AL-Mustaqbal University College

Nuclear Medicine

for B.Sc. Students

By Lecturer

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Lecture Ninth / Brachytherapy

1-Introduction for Brachytherapy

Brachytherapy is a specific form of radiation therapy used to treat cancer. It consists of placing sealed, radioactive sources directly into or next to the tumor to be treated, either directly or by means of catheters.

Brachytherapy has been a part of antineoplastic treatments since the development of contact brachytherapy in the early 1900s. A few years after the discovery of radioactivity, Pierre Curie and Alexander Graham Bell independently observed shrinkage of malignant tumors when radioactive sources were implanted directly inside a mass.[1] Throughout the mid-20th century, brachytherapy use continuously increased, and the technique has become the standard of care as a single modality or as a boost after external-beam radiotherapy (EBRT) for tumors requiring a high radiation dose to be cured.[2-7]

In 2019, brachytherapy remains an optimal tool in the context of radiation use for patients and may involve a wide range of medical specialties in either the referral to or the placement of brachytherapy. In this review, the clinical relevance of brachytherapy in the global oncological landscape is examined in the light of potential gains in local control, survival, quality of life (QOL), treatment sequelae, and value-based evaluations

2-Brachytherapy in the Context of Radiation Use for Patients

2-1 Treatment Modalities

Schematically, radiation therapy is indicated in 3 major situations

1) as curative, definitive radiotherapy (with or without chemotherapy);

2) as adjuvant treatment to decrease the probability of local relapse after surgery; and

3) as palliative treatment of symptomatic metastases.

The common objective of all irradiation techniques is to deliver a radiation dose to the tumor that is high enough to eradicate tumor cells without leading to unacceptable damage to normal tissues. The deoxyribonucleic acid (DNA) chain is the primary target of therapeutic irradiation, and, if not repaired, radiation-induced DNA damage leads to direct cell death, cell cycle redistribution, and microenvironment changes. The therapeutic index of irradiation relies on the differential response between tumors and normal tissue, as tumors cells have a lower DNA repair capability compared with normal tissue cells. However, radiation-induced changes in organs at risk may lead to acute side effects and long-term functional sequelae. Therefore, the ideal technique should be able to deliver therapeutic doses to the tumor with doses as low as possible to the organs at risk.

Schematically,

2 possibilities do exist for delivering therapeutic irradiation:

EBRT and ***brachytherapy***.

In EBRT techniques, which are the most commonly used, the irradiation comes from beams generated outside the patient. Modern EBRT modalities include intensity-modulated radiotherapy (IMRT), stereotactic radiotherapy, and proton therapy. All of those techniques have been developed to increase the ratio between tumor dose and normal tissue dose. The fundamental specificity of brachytherapy is that it relies on the implantation of radioactive sources (or catheters secondarily loaded with radioactive sources) within the tumor (interstitial brachytherapy) or very close to the tumor (plesiotherapy). The implantation is guided by clinical findings and any relevant imaging modality. In some situations, the precise perioperative placement of brachytherapy catheters may need expertise from organ specialists, including urologists, gynecologic surgeons, cardiologists, gastroenterologists, pneumologists, surgical oncologists, interventional radiologists, orthopedists, or dermatologists. This multidisciplinary approach is particularly required for perioperative procedures, in case the target volume is not easily accessible without endoscopic guidance (eg, esophageal or endobronchial tumors) or is close to highly sensitive organs. Thereafter, imaging is done during or just after implantation to guide the dosimetric process, which schematically consists in deciding where the sources should be placed and/or how long those sources should stay in place to achieve a high dose to the tumor without exceeding organs-at-risk dose constraints. The total dose can be delivered through 1) continuous low-dose-rate (LDR) irradiation, 2) low-intensity pulses repeated every hour for up to a few days (pulse-dose-rate irradiation), or 3) a few fractions delivering high doses each time (high-dose-rate [HDR] irradiation). **Various radioisotopes with specific properties in terms of half-life and energy can be used; the most commonly used in modern brachytherapy are iridium-192, cobalt-60, iodine-125, and palladium-103.**

3-Advantages of the Technique

The efficacy of brachytherapy relies on the very high radiation dose delivered directly to the tumor, close to the sources. A specificity of brachytherapy is that there is a rapid dose fall-off at distance from the sources, limiting dose exposure of surrounding tissues.

Brachytherapy offers dosimetric advantages with very sharp radiation dose gradients compared with conventional external-beam techniques. Furthermore, there is no need for additional uncertainty margins around the clinical target volume. Indeed, if the tumor moves during the radiation procedure, the radiation source moves as well. This property differs from conventional EBRT, which requires additional margins to consider set-up and organ motion uncertainties.9 Therefore, brachytherapy combines optimal tumor-to-normal tissue gradients while minimizing the integral dose to the rest of the patient. Treatment can be delivered within a few days compared with protracted fractionated radiotherapy schemes, and this is clinically relevant in proliferating tumors to decrease the overall treatment time, thereby improving local control by limiting tumor repopulation.Dosimetric studies have confirmed that brachytherapy was an optimal tool in the context of radiation use to achieve high tumor doses while decreasing the dose to organs at risk.10-12 Brachytherapy can be used either alone or in combination with EBRT to increase the dose focally in advanced primary tumors requiring high doses to be cured, such as cervical cancer or prostate cancer (PCa).13

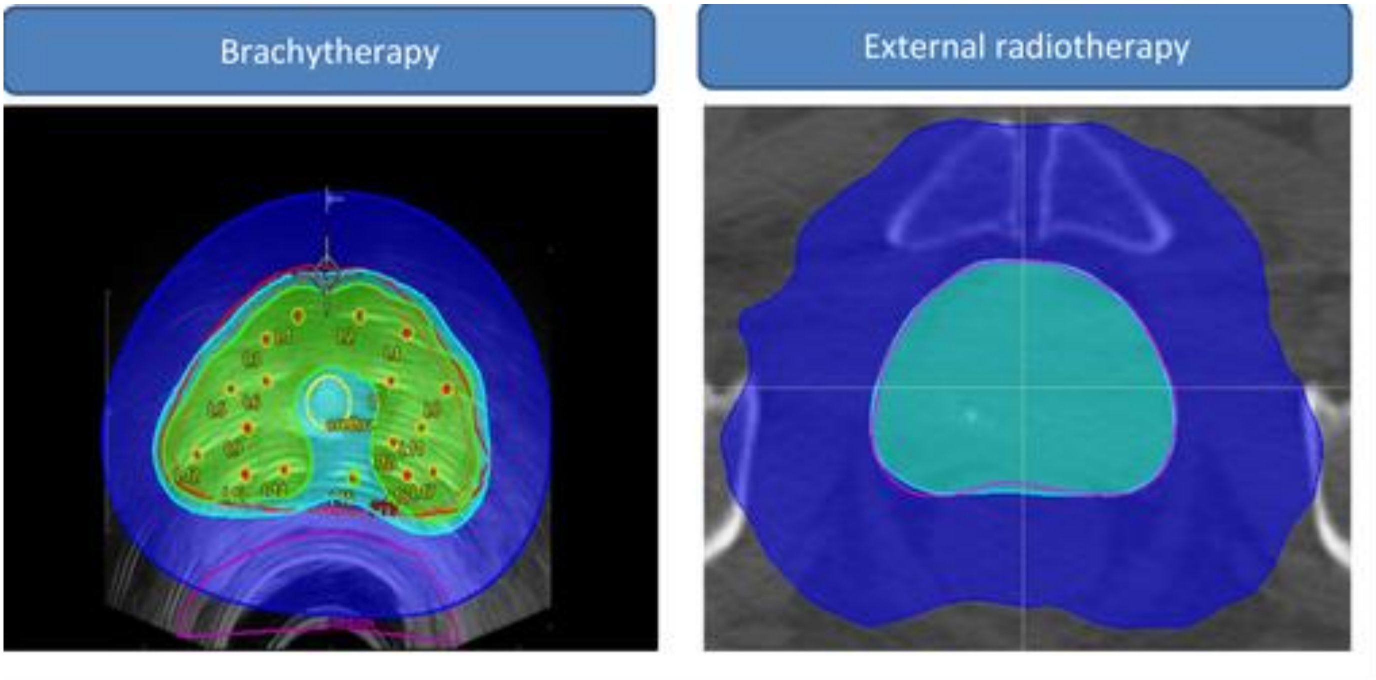

Figure 1: **Comparison of Brachytherapy (BT) and External Radiotherapy for Boosting Primary Tumor in an Example of Prostate Cancer. The figure shows comparison between high dose rate BTboost (left) and Volumetric Modulated Arctherapy (VMAT) (right) for delivering a boost of 15 Gy. The green, light blue, dark blue and green isodoses lines show the part of body that receives at last 18 Gy, 14.25 Gy, and 6 Gy, respectively. With external radiotherapy, no part of the prostate could receive 18 Gy, while there was a major increase in the volume of normal tissue receiving 6 Gy, as compared to BT (442 vs 133 cm^3).**