The theoretical background of radiotherapy

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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 relieve 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 of 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

\[ 1 \text{Gy} \rightarrow 1 \frac{J}{kg} \]
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.

\[ H_T = D \times w_R \]

- \( H_T \) – 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 and testicles

\[ E = \sum H_T \times w_T \]

\begin{align*}
E & \quad \text{Effective dose} \\
H_T & \quad \text{equivalent dose} \\
w_T & \quad \text{tissue weight factor}
\end{align*}

<table>
<thead>
<tr>
<th>Organs</th>
<th>ICRP30(I36) 1979</th>
<th>ICRP60(I3) 1990</th>
<th>ICRP103(I6) 2007</th>
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<tr>
<td>Gonads</td>
<td>0.25</td>
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<td>0.08</td>
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<tr>
<td>Red Bone Marrow</td>
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<td>0.12</td>
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<tr>
<td>Colon</td>
<td>-</td>
<td>0.12</td>
<td>0.12</td>
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<tr>
<td>Lung</td>
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<td>0.12</td>
<td>0.12</td>
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<tr>
<td>Stomach</td>
<td>-</td>
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<td>0.12</td>
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<tr>
<td>Breasts</td>
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<td>0.05</td>
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<tr>
<td>Bladder</td>
<td>-</td>
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<td>0.04</td>
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<tr>
<td>Liver</td>
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<td>0.04</td>
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<tr>
<td>Oesophagus</td>
<td>-</td>
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<td>0.04</td>
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<td>0.05</td>
<td>0.04</td>
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<tr>
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<td>0.01</td>
<td>0.01</td>
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<tr>
<td>Bone surface</td>
<td>0.03</td>
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<tr>
<td>Salivary glands</td>
<td>-</td>
<td>-</td>
<td>0.01</td>
</tr>
<tr>
<td>Brain</td>
<td>-</td>
<td>-</td>
<td>0.01</td>
</tr>
<tr>
<td>Remainder of body</td>
<td>0.30</td>
<td>0.05</td>
<td>0.12</td>
</tr>
</tbody>
</table>
Radiation damage

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

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

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

Strategy:

(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
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.
GTV – gross tumor volume
CTV – clinical target volume
ITV – internal target volume
PTV – planning 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 immobilization depends on the treatment setting and the desired precision.

Immobilization devices 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 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.
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!!!