



Sparing Critical Organs From the Effects of Radiation Therapy

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Question: How are critical structures, such as the heart and lungs, spared from the harmful effects of radiation therapy?

Answer: Critical structures are spared from the harmful effects of radiation therapy through precise treatment planning that uses appropriate beam angles and blocking techniques. Although radiation therapy has proven to be a beneficial treatment modality for a number of benign and malignant diseases, tissue dose tolerance limitations must be considered carefully when planning and prescribing radiation therapy. Prior to the advent of three-dimensional conformal treatment techniques, radiation was administered by way of square or rectangular fields and often was delivered in an anterior or posterior approach with little regard to tissue sparing or tolerance. Conformal treatment techniques allow for precise beam targeting that conforms to tumor shape in a specific location inside a patient's body. Computed tomography (CT) images are obtained and downloaded into a radiation treatment planning computer. This creates a three-dimensional image on which simulated beams of radiation can be superimposed, allowing beam angle and estimated tissue dose exposure to be calculated. With the older treatment techniques, morbidity was high; this dictated the need for extended treatment breaks and a less-than-optimal treatment course. The effectiveness of radiation therapy is influenced directly by the ability to deliver an uninterrupted, optimally therapeutic dose (Withers & McBride, 1998). Occasionally, an anterior or posterior approach still is prescribed as palliative therapy. This is because conformal three-dimensional treatment planning requires additional time to schedule needed CT scans and plan the treatment course. Treatment with palliative intent often needs to be initiated as soon as possible. In addition, the im-

portance of long-term morbidity associated with larger, less precise treatment techniques is not a primary concern when administering radiation therapy with a palliative intent.

Since the 1980s, healthcare providers have had an increased awareness of the long-term side effects of radiation therapy, including the possibility of developing a secondary malignancy. Current radiation treatment planning systems and tissue-sparing techniques developed in the late 1980s have been refined, allowing pinpoint accuracy while limiting unnecessary exposure of normal and sometimes critical structures in or near the prescribed field of radiation. These techniques minimize short- and long-term side effects and decrease the potential for long-term complications. Emami et al. (1991) described radiation tissue dose tolerance levels for specific organ sites. In addition, endpoints, which are specific dose-limiting factors, were identified for each respective organ system. For example, pneumonitis is the endpoint criteria for irradiation of lung tissue. When an entire lung is irradiated, doses should not exceed 2,000 cGy; however, smaller, limited portions of lung tissue can tolerate up to 6,000–7,000 cGy of radiation. Cardiac endpoints are identified as pericarditis, pericardial effusion, or myocardial ischemia. These can be seen at radiation doses between 4,000–7,000 cGy, depending on whether full or partial organ exposure occurs. The criteria set forth by Emami et al. still are considered the standard by which acceptable tissue tolerance is measured. Endpoints are considered to be long-term morbidity that should be avoided. These endpoints are toxic effects seen weeks to months after radiation and have the potential to significantly impair quality of life (Rubin, Constine, & Williams, 1998).

Patients with cancer of the lung, breast, or esophagus as well as Hodgkin's disease who receive radiation therapy are at significant risk for developing cardiac and pulmonary toxicities simply because these tissues are either included in or adjacent to areas that require radiation. Sometimes, totally eliminating all critical structures within the radiation field is not possible. For this reason, the radiation oncology team must localize and minimize exposure to the heart and lungs during the radiation treatment

planning process. This is done through a collaborative approach between the radiation oncologist, medical dosimetrist, and medical physicist, where time and consideration are given to the calculation of the total radiation dose received by each organ and surrounding structure within or near the radiation field. To accurately accomplish this, patients must undergo a radiation treatment planning CT scan while in the radiation treatment position. This allows for precise localization of the tumor in relation to the patient's anatomic structure. This is an essential component of three-dimensional conformal radiation therapy. These CT images are downloaded into a radiation treatment planning computer, the tumor or treatment area then is localized, and the precise work of tissue sparing in regard to tissue tolerance begins (Kirsner, Prado, Tailor, & Bencomo, 2001).

When a radiation treatment plan is considered, the radiation oncologist, medical physicist, and medical dosimetrist examine multiple treatment options and determine which plan will provide the patient with the most optimal dose distribution of radiation to a specified area. As an example, when planning treatments to the left breast, careful consideration must be given to the heart and lungs to avoid potential toxicity. A radiation treatment planning computer superimposes tangential beams of radiation over the patient's previously obtained CT images of the chest (see Figure 1). The computer then places multiple lines, known as isodose distribution lines, over the breast image. Each line is assigned a different color, which allows for clear differentiation, and each color represents a different percentage of radiation coverage that encompasses varying volumes of breast tissue (see Figure 2). The goal of radiation planning is to choose the plan that will deliver 100% of the prescribed dose to the tumor or, in terms of postlumpectomy

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