Unit 5 - RADIATION THERAPY AND RADIATION SAFETY

5.1 RADIATION THERAPY

Radiation therapy is a medical treatment that uses high doses of radiation to kill or damage cancer cells. It is commonly used to treat various types of cancer by targeting the tumor with precision to minimize damage to surrounding healthy tissues.

There are two main types of radiation therapy:

1. **External beam radiation therapy**: Radiation is directed from outside the body toward the tumor.
2. **Internal radiation therapy (brachytherapy)**: A radioactive source is placed directly inside or very close to the tumor.

Radiation therapy can be used alone or in combination with other treatments like surgery, chemotherapy, or immunotherapy. The goal is to shrink or eliminate tumors, alleviate symptoms, and reduce the risk of cancer recurrence.

Common side effects may include fatigue, skin irritation, hair loss in the treated area, and digestive or urinary issues, depending on the area being treated. The specific treatment plan varies depending on the type, location, and stage of cancer.

5.1.1 LINEAR ACCELERATOR

A linear accelerator (linac) is a device used in radiation therapy to deliver high-energy x-rays or electron beams to treat cancer. The machine accelerates charged particles, such as electrons or protons, to very high speeds and then directs them at the tumor. This precision allows the radiation to focus on the cancerous tissue while minimizing exposure to surrounding healthy tissue.

In addition to its ability to treat tumors, a linac can also be used for imaging and delivering advanced techniques such as intensity-modulated radiation therapy (IMRT), stereotactic body radiation therapy (SBRT), and image-guided radiation therapy (IGRT). These features enhance the treatment's effectiveness and accuracy, contributing to better outcomes for patients.

5.1.2 TELEGAMMA MACHINE

A **Telegamma machine** is a type of teletherapy unit used in radiation therapy, primarily for the treatment of cancer. It uses cobalt-60 as a radiation source for the delivery of high-energy gamma rays to target tumors while minimizing damage to surrounding healthy tissues.

Radiation Source (Cobalt-60):

- The machine utilizes a **cobalt-60** source as the primary source of gamma radiation. The cobalt-60 is housed in a shielded capsule to prevent radiation leakage when the machine is not in use.
- The source is moved in and out of the treatment position by the mechanical drive system.

Treatment Head:

- The treatment head houses several components to focus, direct, and shape the gamma radiation beam to ensure precision in treating the target area. It typically includes:
  - **Beam Shaping Device**: This device shapes the beam, sometimes using a collimator to define the size and shape of the radiation.
  - **Block**: The block is used to protect sensitive areas of the body from radiation exposure during treatment.

Mechanical Drive System:

- This system is responsible for positioning the cobalt-60 source and adjusting the orientation of the radiation beam. It moves the radiation source in and out of the treatment head and ensures proper alignment with the patient.

Control Console:

- The operator uses the control console to set up the machine parameters (such as radiation dose, duration, and beam direction). The console also monitors safety protocols and ensures that the system functions as expected.
- It also provides safety interlocks and emergency stop features.

Patient Positioning System:

- This includes the **patient table** and **positioning aids**, which ensure that the patient is properly aligned with the radiation beam for accurate treatment.
- The patient table is adjustable in multiple directions (such as vertical, horizontal, and rotational movements) to position the patient precisely.

Safety and Shielding:

- To ensure the safety of operators and other personnel, the Telegamma machine is equipped with several layers of shielding. This shielding absorbs any scattered radiation and prevents exposure to radiation outside the treatment area.
- Emergency stop mechanisms and interlocks are also incorporated to protect users from accidental radiation exposure.

Dosimetry System:

- This system measures the radiation dose delivered to the patient and ensures it is within prescribed limits. It is a crucial safety and monitoring component to verify accurate dose delivery.

Cooling System:

- The machine is equipped with a cooling system to prevent overheating of the radiation source and treatment head. This is particularly important when the machine operates for extended periods.

Summary of Functions:

- **Gamma Ray Generation**: The cobalt-60 source emits gamma rays that are used for cancer treatment.
- **Beam Shaping and Direction**: Ensures that the radiation is accurately targeted to the tumor, minimizing harm to surrounding healthy tissue.
- **Patient Positioning**: Ensures the patient is positioned precisely for optimal treatment.
- **Safety Mechanisms**: Protects the operator and patient from unnecessary exposure to radiation.

This combination of components ensures that the Telegamma machine provides accurate and safe radiation therapy.

5.1.3 SRS-SRT

Stereotactic radiosurgery (SRS) and stereotactic radiotherapy (SRT) are advanced techniques in radiation therapy that use precise, high-dose radiation to target tumors, often in the brain and spine. They differ primarily in terms of treatment goals and application:

1. **Stereotactic Radiosurgery (SRS)**:
   - **Goal**: A single, high-dose radiation treatment targeting tumors or lesions with extreme precision.
   - **Application**: Typically used for small, well-defined tumors in areas such as the brain, spine, liver, lung, and pancreas.
   - **Mechanism**: SRS delivers highly focused beams of radiation, using imaging guidance (CT, MRI, or PET scans) to target the tumor from multiple angles, sparing surrounding healthy tissue.
   - **Treatment Fractionation**: It is generally a single session of radiation treatment.
2. **Stereotactic Radiotherapy (SRT)**:

- **Goal**: Similar to SRS, but involves delivering multiple smaller doses over a series of sessions.
- **Application**: Used for tumors that are larger or in areas where a single dose would be too risky or cause excessive damage to surrounding tissues.
- **Mechanism**: The precision is similar to SRS, but the dose is spread across several sessions, often in the range of 3-5 treatments.

Recent Advancements:

1. **High-Precision Imaging**: Advancements in MRI and CT scanning, along with integrated imaging systems like MR-guided radiation therapy (MRgRT), improve tumor tracking and treatment precision in real-time.
2. **Adaptive Radiation Therapy (ART)**: This technique adjusts the treatment plan during the course of therapy, based on real-time imaging feedback, ensuring the radiation targets the tumor accurately as it changes over time.
3. **Artificial Intelligence (AI)**: AI is being used to optimize treatment planning, enhance tumor detection, and improve precision by predicting patient response to radiation therapy.
4. **Proton Therapy**: Proton beams are being used in SRS/SRT for their precision in delivering radiation with minimal damage to surrounding healthy tissue, especially in complex or pediatric cases.
5. **Volumetric Modulated Arc Therapy (VMAT)**: VMAT allows for more flexible, efficient delivery of radiation in SRS/SRT, improving treatment speed while maintaining precision.
6. **CyberKnife and Gamma Knife**: These technologies enable non-invasive, highly accurate radiation delivery for brain and spinal tumors. They can be used for a variety of tumor locations with minimal discomfort.

These developments contribute to the growing efficacy of radiation therapy in treating cancers with greater precision and fewer side effects.

5.1.4 CYBER KNIFE

CyberKnife is a type of **stereotactic radiosurgery** system that delivers high-dose radiation to tumors with extreme precision. It is a non-invasive treatment option used primarily for cancer, particularly tumors located in hard-to-reach or sensitive areas of the body. Unlike traditional surgery, CyberKnife does not require any incisions.

Key features of CyberKnife include:

1. **Robotic System**: The CyberKnife system uses a robotic arm that is guided by advanced imaging technologies, such as X-rays or CT scans. This allows for precise targeting of tumors from multiple angles without the need for surgical incisions.

2. **Stereotactic Radiation**: CyberKnife uses stereotactic techniques to deliver focused beams of radiation, which can be delivered in very small, targeted doses. This minimizes the radiation exposure to surrounding healthy tissue.

3. **Treatment for Tumors**: It is effective for treating tumors in various parts of the body, including the brain, spine, lungs, liver, pancreas, prostate, and others. It's especially useful for tumors that are difficult to treat with conventional surgery or when surgery is not an option.

4. **Non-invasive**: One of the main advantages of CyberKnife is that it is non-invasive, meaning it doesn't require surgery, anesthesia, or a long recovery period.

5. **Precision and Flexibility**: CyberKnife can adjust for patient movement, such as breathing or shifting positions, during treatment, ensuring high accuracy in tumor targeting.

CyberKnife is often used for patients who are inoperable due to the location of their tumors or those who prefer a less invasive treatment option. It can be used for both primary tumors and metastatic tumors.

5.1.5 3D CRT

A 3D CRT (Cathode Ray Tube) refers to a type of CRT technology used for displaying three-dimensional content. While CRTs were traditionally used for 2D displays, advancements allowed them to present 3D effects by manipulating the way light and images are projected.

However, unlike modern 3D displays (such as those using OLED, LED, or other flat-panel technologies), 3D CRTs would typically require additional techniques or equipment. This could include the use of special glasses or a stereoscopic effect that presents two different images to each eye, creating a perception of depth.

Although 3D CRTs were used in some early 3D television systems, they are not common today, as newer technologies like 3D LCDs and OLEDs have become more widely used for 3D displays.

5.1.6 IMRT

IMRT stands for **Intensity-Modulated Radiation Therapy**, a sophisticated form of radiation therapy used to treat cancer. It is a type of external beam radiation therapy where the intensity of the radiation is modulated or adjusted to deliver highly targeted doses to a tumor while minimizing exposure to surrounding healthy tissue.

IMRT uses advanced computer software and imaging technology to plan the precise delivery of radiation. It employs multiple beams of varying intensities that are shaped and directed in such a way as to conform to the three-dimensional shape of the tumor.

This allows for higher radiation doses to be delivered to the tumor while reducing the risk of side effects to nearby organs and tissues.

The benefits of IMRT include:

- Better precision in treating irregularly shaped tumors.
- Reduced damage to surrounding healthy tissues.
- The ability to treat tumors near critical structures, such as the spinal cord or brain.

IMRT is commonly used in the treatment of cancers such as prostate, head and neck, breast, and brain cancer.

5.1.7 IGRT

IGRT stands for **Image-Guided Radiation Therapy**. It is a technique used in radiation therapy to improve the precision and accuracy of radiation treatment. IGRT involves the use of advanced imaging technologies, such as X-rays, CT scans, or MRI, before and during each radiation treatment session to visualize the tumor's position and adjust the radiation delivery accordingly.

The key aspects of IGRT include:

- **Real-time imaging**: It allows for real-time images to be captured, ensuring that the tumor is precisely targeted during each session.
- **Tumor tracking**: If the tumor moves due to patient motion (like breathing), the system can adjust the radiation beams to ensure accurate delivery to the correct area.
- **Patient positioning**: IGRT helps in ensuring that the patient is positioned consistently and correctly for each treatment, making adjustments to avoid errors.

IGRT is often used in combination with other advanced techniques like IMRT (Intensity-Modulated Radiation Therapy) to further enhance the treatment's effectiveness. It is particularly useful for treating tumors in areas that are difficult to target or those that shift in position, such as lung or prostate cancer. The precision of IGRT helps minimize the exposure of healthy tissues to radiation and reduces side effects.