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Image-guided Radiation Therapy:
Portal Imaging

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Image-guided Radiation Therapy: Portal Imaging

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Precisely planning where to deliver radiation treatment requires a method to verify the dose location before treating the patient, during treatment and after treatment. Image-guided radiation therapy (IGRT) uses several methods to verify radiation delivery, including computed tomography, ultrasonography, portal imaging and the use of implants and fiducials, electromagnetic transponders, motion tracking and video surface imaging. Advances in IGRT have reduced the uncertainty in radiation treatments, allowing radiation oncologists to reduce treatment margins and maximize dose to the target while decreasing dose to normal structures. This article focuses on the use of portal imaging to guide treatment delivery.

After completing this article, the reader should be able to:

- Understand the use of portal imaging in image-guided radiation therapy.
- Define the quality assurance process for electronic portal imaging.
- Recognize ways to enhance the use of electronic portal imaging.
- List examples of standard treatment field borders.

Physicians began using radiation to treat cancer shortly after the discovery of x-rays by Wilhelm Conrad Roentgen in 1895.[1] Early pioneers in radiation therapy lacked the ability to measure treatment dose, so prescriptions called for an erythema dose, or the amount of radiation that would turn the skin red. Since that time, radiation safety concerns and technology advances have changed the delivery of radiation therapy. The ability to more precisely measure radiation dose, gantry-mounted linear accelerators, treatment planning systems, multiple image-guidance modalities and record-and-verify systems are a few of the technological developments that have improved the efficacy and safety of radiation treatment.[2] The goal of radiation therapy is to deliver a prescribed dose to the target area while minimizing dose to the structures around the target. Portal imaging is an image-guidance technique that can help ensure the dose is targeted to the correct area.

Dose delivery is a complex procedure involving several steps. At the initial consultation, the radiation oncologist discusses various treatment options with the patient. During simulation, the patient lies on the couch in the proper position with the appropriate immobilization devices in place. Next, the radiation therapist acquires either simulation radiographs or computed tomography (CT) images of the treatment area. In dosimetry, the radiation oncologist draws the contours depicting the target volume, as well as the normal surrounding structures and the specific beam arrangements to best treat the patient. Finally, the patient returns to the department so the fields to be treated can be verified. Verification involves acquiring portal images that are approved by the radiation oncologist before radiation treatments begin.

In the past 30 years, computers have changed how radiation therapy is administered.[3] Digitally controlled radiation treatment equipment can shape the radiation beam with multileaf

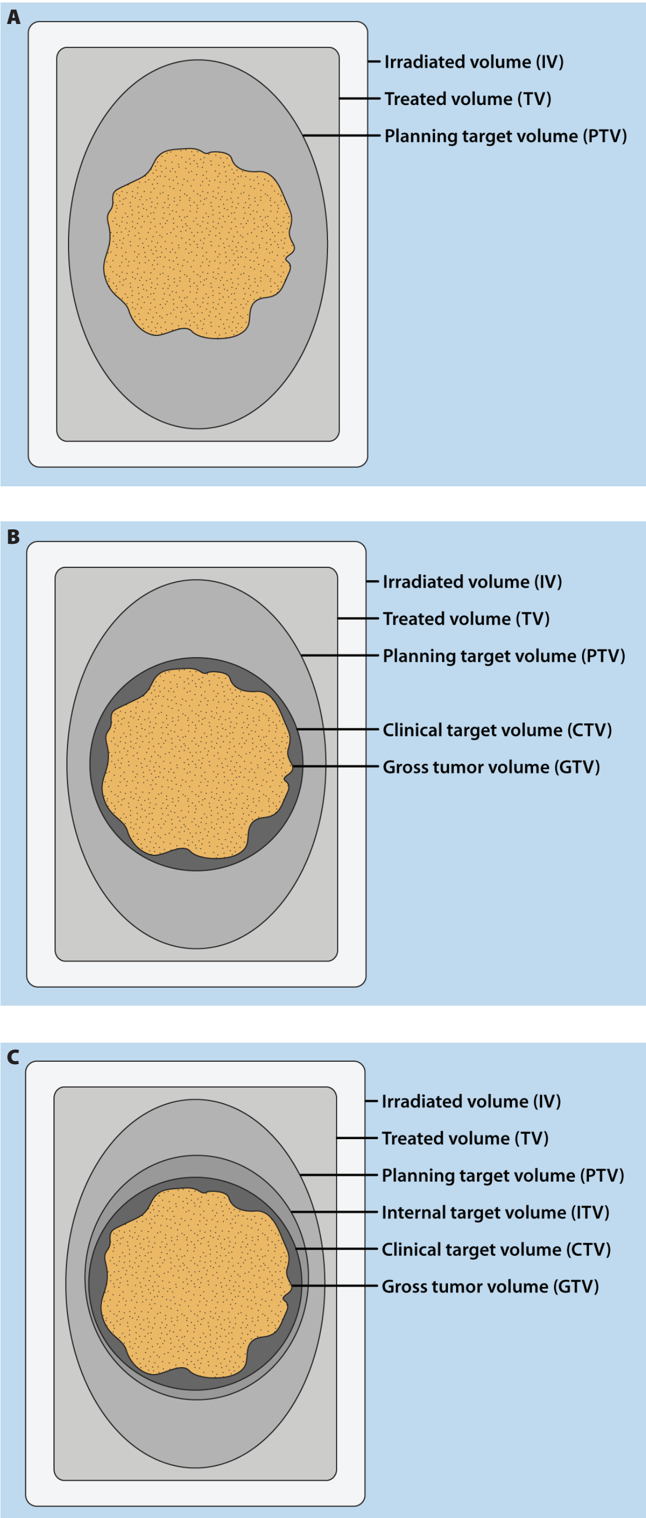

Figure 1. *Illustration of how treatment boundaries changed over time. A. ICRU Report No. 28 (1978). B. ICRU Report No. 50 (1993). C. ICRU Report No. 62 (1999). Volumes used for radiation treatment planning. The gross tumor volume (GTV) includes the palpable or visible tumor. The clinical target volume (CTV) includes the tumor and presumed microscopic spread. The internal target volume (ITV) consists of the CTV and an internal margin built into the treatment plan. The planning target volume (PTV) includes the CTV and margins that account for geometric uncertainties. The treated volume represents the minimum target dose that adequately covers the PTV plus an additional margin to cover limitations in treatment technique. The irradiated volume contains tissue that receives a significant amount of the prescribed dose.*

collimators or other field-shaping devices. Treatment planning systems now are capable of integrating state-of-the-art radiation transport algorithms, graphical visualization techniques and each treatment unit's capabilities. Treatment plans using CT simulation are known as 3-D conformal therapy because the treatment is planned in 3 dimensions.[1] The 3-D delineation of the gross tumor volume (GTV), clinical target volume (CTV) and organs at risk allow for a smaller planning target volume (PTV) (see **Figure 1** and **Box**).[4] The fusion of diagnostic CT, magnetic resonance (MR) or positron emission tomography (PET) images to the simulation image in the treatment planning system provides a more accurate depiction of the tumor and target area.[3]

Intensity-modulated radiation therapy (IMRT) plans also use CT simulation images; however, the plans are created using an inverse planning method.[3] This type of plan begins with the delineation of the target and normal structures. The physician, working with the medical dosimetrist, determines the amount of dose to the tumor and the acceptable normal tissue dose. A set of radiation patterns is derived from these constraints and sent to the appropriate radiation treatment unit. The final plan consists of static or dynamic beam segments with nonuniform intensities.

The ability to plan the precise location of the radiation dose requires a method to verify where the dose is being delivered during treatment. By using advanced imaging technology, image-guided radiation therapy (IGRT) provides a way to verify radiation delivery. Advances in IGRT have decreased the uncertainty in radiation treatment and have allowed radiation