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The Emergence of Advanced Brachytherapy Techniques for Common Malignancies

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Brachytherapy involves the placement of radioactive sources either within tissues (interstitial implants) or in contact with tissues at risk (intracavitary therapy). The word "brachytherapy" means "short therapy," implying that the effective radiation is limited to regions in close proximity. The radiation is emitted outward from the radioactive source (seeds or ribbons) thereby treating from the inside out, unlike external beam radiotherapy, wherein radiation must traverse normal tissue to reach the targeted tumor cells (Fig. 1). The specific radioisotope used is based on several variables including half-life, energy, and patient/personnel safety. Brachytherapy has been used for several decades and serves as an integral method of radiation delivery. It affords maximal radiation dose escalation and higher conformality (confinement of the radiation to the tumor region while sparing normal tissues). A higher radiation dose has been shown in many situations to provide improved results by increasing local tumor control. Brachytherapy has a wide array of clinical applications and has been used in many different cancer sites as a sole modality or in conjunction with external beam radiotherapy. It has been used intraoperatively in situations where optimal surgical resection is not possible as well as postoperatively to target potential regions of residual microscopic disease.

Although the use of brachytherapy has a long history, the recent advent and integration of sophisticated imaging modalities has improved the accuracy of applicator placement, allowed conformal radiation treatment planning, and resulted in more reliable quality assurance measures. In this overview, general brachytherapy principles coupled with recent advances in image guidance techniques are described in the context of three of the most common clinical

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Fig. 1. Iodine 125 radioactive seeds used for permanent LDR prostate brachytherapy.

applications of low dose rate (LDR) and high dose rate (HDR) brachytherapy, namely, breast, prostate, and gynecologic malignancies.

BRACHYTHERAPY RADIOBIOLOGY: HIGH DOSE RATE VERSUS LOW DOSE RATE

Brachytherapy can be subdivided by the rate at which the radiation dose is delivered–high dose rate (HDR) and low dose rate (LDR). By definition, HDR delivers the radiation dose rapidly or at a dose rate greater than 12 Gy/h, similar to the dose rate delivery of conventional external beam radiotherapy using linear accelerators. The key benefits of an HDR program include patient convenience and avoidance of radiation exposure for hospital personnel owing to computer-assisted remote afterloading techniques. Patients receiving HDR brachytherapy can potentially be treated as outpatients contingent upon the clinical scenario, with treatment times lasting only a few minutes. The HDR uses a single highly radioactive source (iridium 192) that is attached to a cable and housed within a computer-controlled robotic machine referred to as an HDR remote afterloader. When treatment is delivered, the radioactive source is pushed from the remote afterloader through a tube to a location next to or within the targeted tissue (Fig. 2). The location and time that the radioactive source pauses along its path determine the distribution and amount of radiation delivered. The radiation oncologist determines the desired dose distribution for the precise treatment delivery that allows for target coverage and minimal exposure of healthy tissue in the immediate vicinity. Used in Europe and Japan for over three decades, HDR brachytherapy has been on the rise in the United States in recent years. This trend toward HDR and away from LDR is a result of the enhanced control of dose delivery, the decrease in radiation safety concerns, and the potential for outpatient treatment. Common sites treated with an HDR brachytherapy component are gynecologic, breast, prostate, endobronchial, and head and neck cancers.

In contrast, LDR brachytherapy is defined as a dose delivered at a rate that is less than 2.0 Gy/h. This approach may involve manual afterloading of brachytherapy catheters/devices or the surgical placement of sealed radiation sources directly in or near the area being treated. Customized for each patient by varying the strength and placement of the radiation sources, LDR