Basics of Radiation Treatment

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Cancer is the second-leading cause of death in the United States, exceeded only by heart disease (American Cancer Society, 2008). Approximately 1.43 million non-skin cancer cases will be diagnosed in 2008 (ACS) and three out of four patients with cancer are likely to receive radiation during the course of the illness (Belka & Camphausen, 2006). Understanding the basics of radiation and treatment goals are essential to provide the best possible patient care.

Radiation can be very effective for curative purposes, localized control, and palliation of pain and symptoms. It also can be used in the neoadjuvant setting to shrink a tumor before surgery.

What Is Radiation?

Radiation is any type of radiant energy that can impart energy to the medium through which it passes (Zeman, 2000). Radiation kills cancer cells by permanently damaging the cell DNA or by creating free radicals that damage cell DNA (Zeman). Accurate and precise delivery of radiation to the tumor can minimize damage to surrounding healthy tissue.

Radiation Delivery Methods

Radiation can be delivered using multiple techniques, but, in general, three are used for cancer treatment (see Figure 1). This article will focus on teletherapy or external beam radiation therapy.

Teletherapy or External Beam Radiation Therapy

External beam radiation therapy, the most common radiation delivery method, involves delivery of high-energy x-rays or particles to a specific area to treat the disease (Watkins-Bruner, Haas, & Gosselin-Acomb, 2005). The treatment area is determined by visible tumor, microscopic tumor, and positional boundaries. The boundaries create gross tumor, clinical tumor, and planning target volumes (see Table 1). Other patient-related positional uncertainties that should be accounted for include organ motion, digestion, excretion, weight, and ability to remain still.

What Is the Linear Accelerator?

The linear accelerator is the most commonly used treatment machine. Located a distance from the tumor site, the linear accelerator produces the radiation the patient will receive through high-energy x-rays and electrons (see Figure 2).

Through microwave technology, electrons either accelerate to a high-energy state and exit as an electron beam or are directed into a target to produce x-rays. X-rays collide inside the linear accelerator and scatter and bump into a heavy metal target in the machine, where a portion are collected and shaped into a beam equal in size to the area of the targeted tumor (Watkins-Bruner et al., 2005).

Treatment design and planning takes place within the physics and dosimetry rooms where beams are customized for each patient. Three-dimensional conformal and intensity-modulated radiation therapies have advanced cancer treatment by providing a more heterogeneous dose to the treatment area and sparing healthy tissues as much as possible (Bourland, 2000). Treatment-planning techniques can more precisely define radiation delivery to an irregularly shaped tumor. Conformal treatment with a computer-controlled multileaf collimator helps reduce radiation exposure to at-risk organs (see Figure 3). Additional shielding or lead blocks may be used to minimize exposure of normal tissue near the treatment area (Bourland).

The desired treatment depth determines the type and amount of energy used. For example, many skin cancers are treated with electrons because they travel a finite distances before stopping. Photons, on the other hand, have wavelength, frequency, and energy ranges over an unlimited order of magnitude (Bourland, 2000) and, therefore, are used on deeper cancers such as lung tumors.

The linear accelerator's radiation beam is projected through a section known as the gantry, which can rotate 360° around the patient. The patient is positioned on a moveable table called the couch, which can move in vertical, longitudinal, lateral, or arc motions (Bourland, 2000). This setup allows the radiation to be delivered to the tumor from any angle (Radiologic Society of North America, Inc., 2007).

The linear accelerator is controlled by a radiation therapist (see Figure 4) who is responsible for ensuring that the dose is delivered to the correct area as prescribed. The therapist uses visual and

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audio monitoring devices from inside a lead-shielded room throughout treatment. Multiple quality assurance checks and balances are in place to ensure that only the targeted area is treated.

Dosage

The radiation dose that is delivered to the patient usually is provided in a five day per week pattern called fractionation, meaning that the dosage accumulates to the prescribed treatment level over the course of the week. The fractional amount delivered each day is related to the amount of energy absorbed per unit mass. The amount of energy absorbed previously was known as a radiation absorbed dose, but is now known as Gray or centigray. One gray equals 100 centigray; 1 centigray equals 100 radiation-absorbed doses (Watkins-Bruner et al., 2005). Fractionation helps spare acute reactions in the tissues, allows for a higher cell kill, and avoids damage to normal tissues which might not be repaired if the dose was delivered all at once (Halperin, Schmidt-Ullrich, Perez, & Brady, 2004).

The total delivered dose is determined by tissue tolerance in the treatment area. Tissue tolerance is defined as the therapeutic irradiation dose believed to minimize the risks of complications or permanent damage (Haas & Kuehn, 2001). Normal tissue tolerance depends on the ability of the dividing cells to produce enough mature cells to ensure organ function.

Radiation-induced lethality does not occur instantaneously because cells continue to function and undergo several divisions before final mitotic death (Halperin et al., 2004). Fractionation assaults the tumor cells by not allowing them to repair between treatments.

Simulation

Patients must undergo a computed tomography simulation to prepare for radiation. The simulation has diagnostic radiographic and fluoroscopic capabilities and can mimic the functions and motions of the linear accelerator. The patient is placed on the simulator table in the anticipated treatment position. The computed tomography scan simulates the radiation properties of the treatment beam, allowing the anatomy to be viewed from the direction of the radiation beam. Field shaping is done through a computerized virtual simulation workstation (Purdy, 2004). IV contrast may be administered during the simulation to improve visualization. Immobilizers, including face masks, head holders, foam molds, cushions, pillows, bite blocks, and vacuum bags that are shaped to the corresponding body part, also may be used during the simulation to maintain patient position. Communication with the patient during the simulation is imperative to determine comfort in the position he or she will be required to maintain throughout treatment.

Once the radiation oncologist views the planning scan, an isocenter will be placed on the computed tomography scan. The isocenter is the center of treatment through which all rotational axes must intersect (Bourland, 2000). The isocenter location is determined by clinical examinations, magnetic resonance imaging, computed tomography scans, surgical reports, positron emission tomography scans, etc. (Zeman, 2000). Once the isocenter is placed and the information is obtained, freckle-sized tattoos or fiducial markers are placed on the patient. The tattoos are lined up with laser beams in the treatment room and assist with the daily treatment setup. Tattoo information and any needed immobilizers will be recorded on a prescription in the treatment record. The patient should be photographed in the anticipated treatment position so accurate replication occurs during each treatment.

Table 1. Radiation Treatment Planning

TREATMENT BOUNDARY	TREATMENT VOLUME	INCLUDED AREA
Visible tumor	Gross tumor	Gross malignant growth and abnormally enlarged lymph nodes
Microscopic tumor	Clinical tumor	Tissue volume that contains the gross tumor and the subclinical microscopic malignant disease
Positional	Planning target	Clinical tumor volume with margin for geometric uncertainty, variation in setup, and an anatomic motion during treatment

Note. Based on information from Halperin et al., 2004; Watkins-Bruner et al., 2005.

Brachytherapy: short or slow radiation therapy placed into or near tissue or body cavities or on the skin at or near the tumor

Radiopharmaceuticals (unsealed sources): liquid radioactive sources that are ingested, injected, or instilled with characteristics that determine treatment locations

Teletherapy: radiation projection generated by electricity and provided via external beam machines

Figure 1. Definitions of Radiation Delivery Systems

Note. Based on information from Halperin et al., 2004; Watkins-Bruner et al., 2005.

Note. The linear accelerator's gantry rotates around the patient during treatment. The couch rotates around the circle on the floor and moves up and down. The multileaf collimator is located near the tip of the gantry. Any needed shielding blocks would be placed at the tip of the gantry.

Figure 2. Linear Accelerator

Note. Photo courtesy of Robert Wood Johnson University Hospital Department of Radiation Oncology. Used with permission.

Positioning

Actual treatment setup will take place after planning is complete, possibly occurring the same day as the simulation. Setup is a practice run that offers the healthcare team an opportunity to make adjustments based on simulation information. Portal imaging, an x-ray which compares simulation films to the anticipated treatment films, validates the data (Kudchadker, Chang, Bryan, Maor, & Famiglietti, 2004). Obtaining a portal image at the beginning of treatment and weekly thereafter is common. The radiation oncologist will verify that the two images match each other within a prescribed parameter (often millimeters) and, once the films are approved, treatment begins.

The patient is informed that he or she should not feel the treatment and that the experience is comparable to having an x-ray. Noises that patients hear will be from the movement of the linear accelerator. The therapist is able to view the patient during treatment, and the patient is taught to raise a hand if assistance is required. As the patient becomes more acclimated to treatment, the daily setup and treatment may only take minutes. Side effects may not occur until one to two weeks into treatment and are likely to last two to three weeks after the treatment ends. Patients should be informed of possible side effects, such as fatigue, skin redness, and hair loss in the treatment area prior to treatment.

Note. The multileaf collimator's open or closed position during treatment is predetermined in the planning phase.

Figure 3. Multileaf Collimator

Note. Photo courtesy of Robert Wood Johnson University Hospital Department of Radiation Oncology. Used with permission.

Dosimetrist: responsible for calculating doses to the treatment area and the shape of the planned radiation beams

Physicist: ensures treatment machines deliver the correct amount of radiation to the patient

Radiation oncologist: a physician who specializes in radiation as the main modality for cancer treatment

Radiation therapist: a technician with advanced training in radiology who ensures correct dose, location, and treatment schedule

Figure 4. Radiation Treatment Team Members

Note. Based on information from National Cancer Institute, 2008.

Conclusion

Patients receiving radiation experience many stresses during treatment. Radiation may be the first step in cancer treatment and, by providing a guiding hand and being available for the many questions that arise, oncology nurses can assist patients through the journey. Understanding the radiation therapy process will help oncology nurses react to their patients' experiences and better enable them to answer questions, assist during treatments, and accurately diagnose and treat the side effects that patients may be experiencing.

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