The theoretical background of radiotherapy

Ibrahimović Amra

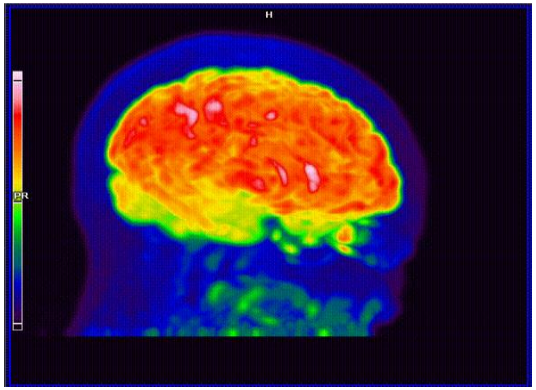
What is radiotherapy?

- Radiotherapy is a type of treatment for cancer and many other diseases
- In radiotherapy we use energy from the beam to kill cancerous cells
- Therapy can be performed with:
  - Electrons
  - Photons
  - Hadrons (protons and neutrons)
  - Heavy ions (e.g. Carbon ions)
- Types of radiotherapy:
  - External radiotherapy
  - Brachytherapy
- Application of radiotherapy:
  - To cure the patient
  - For palliative purposes (to relieave pain, but not cure)

How to detect cancer?

- Diagnostic search can be performed on diagnostic machines :
  - ❖CT(Computerized Tomography)
  - ❖PET(Positron Emission Tomography)
  - ❖MRI (Magnetic Resonance Imaging)

CT image (anatomic, obtained by x-rays)



PET image (metabolic, obtained by beta emitter)

MRI image (anatomic, obtained by interaction with a magnetic field)

Sizes and units in radiotherapy

- The energy which the particles deposit in tissue cause the dose
- Types od doses:
    - Absorbed dose
    - Equivalent dose
    - Effective dose

Absorbed dose

- The absorbed dose is defined as the energy deposited by ionizing radiation per unit mass of material. Measuring unit is Gray.
- 1Gy presents 1 J/Kg

$$1\text{Gy} \Rightarrow 1\frac{J}{kg}$$

Equivalent dose

- The equivalent dose is defined as the absorbed dose multiplied by the radiation weight factor.
- The radiation weight factor was estimated based on the damage which is produced in our tissue
- Measuring unit is Sivert

Radiation type	Radiation weight factor
X-rays	1
γ-zrake	1
Electrons and positrons	1
Neutrons	Energy dependence
Protons 2 MeV	2
α particles and heavy ions	20

$$H_T = D \times w_R,$$

H_T – Equivalent dose
D – Absorbed dose
W_R – Radiation weight factor

Effective dose

- The effective dose is defined as the equivalent dose multiplied by the tissue weight factor which is based on the organ's sensitivity and summing for whole body.
- This is only the one number
- The most sensitive organs are the eye lenses, ovaries andtesticles

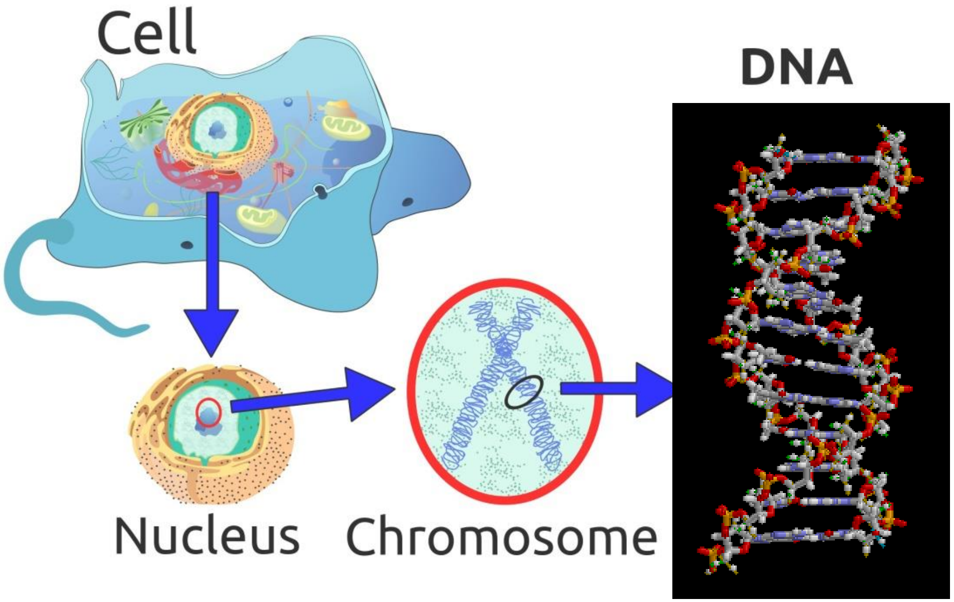
$$E = \sum H_T \times w_T$$

E – Effective dose
H_T – equivalent dose
W_T – tissue weight factor

Organs	Tissue weighting factors		
	ICRP30(I36) 1979	ICRP60(I3) 1990	ICRP103(I6) 2007
Gonads	0.25	0.20	0.08
Red Bone Marrow	0.12	0.12	0.12
Colon	-	0.12	0.12
Lung	0.12	0.12	0.12
Stomach	-	0.12	0.12
Breasts	0.15	0.05	0.12
Bladder	-	0.05	0.04
Liver	-	0.05	0.04
Oesophagus	-	0.05	0.04
Thyroid	0.03	0.05	0.04
Skin	-	0.01	0.01
Bone surface	0.03	0.01	0.01
Salivary glands	-	-	0.01
Brain	-	-	0.01
Remainder of body	0.30	0.05	0.12

Radiation damage

!!! Normal healthy cells have a repair mechanism, while cancerous do not. Therefore, fractionation treatment is used.



❖Radiation damage is manifested through damage to genetic material (DNA) in the cells of the body.

❖**Types of DNA damage**

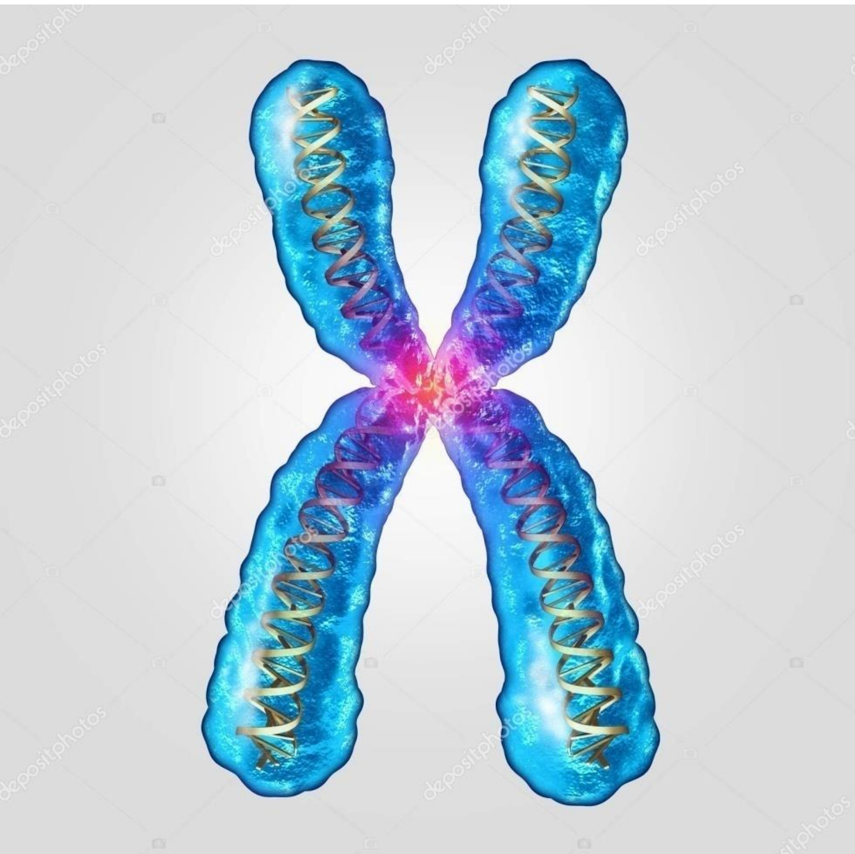
1. Single
2. Double

❖**There are three possible outcomes**

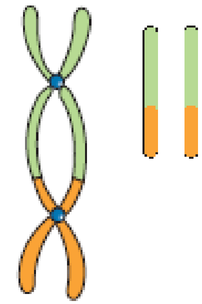
1. After damage, the cells are completely repaired and continue to function normally
2. Improperly repaired cells continue to live with mutations that may develop secondary cancer in the future
3. Cell death

Some types of mutations

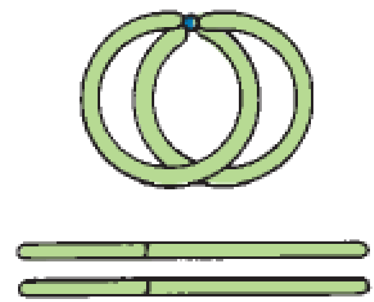
Normal healthy chromosome



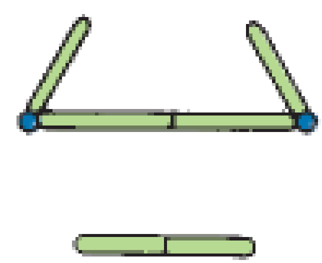
Dicentric chromosomes



Rings and acentric fragments



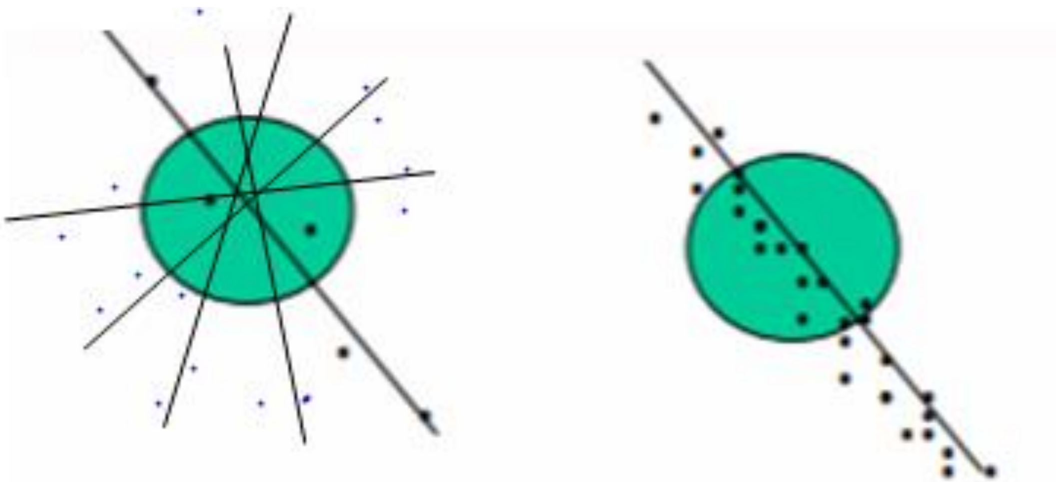
Anaphase bridges and acentric fragments



- Two reasons for investing in the development of particle radiotherapy:

1. Hadrons and particles break both strands of DNA, preventing mutations
2. They have the power to destroy radioresistant tumors

RBE (Relative biological efficency)



Radiation which has low energy transfer

Radiation which has a high energy transfer

Radiation that leaves more energy per unit time produces more ionization in one region, and radiation that leaves less energy per unit time produces less ionization and creates more damage because the ionization will spread beyond the desired region and thus cause more harm to the organ / tissue.

RBE – Relative biological efficiency is a comparison of the amount of damage in the body. This factor shows how much dose does the same damage as some reference radiation (e.g. X-rays ili Co60 gamma radiation)

Phantoms

Phantoms are used in radiotherapy and diagnostic purposes to test the machine's and beam's parameters, because these phantoms simulate the body.

Phantom for CT made from plaxiglass

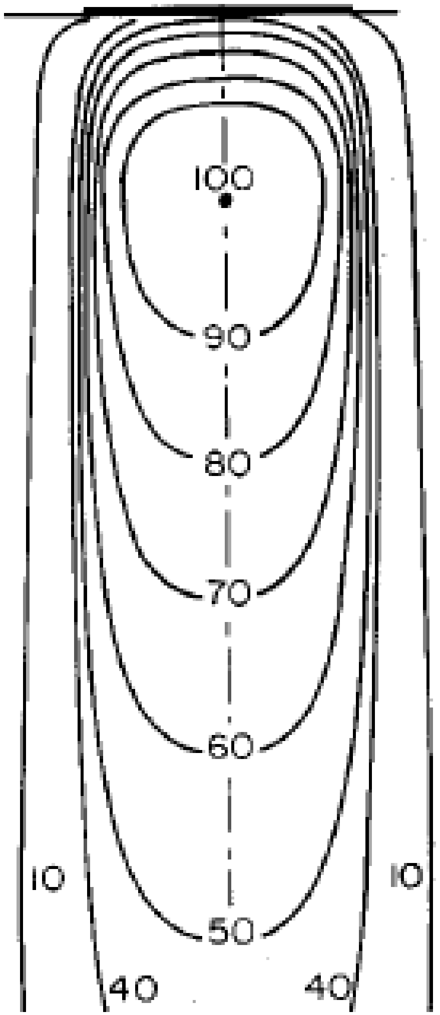
Water radiotherapy phantom

Radiotherapy treatment planning

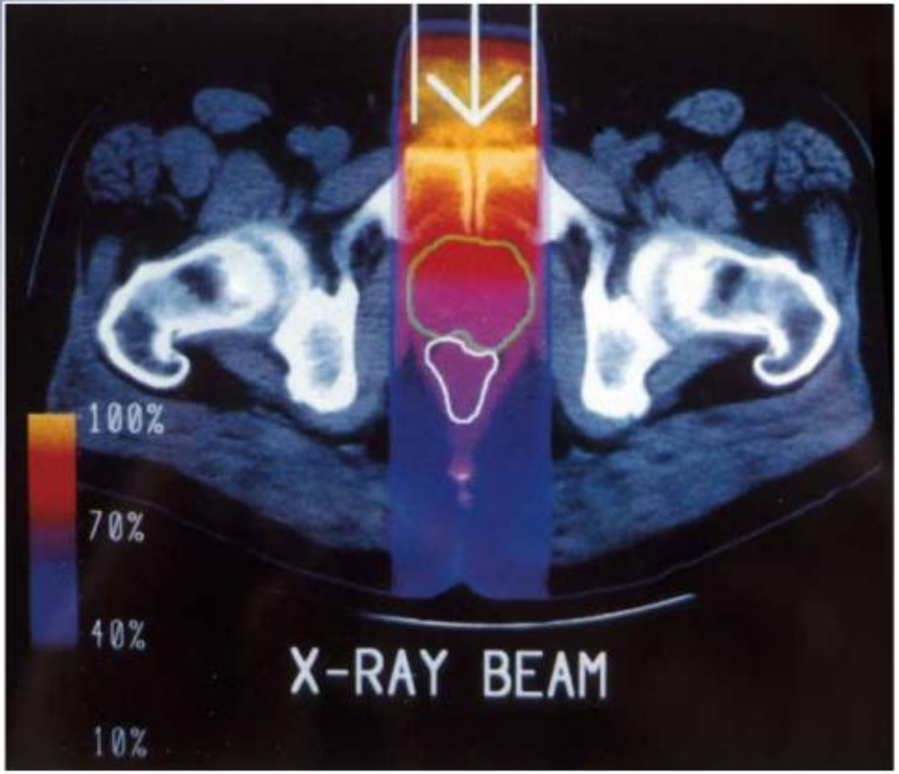
Keywords

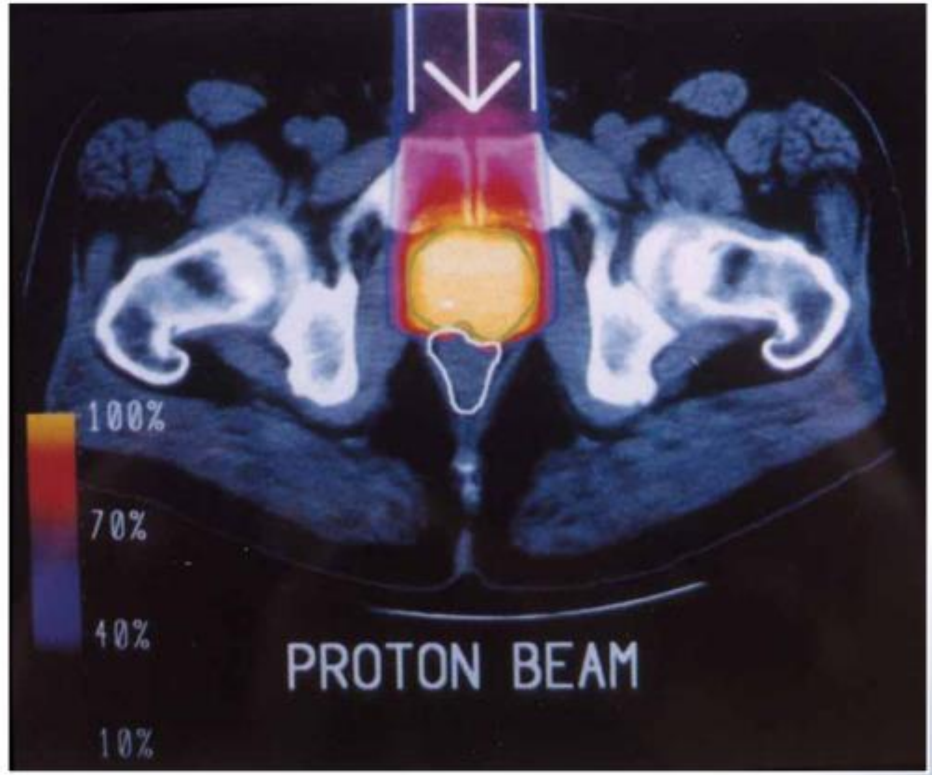
- SSD–Source to Surface Distance
- SAD–Source to Axis Distance
- ISOCENTER–the center of the tumor through which the axis of rotation of the machines passes

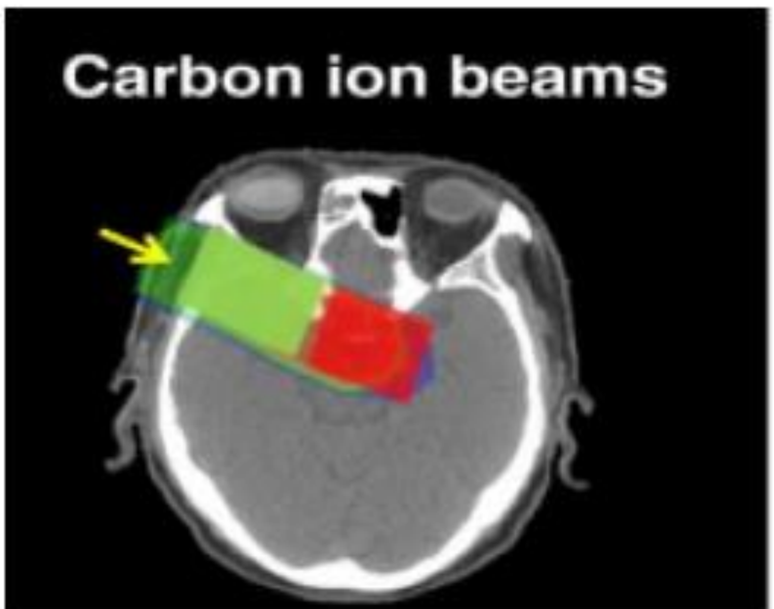
Dose distribution

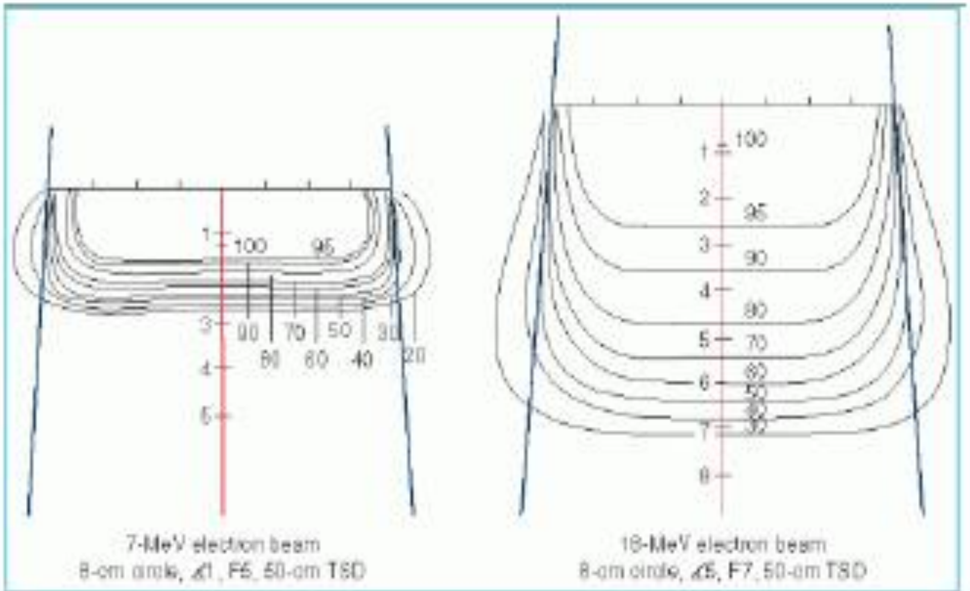


- As radiation enters the patient, it begins to interact with the patient.
- The dose distribution over the phantom is measured by radiation detectors.
- Dose distribution by depth consists of a family of curves where each curve represents the area of the same dose and is most commonly normalized to the area where 100% of the dose is located or where the maximum dose is.
- Interaction depends on several factors and all of these must be taken into account when planning therapeutic treatment:
  - Beam energy
  - Depth of cancer
  - Field size
  - SSD
  - Beam collimation
  - Shape of patient
  - Presence of sensitive organs


100%
70%
40%
10%
X-RAY BEAM

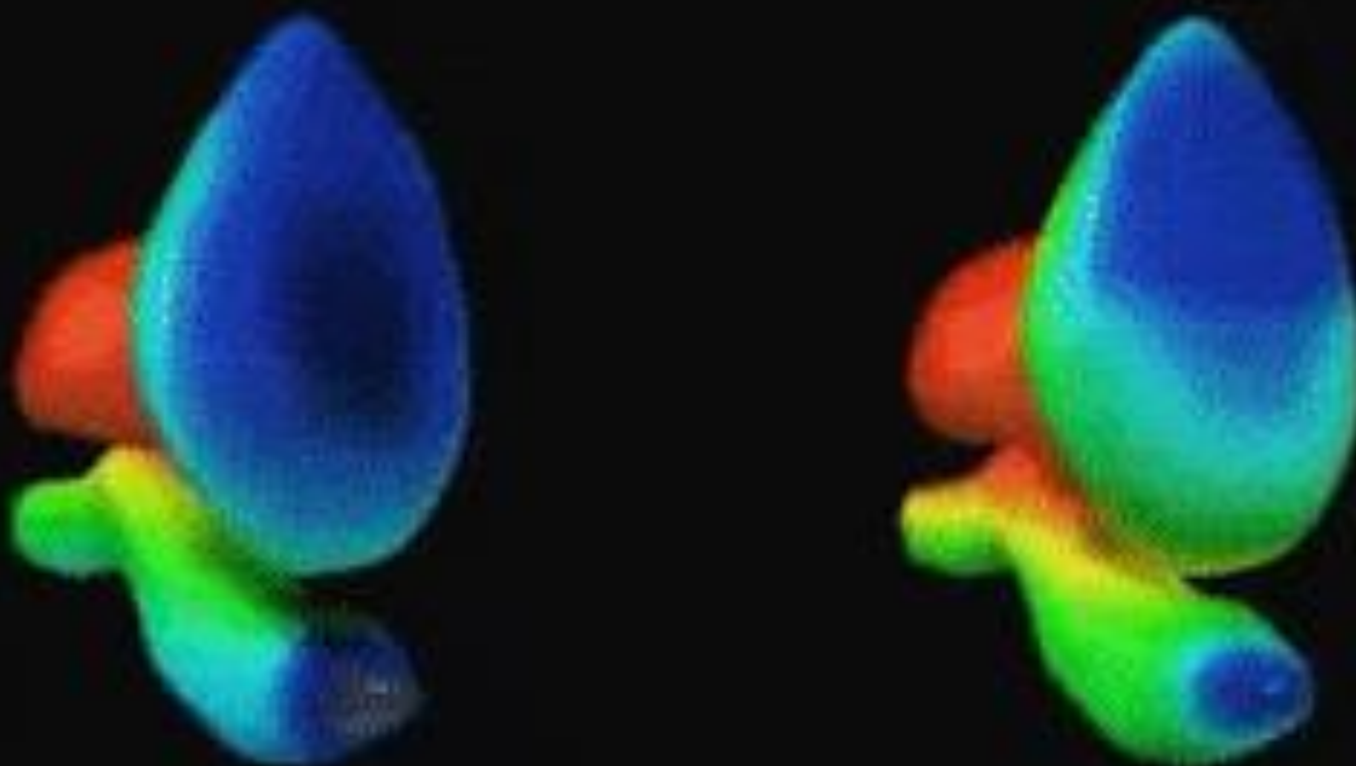

100%
70%
40%
10%
PROTON BEAM


Carbon ion beams


7-MeV electron beam
18-MeV electron beam

SmartBeam™ IMRT vs. Conformal RT

3D Dose Distribution

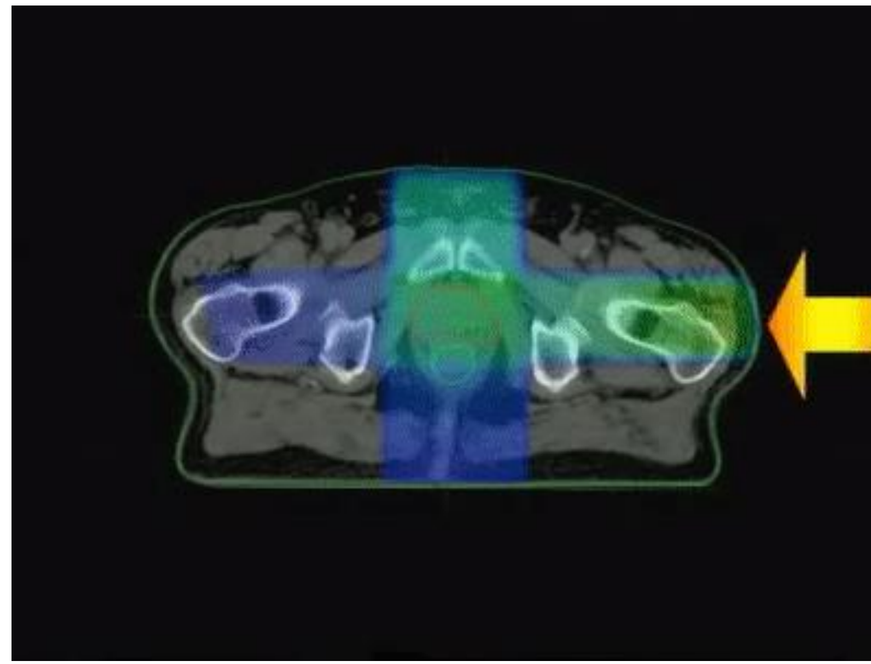


Multiple fields

The most important goal of treatment planning is to deliver the highest dose to the tumor and the least to the surrounding tissue. This is best achieved by using more fields from different angles than from one angle.

<u>Strategy:</u>

(a) using fields of appropriate size
(b) increasing the number of fields
(c) selecting appropriate beam directions
(d) using appropriate beam energy
(f) using beam modifiers such as wedge filters and compensators



Stationary and rotational radiotherapy

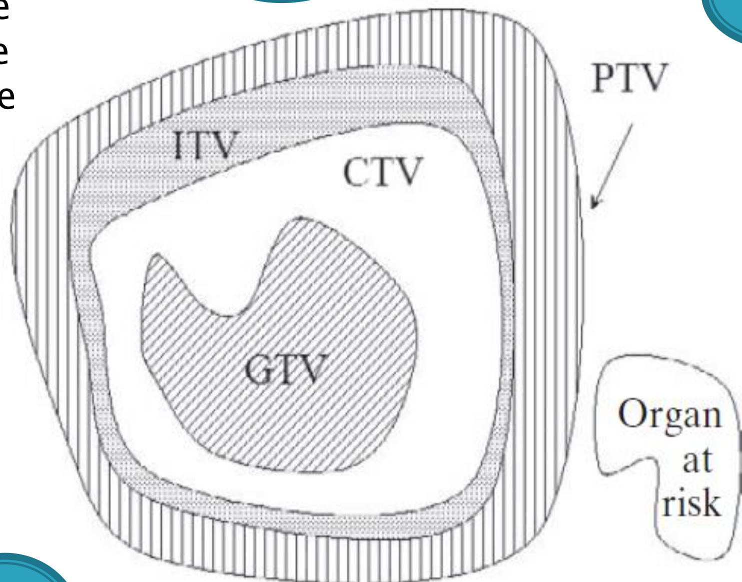
- The difference between stationary and rotational therapy is that in rotational therapy, the treatment beam is constantly circulating around the patient, and in stationary radiate only in certain positions.
- In both species, the center of rotation of the machine is in the tumor within the patient and is called the isocenter.

VOI (volume of interest) and margins

GTV- gross tumor volume
CTV-clinical target volume
ITV-internal target volume
PTV-planing target volume

GTV- exactly location of the tumor

CTV- margin whose consists present and any other tissue with presumed tumor



ITV- margin added to CTV to compensate for internal physiologic movements and variation in size, shape, and position

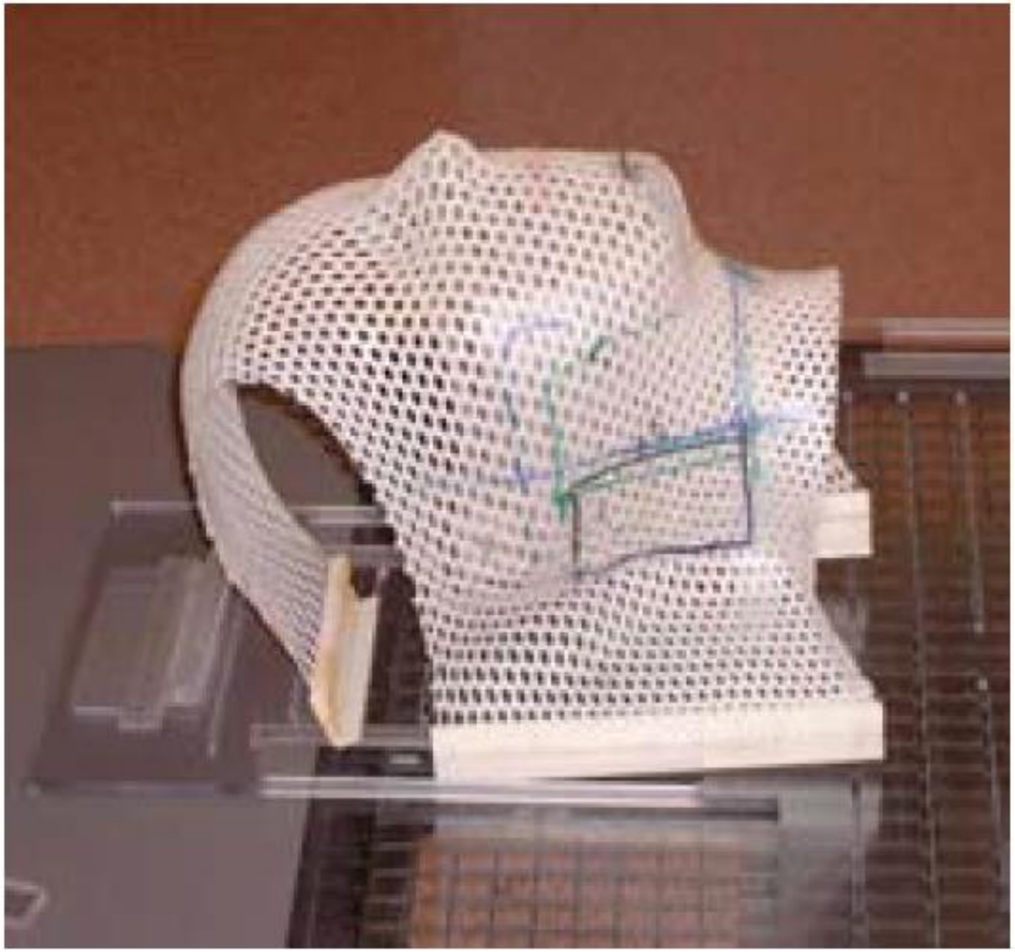
PTV- margin for patient movement and setup uncertainties

Organ at risk- presence of organs with high sensitivity to radiation

- Maximum dose –The highest dose in the target area is called the maximum target dose
- Minimum dose in target –The minimum target dose is the lowest absorbed dose in the target area
- Mean Target Dose –If the dose is calculated at a large number of discrete points uniformly distributed in the target area, the mean target dose is the mean of the absorbed dose values at these points

Patient positioning and immobilisation

- Patient positioning and immobilization depends on the treatment setting and the desired precision.
- Immobilization deviceses have two basic roles :
  - To immobilize the patient during treatment
  - To allow the best keeping of the patient's position from simulations until treatment or between two treatments
- Some immobilization devices are masks, pillows, belts, elastic belts, vacuum devices

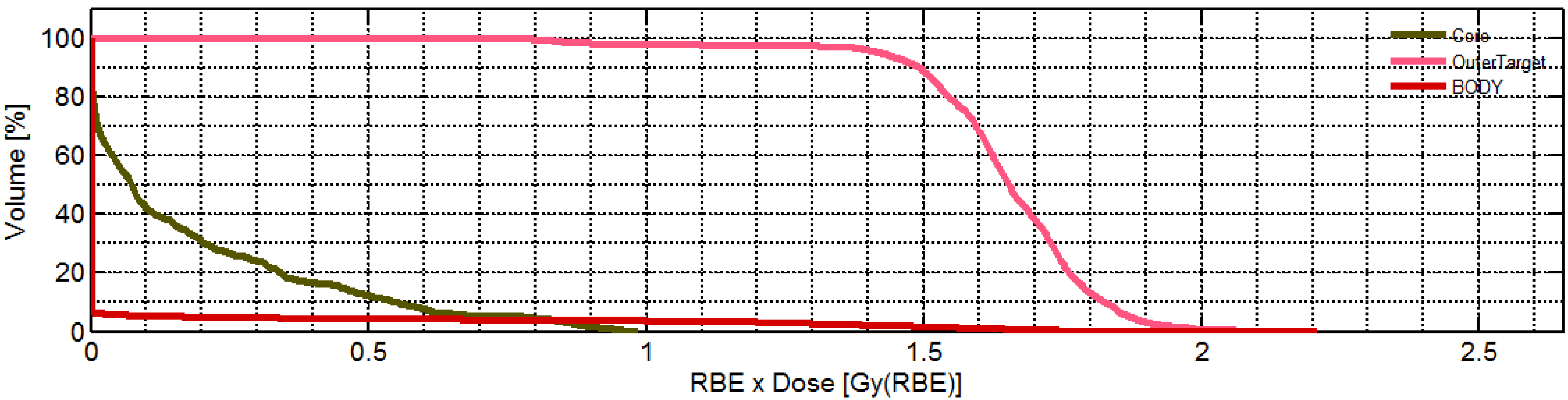


Immobilization head mask

Immobilization pillows

DVH-dose volume histogram

- DVH not only provides quantitative data on how much the dose is absorbed in a volume, but also summarizes the entire dose distribution into a single curve for each anatomical structure of interest.



	mean	std	max	min	D_2	D_5	D_50	D_95	D_98	V_0Gy	V_0.4Gy	V_0.8Gy	V_1.3Gy	V_
Core	0.1815	0.2396	0.9866	2.0386e-09	0.8909	0.7849	0.0744	2.4933e-05	6.0723e-07	1	0.1682	0.0470	0	
OuterTarget	1.6449	0.1770	2.1789	0.7475	1.9408	1.8726	1.6533	1.4205	0.9187	1	1	0.9949	0.9722	
BODY	0.0640	0.2912	2.2101	0	1.4572	0.2364	0	0	0	1	0.0462	0.0405	0.0282	

Modern radiotherapy methods

- **3D Conformal Radiotherapy** — Under 3-dimensional conformal radiotherapy (3-D CRT) we mean treatments based on three-dimensional anatomical information and use drugs that match the target volume as closely as possible to give the tumor the appropriate dose and the lowest possible dose to normal tissue.
- **Intensity Modulated Radiotherapy** - The Intensity Modulated Radiotherapy (IMRT) refers to an irradiation technique in which the patient is fed unequal radiation intensity from any treatment position to optimize dose distribution.
- **Stereotactic radiosurgery** - This involves delivering a complete dose with a single fraction in the head region.
- **Stereotactic Radiotherapy** - Assumes delivery of this dose in fractions. Both use very thin beams for extreme precision.
- **Image guided radiotherapy** — It can be defined as a radiotherapy procedure that uses imaging methods at different stages of the process: obtaining patient information, scheduling treatment, simulating treatment, placing the patient, and localizing the patient before and during treatment.

THANK YOU!!!