume
- In contrast to the situation with the maximum absorbed dose, no volume limit is recommended when reporting minimum dose
- The Minimum Planning Target Dose is the lowest dose in the Planning Target Volume

ICRU 50

Average Dose ($D_{average}$)

- The determination of the average, the median and modal doses is based on the calculation of the dose at each one of a large number of discrete points (lattice points), uniformly distributed in the volume in question

- The Average Dose is the average of the dose values in these lattice points and can be' expressed by

ICRU 50

- Equation

$$D_{average} = \frac{1}{N} \sum_{V} D_{i,j,k}$$

- where N is the number of lattice points, i is the column index in this lattice, j is the row index, k is the level index, and Dij ,k is the dose at the lattice point ij,k located inside the volume V.

ICRU 50

Median Dose: D_{median}

The median dose is the central value of the doses at all lattice points

Modal Dose: D**modal**

The dose that occurs most frequently at the lattice points

** There may be more than one modal dose value, which then makes this concept useless for reporting purpose

Three Levels of Dose Evaluation for Reporting

ICRU 50

- The level of completeness and accuracy of reporting therapeutic irradiation depends to a large extent on the situation in the department and on the aim of the treatment.

ICRU 50

- Level 1 –BASIC TECHNIQUE –

- Minimum standards, 2-D reporting (using depth dose tables)
- According to the recommendations of ICRU, as a basic requirement, the following doses should always be reported
    - the dose at ICRU reference point and its variation along central beam axis
    - the maximum dose to the PTV
    - the minimum dose to the PTV

ICRU 50

- Level 2 – ADVANCED TECHNIQUE -prescribing and reporting state-of-the-art techniques (using computational dosimetry and 3D imaging)
- Dose distribution computed for planes

- Level 3 – DEVELOPMENTAL TECHNIQUE -optional research-and-development reporting (using techniques for which reporting criteria are not yet established)
- Dose distributio computed for volumes

International Commission on Radiation Units & Measurements

SEARCH search... go

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About ICRU

For nearly 90 years, ICRU has established international standards for radiation units & measurement.

Current Program

- Diagnostic Radiology & Nuclear Medicine
- Radiation Therapy
- Radiation Protection
- Radiation Science

Questions? Comments? »

Reports

ICRU Report 91, Prescribing, Recording, and Reporting of Stereotactic Treatments with Small Photon Beams

ICRU Report 90, Key Data For Ionizing-Radiation Dosimetry: Measurement Standards And Applications

ICRU Report 89, Prescribing, Recording, and Reporting Brachytherapy for Cancer of the Cervix

Current Events

90th Anniversary Celebration

ICRU and ICRP to Celebrate Respective 90th Anniversaries in Stockholm

ICRU Timeline 1928 - 2018

Hans Menzel 42nd L.S. Taylor Lecture

H.H. Rossi Lecture given by Hans Menzel

About ICRU

Mission Statement

To develop and promulgate internationally accepted recommendations on radiation related quantities and units, terminology, measurement procedures, and reference data for the safe and efficient application of ionizing radiation to medical diagnosis and therapy, radiation science and technology, and radiation protection of individuals and populations.

ICRU at a Glance (PDF) »
More About ICRU »

International Commission on Radiation Units and Measurements

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HISTORY

The ICRU (originally known as the International X-Ray Unit Committee and later as the International Committee for Radiological Units) was conceived at the First International Congress of Radiology (ICR) in London in 1925 and officially came into being at ICR-2 in Stockholm in 1928. The primary objective was to propose a unit for measurement of radiation as applied in medicine. From 1950 the ICRU expanded its role significantly to embrace a wider field. Initially meetings were held every 3 years at ICR congresses (excluding the 13-year period encompassing World War II) with one physicist and one radiologist from each participating country having the right of attendance. The Chairman was nominated by the ICR host country. A permanent Commission was elected in 1953.

L S Taylor (USA) served ICRU as a member [1928 – 1934] and then Secretary [1934 – 1953], first permanent Chairman [1953 – 1969] and then Honorary Chairman [1969 until his death in 2004]. Subsequent ICRU Chairmen have been: H O Wyckoff (USA) [1969 – 1985]; A Allisy (France) [1985 – 1997]; A Wambersie (Belgium) [1997 – 2006]; and P M DeLuca, Jr (USA) [2006 – 2009]. H-G Menzel (Germany) is the current Chairman.

MEMBERSHIP

Since the sixth meeting in 1950 members have been elected to the ICRU by incumbent Commissioners. The Commission is composed of a maximum of 15 members selected for their scientific ability and is widely regarded as one of the foremost panel of experts in radiation medicine and in the other fields of ICRU endeavor. Meetings of the full Commission are held annually.

CURRENT MEMBERS

H-G Menzel (Germany), *Chairman*
P M DeLuca, Jr (USA) *Vice Chairman*
T R Mackie (USA), *Secretary*
S M Bentzen (USA), Executive Director
V Grégoire (Belgium), Executive Director
J M Boone (USA)
M-E Brandan (Mexico)
A Chiti (Italy)
D T Burns (France)
E Fantuzzi (Italy)
R W Howell (USA)
P Olko (Poland)
B O'Sullivan (Canada)
D Rogers (Canada)
N Saito (Japan)

FUNDING

Income is currently derived mainly from the sale of ICRU Reports. Financial

A Wambersie (Belgium) [1997 – 2006]; and P M DeLuca, Jr (USA) [2006 – 2009]. H-G Menzel (Germany) is the current Chairman.

MISSION

To develop and promulgate internationally accepted recommendations on radiation-related quantities and units, terminology, measurement procedures, and reference data for the safe and efficient application of ionizing radiation to medical diagnosis and therapy, radiation science and technology, and radiation protection of individuals and populations.

AIMS

- To collect and evaluate the most relevant data and information pertinent to the problems of ionizing radiation for inclusion in its reports.
- To strive to maintain close contacts with organizations, professional societies and statutory bodies that benefit from its work.

COLLABORATIONS

Professional societies, government agencies and departments, national laboratories and statutory organizations, the US National Council on Radiation Protection (NCRP), international organizations including the International Atomic Energy Agency (IAEA), World Health Organization (WHO), the International Commission on Radiological Protection (ICRP), the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the International Organization for Standardization (ISO), the International Bureau of Weights and Measures/*Bureau International des Poids et Mesures* (BIPM) and the International Committee for Weights and Measures/*Comité International des Poids et Mesures*

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EVOLUTION OF RADIATION UNITS (ICRU RECOMMENMDATIONS)

QUANTITY		UNIT			DATE
Name	Symbol	Unit	Special name	Symbol	
Exposure	X	1 e.s.u. per 0.001293 g of air	röntgen	r→R	1928
Absorbed dose	D	erg g^{-1}			1950
Activity	A	3.7×10^{10} s^{-1}	curie	Ci	1953
Absorbed dose	D	100 erg g^{-1}	rad	rad	1953
Fluence	Φ	cm^{-2} or m^{-2}	(reciprocal area)	(SI)	1962
Dose equivalent	H	100 erg g^{-1}	röntgen equivalent man	rem	1971
Absorbed dose	D	J kg^{-1}	gray	Gy (SI)	1974
Activity	A	s^{-1}	bequerel	Bq (SI)	1974
Dose equivalent	H	J kg^{-1}	sievert	Sv (SI)	1977

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ICRU 50

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Volume II. ICRU Reports 12, 13, 15, 16, 17, 18, 20
Volume III. ICRU Reports 22, 23, 24, 25, 26
Volume IV. ICRU Reports 27, 28, 30, 31, 32
Volume V. ICRU Reports 33, 34, 36
Volume VI. ICRU Reports 37, 38, 39, 40, 41
Volume VII. ICRU Reports 42, 43, 44
Volume VIII. ICRU Reports 45, 46, 47
Volume IX. ICRU Reports 48, 49, 50, 51
Volume X. ICRU Reports 52, 53, 54, 55

(Titles of the individual Reports contained in each volume are given in the list of Reports set out above.)

The following ICRU Reports are now superseded and/or out of print:

ICRU Report No.	*Title and Reference**
1	*Discussion on International Units and Standards for X-ray work,* Br. J. Radiol. **23,** 64 (1927).
2	*International X-Ray Unit of Intensity,* Br. J. Radiol. (new series) **1,** 363 (1928).
3	*Report of Committee on Standardization of X-ray Measurements,* Radiology **22,** 289 (1934).
4	*Recommendations of the International Committee for Ra-*

10a

ICRU 50

The currently available ICRU Reports are listed below.

ICRU Report No.	*Title*
10b	*Physical Aspects of Irradiation* (1964)
10f	*Methods of Evaluating Radiological Equipment and Materials* (1963)
12	*Certification of Standardized Radioactive Sources* (1968)
13	*Neutron Fluence, Neutron Spectra and Kerma* (1969)
15	*Cameras for Image Intensifier Fluorography* (1969)
16	*Linear Energy Transfer* (1970)
17	*Radiation Dosimetry: X Rays Generated at Potentials of 5 to 150 kV* (1970)
18	*Specification of High Activity Gamma-Ray Sources* (1970)
20	*Radiation Protection Instrumentation and Its Application* (1970)
22	*Measurement of Low-Level Radioactivity* (1972)

Reports

ICRU Report 91, Prescribing, Recording, and Reporting of Stereotactic Treatments with Small Photon Beams

ICRU Report 90, Key Data For Ionizing-Radiation Dosimetry: Measurement Standards And Applications

ICRU Report 89, Prescribing, Recording, and Reporting Brachytherapy for Cancer of the Cervix

ICRU Report 92: IN PREPARATION

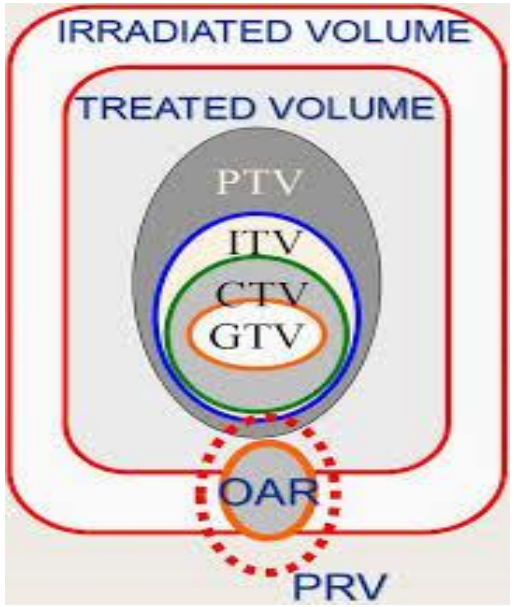
Prescribing, Recording and Repornon Beam therapy

Take home message

ICRU 50

- For nearly 90 years ICRU has established international standards for radiation units and measurements
- Precise for each specific segment
- Refer according to your interest and need!!!!

ICRU 62 - Prescribing, Recording and Reporting Photon Beam Therapy Report 62



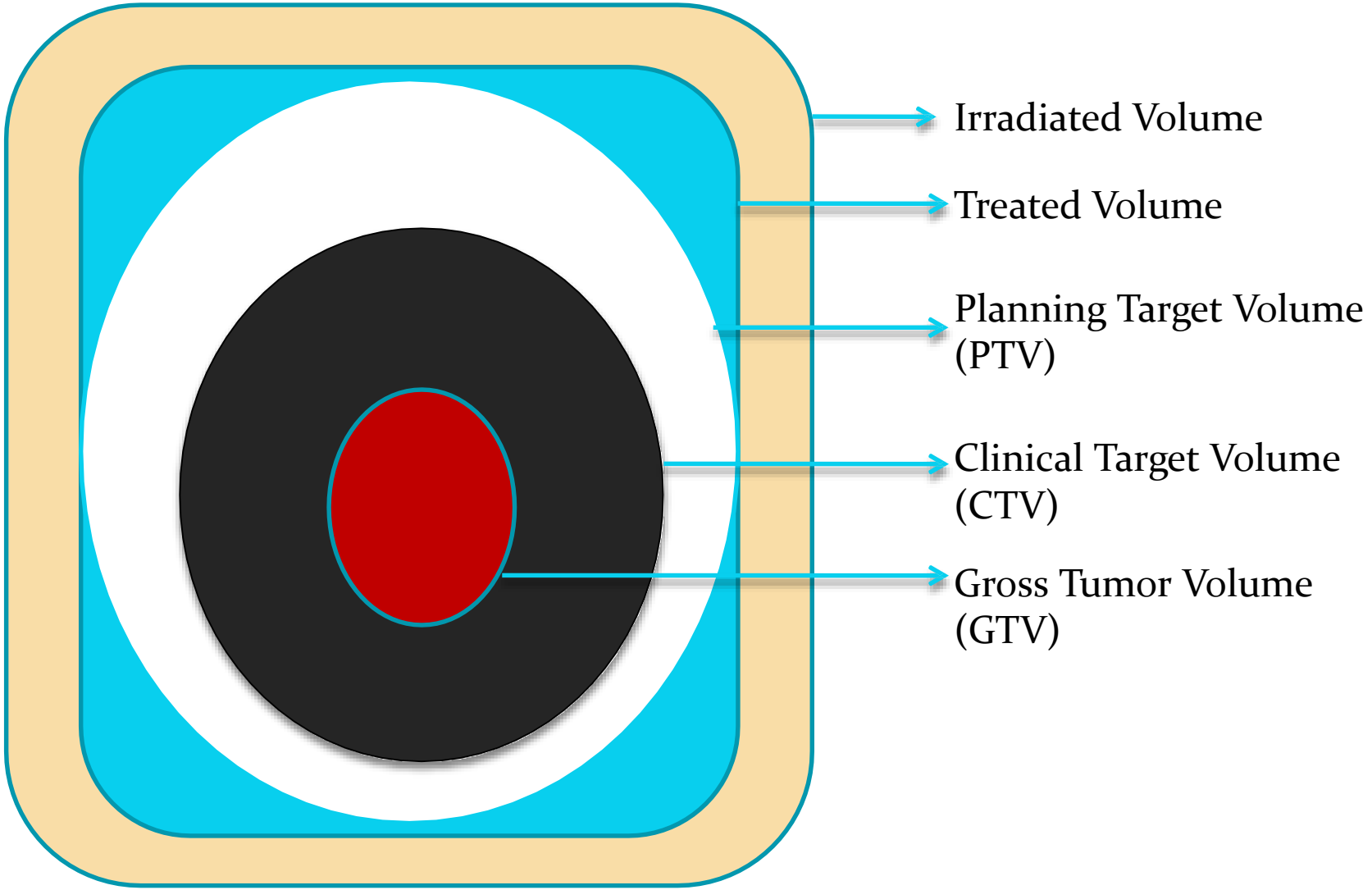
INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS (ICRU)

ICRU 50 (1993): 1993 to 1999

ICRU 62 (1999): 1999 to till date

ICRU 83 (2010): 2010 on wards

ICRU 50


Irradiated Volume
Treated Volume
Planning Target Volume
(PTV)
Clinical Target Volume
(CTV)
Gross Tumor Volume
(GTV)

ICRU 50

Volumes defined prior to treatment planning :

- Gross Tumor Volume (GTV)
- Clinical Target Volume (CTV)

Volumes defined during the treatment planning :

- Planning target Volume (PTV)
- Organs at risk
- Treated Volume
- Irradiated Volume

ICRU 62 ????

- ICRU 50 - Stimulated broad interest, questions, debates and discussion
- In intervening years, irradiation techniques have advanced
- Development of conformal therapy and expected therapeutic gain as well as geometric miss
- Probability of Benefit versus Risk of complications

Formulated need for 62, supplement to 50

- Define additional concepts and formulate more accurate definitions facilitating exchange of scientific and clinical information

Justify update of ICRU 50 !!!

- 1. Improvements in staging and imaging procedures
- 2. improvements in delivery of precision RT techniques
- 3. advances in our understanding of normal tissue response
- In intervening years, irradiation techniques have advanced

ICRU REPORT 62

Prescribing, Recording and Reporting Photon Beam Therapy (Supplement to ICRU Report 50)

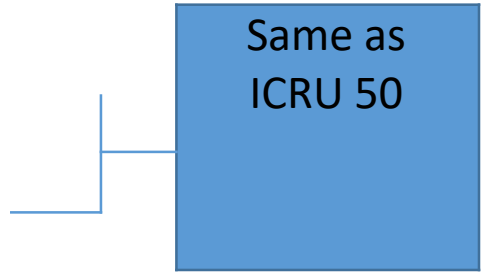
1999

INTERNATIONAL COMMISSION
ON RADIATION UNITS AND
MEASUREMENTS

ICRU 62

Volumes defined prior to treatment planning :

-Gross Tumor Volume (GTV)
-Clinical Target Volume (CTV)



Volumes defined during the treatment planning :

-Planning target Volume (PTV)
-Treated Volume
-Irradiated Volume
-Planning Organ at Risk Volume (PRV)
-Conformity Index

ICRU-62

- Gives more detailed recommendations on the different margins that must be considered to account for anatomical & geometrical variations & uncertainties.
- PTV has been separated into two components: an internal margin and set-up margin.
- Classisfied organs at risk depending on response to radiation.
- Defined planning organ at risk volume (PRV)
- Report dose to the OAR/PRV
- Introduced conformity index
- Gives recommendations on graphics

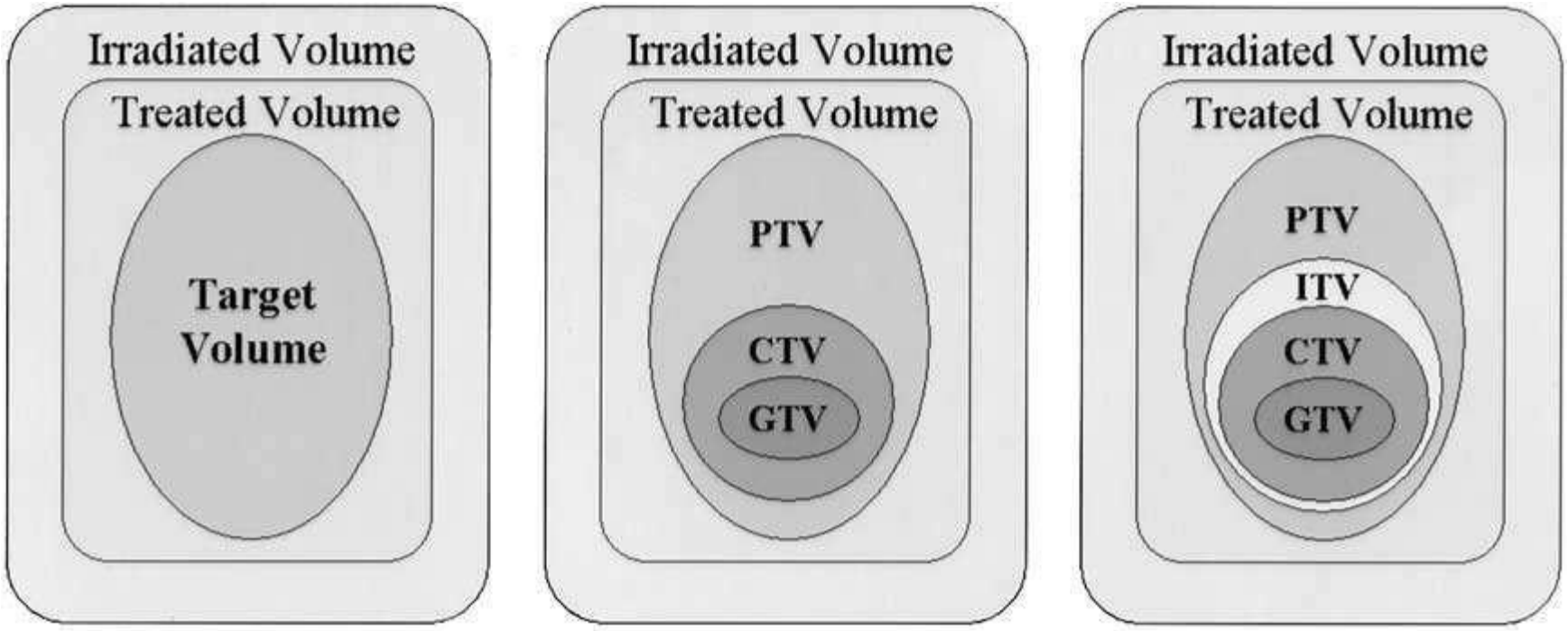
Important Remarks

1. Reporting is emphasized - responsibility physician, appropriate exchange of information between centres

2. Levels of completeness or complexity in the recommendations of reporting

ICRU-62

VOLUMES



(A) ICRU 29 (B) ICRU 50 (C) ICRU 62

To achieve accurate radiation therapy, it must be possible to precisely relate the positions of tissues, organs or volumes in the patient to the positions and orientation of beams used for both imaging or therapy.

Coordinate System

- For accurate RT - relate the position of tissue, organ or volume in patient to position and orientation of beam used for both imaging and therapy
- This requires the use of three coordinate systems
  - one within the patient
  - one related to the imaging unit
  - one related to the treatment machine

Reference Points

- Alignment of the patient in a reproducible and stable position is a prerequisite for correct definition of volumes and set-up of beams

- Adequate patient immobilization systems are the most effective means to accomplish this

✓ Internal Reference Points - anatomical landmarks (e.g., bony structures or gas-filled cavities)

✓ External Reference Points -face masks, bite blocks and shells,skin markings or alignment tattoos)

Volumes

ICRU 62

Table 1. Summary of the ICRU Nomenclature for Volumes (1970s to Present)

ICRU Report 29: 1970s-1993	*ICRU Report 50: 1993-1999 (Present)*	*ICRU Report 62: 1999-Present*
Target volume	GTV CTV PTV	GTV CTV Internal target volume PTV
Treatment volume	Treated volume	Treated volume
Irradiated volume	Irradiated volume	Irradiated volume
Organ at risk	Organ at risk	Organ at risk Planning risk volume
Hot spot hot spot (area outside target that receives dose larger than 100% of specified target dose) (at least 2 cm^2 in a section)	Hot spot (volume outside PTV that receives dose larger than 100% of specified PTV dose) (>15 mm diameter)	Hot spot hot spot (volume outside PTV that receives dose larger than 100% of specified PTV dose) (>15 mm diameter)
Dose heterogeneity (no value given)	Dose heterogeneity (+7 to −5% of prescribed dose)	Dose heterogeneity (+7 to −5% of prescribed dose)

INTERNAL MARGIN (IM) & INTERNAL TARGET VOLUME (ITV)

- It is the margin given around the CTV to compensate for all variations in the site, size and shapes of organs and tissues contained in or adjacent to CTV.

- These may result from respiration, different fillings of the bladder and rectum, swallowing, heart beat, movements of bowel etc.

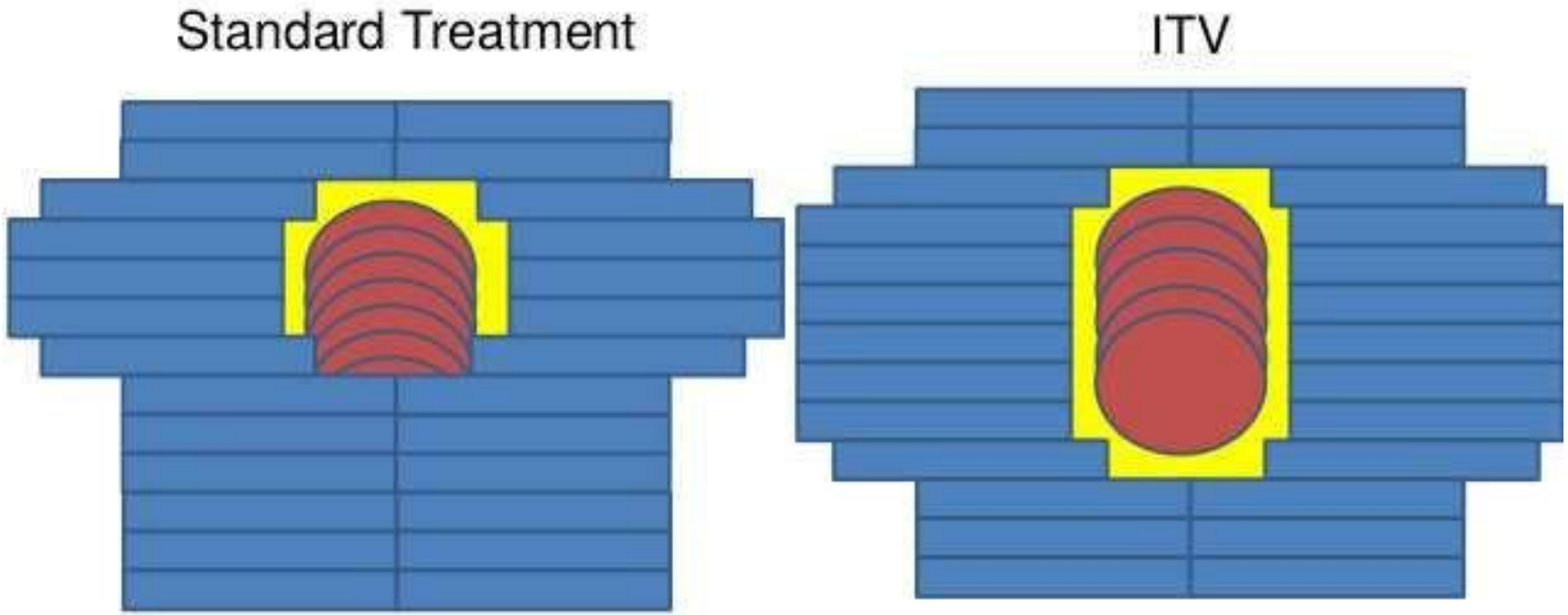
- These are physiological variations which are very difficult to control and result in changes in the site, size and shape of CTV.

Internal Target Volume (ITV)

- Consists of the CTV plus an internal margin.
- It is the margin given around the CTV to compensate for all variations in the site, size and shapes of organs and tissues contained in or adjacent to CTV.
- The internal margin is designed to take into account the variations in the size and position of the CTV relative to the patient's reference frame (usually defined by the bony anatomy), i.e., variations due to organ motions such as breathing, bladder or rectal contents, etc.

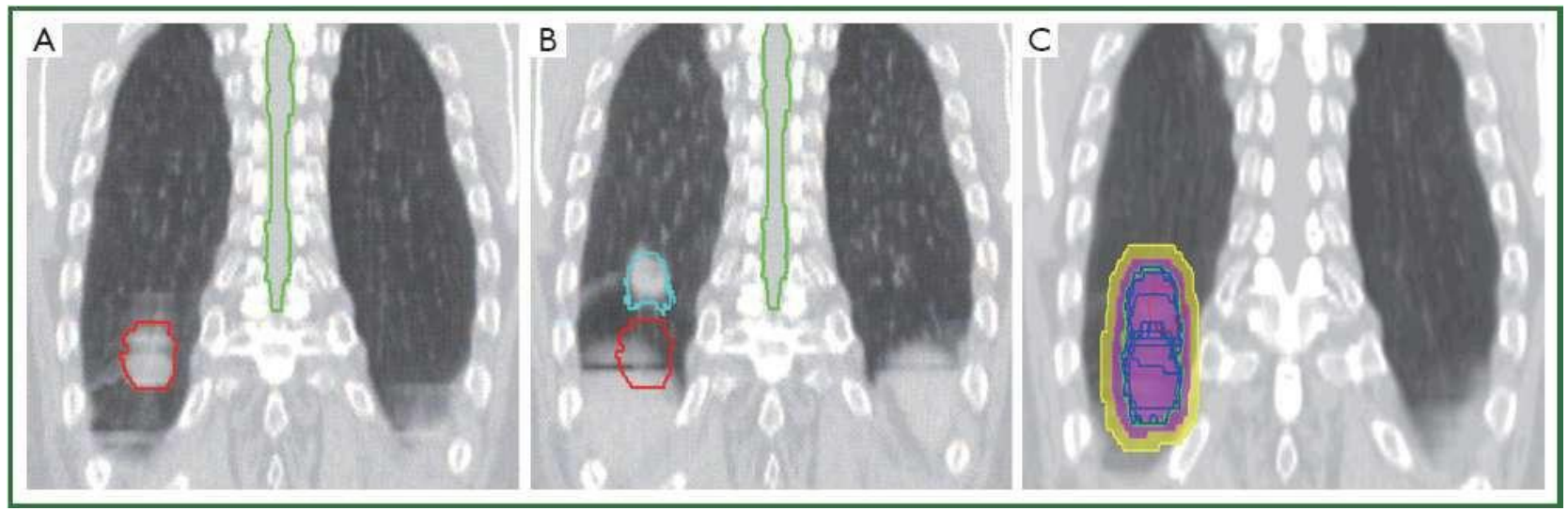
Internal target volume (ITV) = CTV+IM

Motion management during treatment



Internal Target Volume (ITV) approach:

- Treat track of tumor motion
- Based on a 4-D dataset
- Custom margins for each tumor


A
B
C

SET-UP MARGIN (SM)

- There can be many uncertainties (inaccuracies and lack of reproducibility) in patient positioning and alignment of the therapeutic beams during treatment planning and through all treatment sessions.

- These uncertainties depend on factors like :
  - variations in pt. positioning
  - mechanical uncertainties of the equipment (sagging of gantry, collimators, and couch)
  - dosimetric uncertainties
  - transfer set-up errors from CT & simulator to the treatment unit
  - human factors

SET-UP MARGIN (SM) is the margin that must be added to account specifically for uncertainties (inacuracies & lack of reproducibility) in patient positioning and aligment of the therapeutic beams during treatment planning and through all treatment sessions.

ITV = CTV + IM

PTV = CTV + combined IM & SM

PLANNING TARGET VOLUME (PTV) by ICRU 62

- Introduce the concept of setup margin.
- Setup margin is the Uncertainty in patient positioning and mechanical uncertainty of the equipment which arise due to sagging of gantry or collimator or couch, Dosimetric uncertainty, transfer setup error , human error, etc.

PTV=CTV+IM+SM

PLANNING ORGAN AT RISK VOLUME

- PRV to OAR is analogous to the PTV for the CTV.
- Aim is to account for movements of the OAR due to movements, changes in size and shape and setup uncertainities.
- PTV and PRV may overlap, then it is the responsibility of the radiation oncologist to decide depending on the importance of the treatment versus risk of critical organ damage.

ICRU-62

SYSTEMATIC AND RANDOM ERRORS

- **Systematic errors** – treatment preparation errors (influence all fractions) like full rectum

- **Random errors** – treatment execution errors (influence only the single fraction) like positioning

Category	Intra# variation during single #		Inter# variation during entire course	
	Random	Systemic	Random	Systemic
Variations of CTV				
In size	Physiological processes (circulation, respiration, peristalsis)	Physiological processes (circulation)	Physiological processes (e.g., degree of bladder filling, bowel gas)	Tumor reduction or swelling
In position relative to a fixed point in the patient	Physiological processes (circulation, respiration, peristalsis)	Change in treatment position (prone-supine)	Physiological processes (e.g., degree of filling of cavities)	Weight loss
Variations in position of the patient relative to the treatment beams	Patient movements		Daily set-up	Technical errors

CONFORMITY INDEX (CI)

- It is defined as the quotient of the Treated Volume and the volume of PTV.
- Can be employed when the PTV is fully enclosed by the TV, then it is the quotient of the TV and the volume of the PTV
- CI = TV/PTV
- It can be used as a part of the optimization procedure.

Revising Irradiated Volume & Treated Volume

- Size of the Irradiated Volume relative to the Treated Volume may increase as the number of beam directions increases

- Implies a compromise so thus it is the responsibility of the radiation oncology team to select what is judged to be the optimal treatment

- In "conformal therapy" using beam shaping, e.g., by MLC (Multi Leaf Collimator), or customized blockings, both Treated Volume and Irradiated Volume can be reduced

PLANNING ORGAN AT RISK VOLUME (PRV)

- This is a volume which gives into consideration the movement of the Organs at Risk during the treatment.

- An integrated margin must be added to the Organ at Risk to compensate for the variations and uncertainties, using the same principle as PTV and is known as the Planning Organ at Risk volume (PRV).

- A PTV and PRV may occasionally overlap.

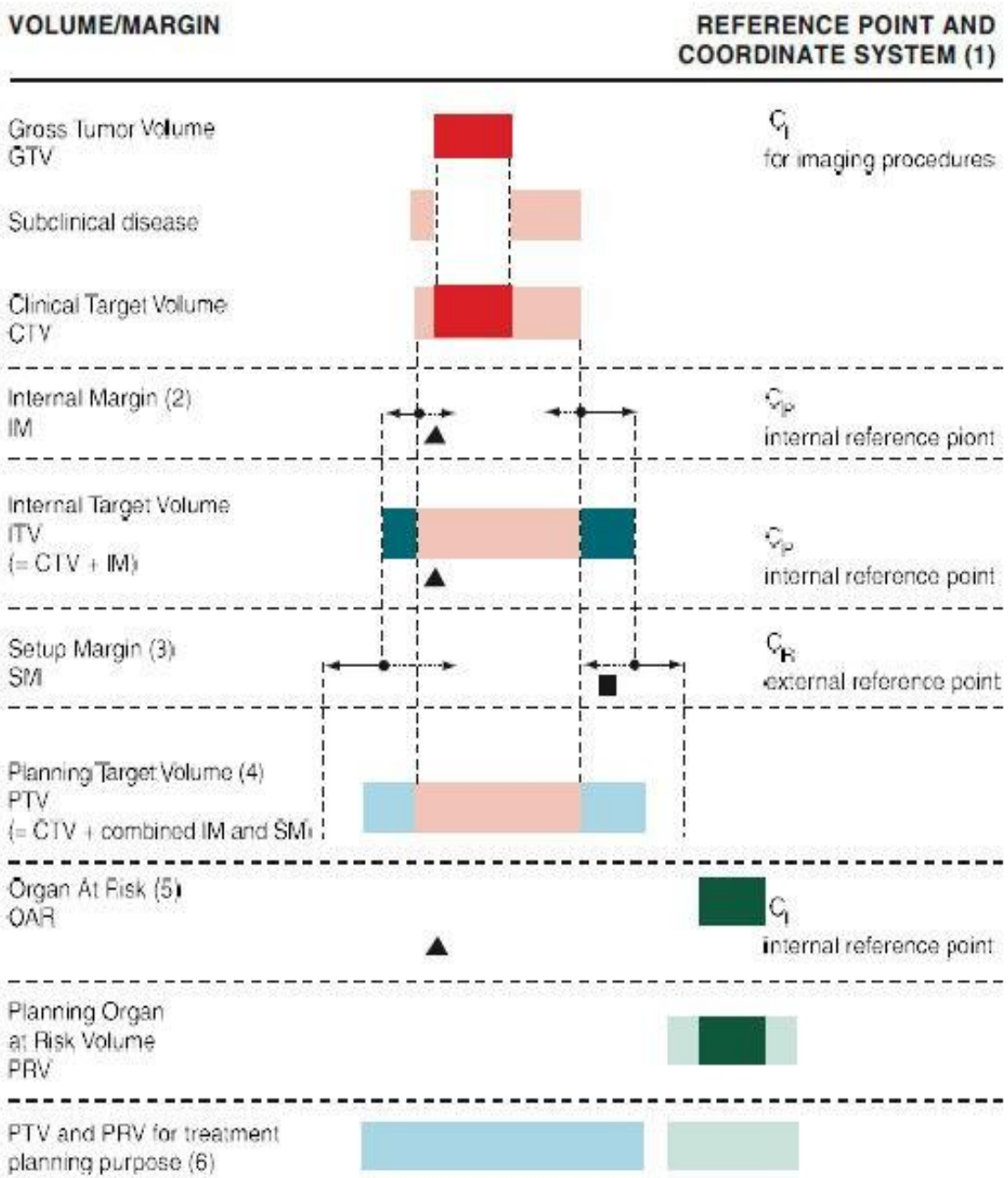
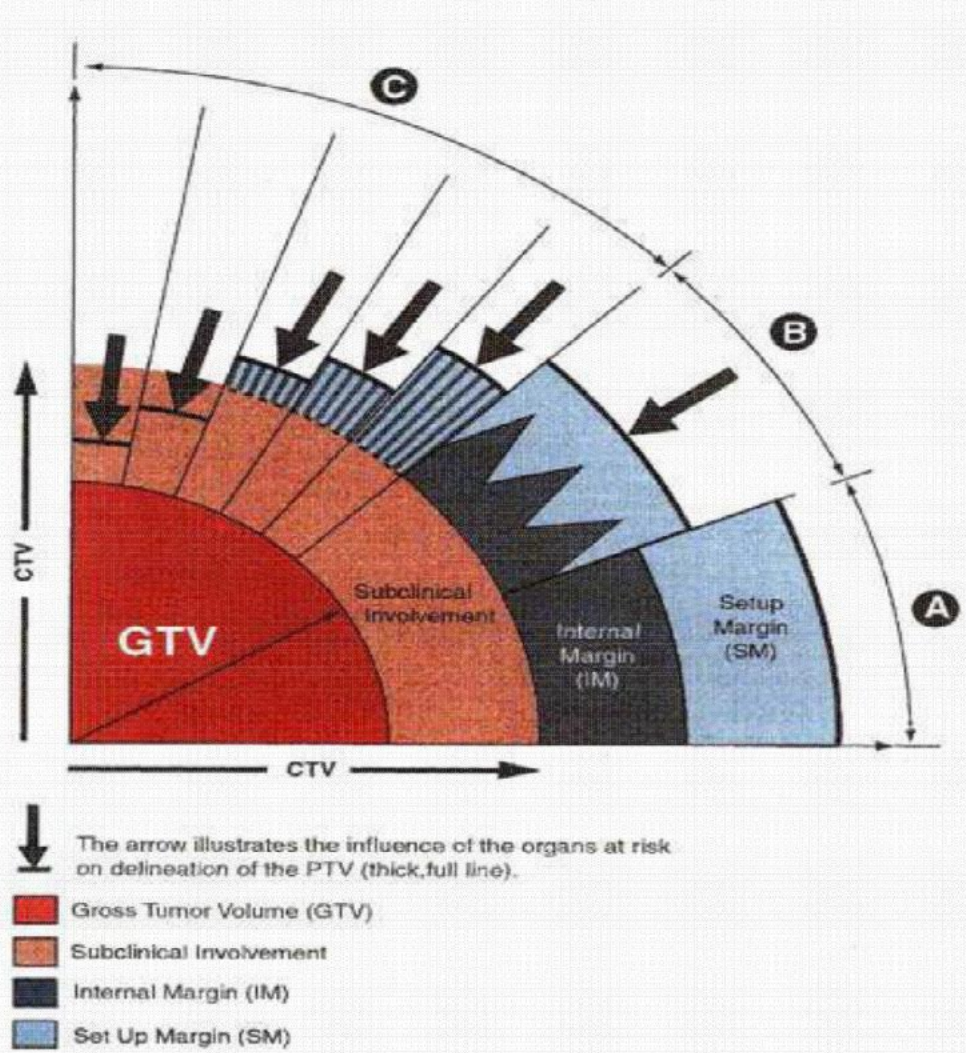


Fig. 3.21 Treatment volumes according to the ICRU-62 report

ICRU 62 Definitions



GRAPHICS

- These are used to delineate the different volumes and the other landmarks
- These are in different colors for an easy and uniform interpretation
- The convention recommended and used in ICRU 62 are:

GTV - Dark Red
CTV – Light Red
ITV – Dark Blue
PTV – Light Blue OR – Dark Green
PRV – Light Green
Landmarks - Black

ABSORBED DOSE DISTRIBUTION

- The dose given to the tumor should be as homogenous as possible.

- In cases of heterogeneity of doses, the outcome of the treatment cannot be related to the dose. Also, the comparison between different patient series becomes difficult.

- However, even if a perfectly homogenous dose distribution is desirable, some heterogeneity is accepted due to technical reasons.

The heterogeneity should be foreseen while prescribing a treatment, and, in the best technical and clinical conditions should be kept within +7% and -5% of prescribed dose

(Wittkamper et al., Brahme et al., Mijnheer et al.).

Recommendations for Reporting

AIM

- Promote uniformity between radiotherapy centres.
- Exchange information.
- Use same terminology and definitions.
- Deals with volumes and doses.
- Valid for photon beam therapy.

ICRU-50

DOSE REPORTING

- Acceptable dose heterogeneity : +7% to - 5% of the prescribed dose.

- Doses reported are :

- Dose at ICRU reference point
- Minimum dose to PTV
- Maximum dose to PTV
- Mean dose to PTV
- Modal dose
- Median dose

ORGANS AT RISK (OAR)

ICRU 50

- These are normal tissues whose radiation sensitivity may significantly influence the treatment planning and/or prescribed dose.

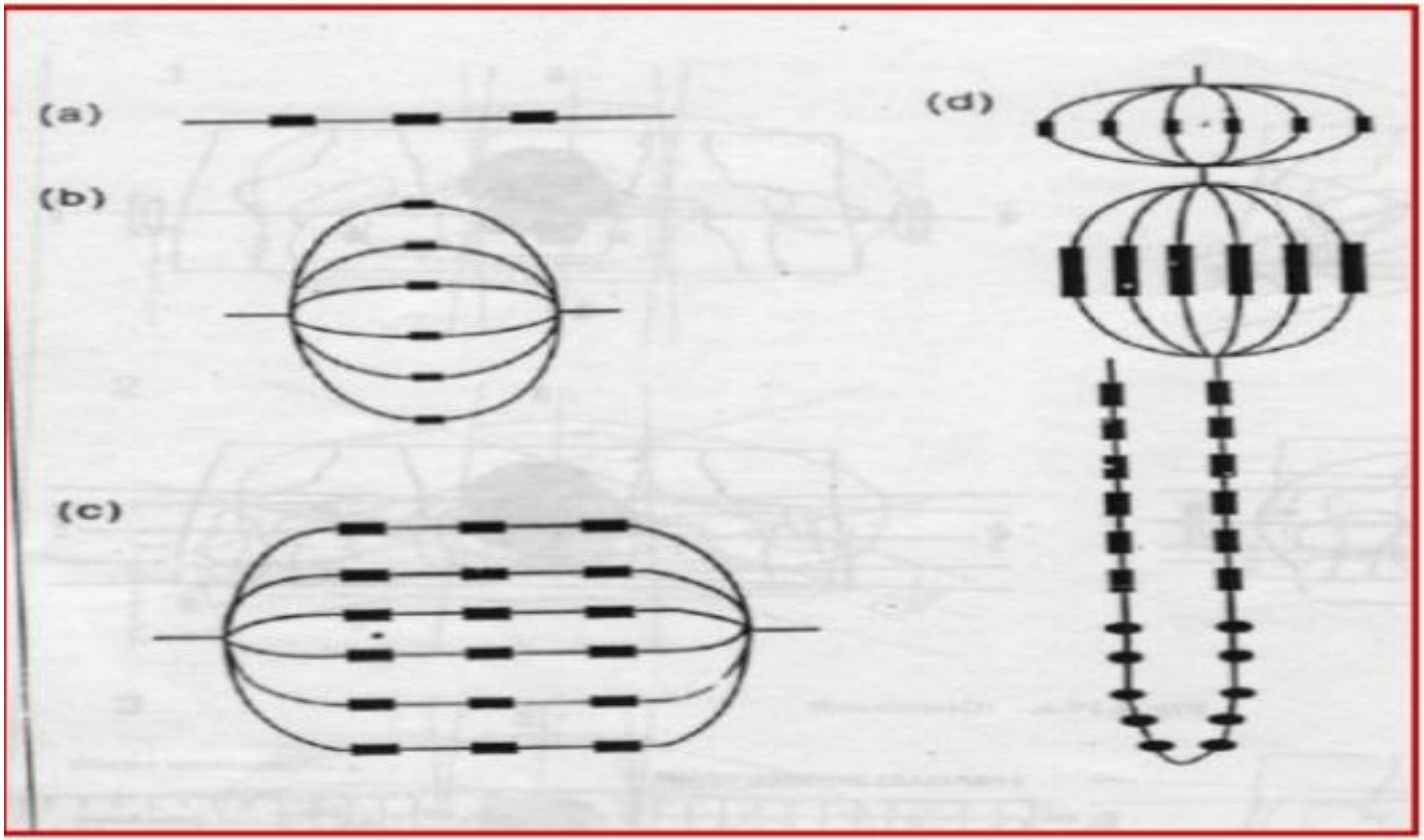
- They may be divided into 3 classes :

1. Class I : Radiation lesions are fatal or result in severe morbidity.
2. Class II : Radiation lesions result in mild to moderate morbidity.
3. Class III : Radiation lesions are mild, transient, and reversible, or result in no significant morbidity.

ICRU-62

CLASSIFICATION OF ORGANS AT RISK

- Classified as :
  - Serial – whole organ is a continuous unit and damage at one point will cause complete damage of the organ (spinal cord, digestive system). So even point dose is significant
  - Parallel – organ consists of several functional units and if one part is damaged, the rest of the organ makes up for the loss (lung, bladder). Dose delivered to a given volume or average/mean dose is considered
  - Serial-parallel – kidney (glomerulus- parallel, tubules- serial), heart (myocardium- parallel, coronary arteries- serial).


(a)
(b)
(c)
(d)

ORGANS AT RISK

- According to the functional models based on the FSU (Functional Sub Unit) concept *[Withers et al., Kallman et al., and Olsen et al.]*for the purpose of evaluation of the volume-fractionation-response, the tissues of an Organ at Risk are considered to be functionally either serial, parallel or serial-parallel structures

- eg : Spinal cord has a high relative seriality meaning that a dose above tolerance limit to even small volume of this OR may be deleterious. On the other hand, Lung has a low relative seriality meaning that the most important parameter is the relative size of volume that is irradiated above tolerance level

Three levels of Dose Reporting ICRU 50

- Level 1: Basic Techniques : This basic level may sometimes be sufficient in any center when simple treatments are performed
- Level 2: Advanced Techniques: At this level, it is assumed that the GTV, CTV, and PTV can be defined
- Level 3: Developmental Techniques: At this level, 3-D dose computation of any beam arrangement (such as non-coplanar beams) and dose/volume histograms are available.

ICRU 50

- The 3 levels of reporting could be described as follows:

- Level 1: Only the dose at the Reference Point and its variation along a central beam axis is available
- Level 2: The dose distribution can be computed for plane(s)
- Level 3: The dose distribution can be computed for volumes.

At any level, the dose at the ICRU Reference Point and the best estimation of the maximum and the minimum dose to the PTV should be reported.

Additional information which is considered as relevant should also be added. This could be related to :

- a more accurate and detailed description of dose distribution e.g., average dose and its standard deviation, dose - volume histograms (DVH) etc.

- an accurate description of the dose at different anatomical sites (including Organs at Risk).

- Note- ICRU Reports 50 and 62 do not make strict recommendations regarding dose prescription; rather ICRU states that the *radiation oncologist should have the freedom to prescribe the parameters in his/her own way, mainly using what is current practice to produce an expected clinical outcome of the treatment*

- Reporting these additional information ultimately contributes to the developments and improvements in Radiotherapy.

- Now it is digital era, new guidelines to be set for prescription, reporting and recording of dose - thus ICRU 83

CONCLUSIONS

- Proper identification and delineation of GTV is the most important factor in treatment.

- Other volumes like CTV, PTV, ITV should also be properly delineated.

- The errors like set-up error and human errors should be kept to a minimum.

- Dose prescription, fractionation andcalculation should be done in the same way by all the different centers throughout the world for the proper exchange of information and reporting.

- ICRU Report 62 literally emphasizes prescribing recording and reporting of photon beam therapy
- Authenticate 50 and is supplement to it
- Gives special attention for the level of completeness and complexity required in recommendations of reporting
- Prescription of treatment is chief responsibility of RO


IRRADIATED VOLUME
TREATED VOLUME
PTV
GTV
OAR
PRV
Thank you