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Different Techniques of Radiotherapy for Breast Cancer

Md Mokhlesur Rahman[1], Shadia Tun Nayeem[1]
[1]Gono Bishwabidyalay (University)

Preface: Among the all other cancers for women, breast cancer is still leading the malignant tumor. This cancer usually starts in one area and gradually spreads with a predictable pattern to nearby lymph nodes and blood vessels, eventually affecting the rest of the body. In earlier treatment approaches, doctors recognized that removing the main tumor was not always enough because microscopic cancer cells could still remain. To address this, radiation therapy was either used alongside surgery to eliminate leftover cancer cells or chosen instead of surgery when operating was not practical due to location or concerns about appearance and function. [1].

Phases: For the adjuvant and non-adjuvant phases, many treatment comparisons show a 10–25% reduction in breast cancer mortality and recurrence, with no increase in non-breast-cancer deaths. However, certain therapies pose additional risks. Radiotherapy increases mortality risks linked to heart disease, lung cancer, and esophageal cancer, with severity correlating to radiation doses received by these organs [2]. And compared to standard radiotherapy, concurrent chemoradiation increased pCR rates (14% vs 22%, P<.001) but showed no significant difference in disease-free (69% vs 81%, P=.186, HR 0.51) or overall survival (74% vs 89%, P=.162, HR 0.46) at 3 years. Toxicity included 25% pneumonitis, 25% dermatitis, and one death from a study of Muriel Brackstone et al. [3].

- **Non-Adjuvant:** Non-adjuvant/neo-adjuvant radiotherapy is given before primary treatment to shrink tumors, improving surgical success. It may boost disease-free survival without affecting overall survival, especially in estrogen receptor-positive early-stage breast cancer patients [4].
- **Adjuvant:** Adjuvant radiotherapy, given after surgery in women under 50 with early-stage breast cancer, reduces recurrence risk by eliminating residual cancer cells. Factors like cancer type, stage, and lymph node involvement guide treatment, though cardiac toxicity is a concern for left-sided breast cancer due to heart proximity [5].
- **Concurrent:** Concurrent radiotherapy, combined with chemotherapy, improves treatment for locally advanced breast cancer (LABC) that is inoperable. Studies show higher response rates with concurrent chemoradiotherapy (CCRT) compared to systemic therapy alone, making it a potential option when neoadjuvant approaches are less effective [6].

Types: Depending on how the radiotherapy is given, treatment type has two forms.

EBRT: External Beam Radiation Therapy (EBRT) delivers radiation from outside the body to the targeted area, typically following breast-conserving surgery (BCS) or mastectomy. It focuses on treating the whole breast, chest wall, and sometimes nearby lymph nodes to eliminate remaining cancer cells and reduce recurrence risk. Treatment usually typically given daily, five days a week, for 6 to 7 weeks. A shorter, more intense course called accelerated radiation may last 3 to 4 weeks [7].

Modalities: From the most commonly used modalities, study shows that both IMRT and VMAT demonstrates superior conformity compared to 3D-CRT, with increases of 27% and 30%, respectively. Additionally, inverse planning techniques (IMRT and VMAT) provides more homogeneous dose distributions (10% improvement) and reduced hotspots (14% reduction) relative to 3D-CRT [8].

- **3DCRT:** 3DCRT utilizes three dimensional images to plan and uses forward treatment planning where dose distributions are calculated after given beam parameters.
- **IMRT:** A developed form of 3DCRT where by the beam modulation with MLC the intensities are calculated to provide the given objectives and constraints on dose distributions to the target volume and organs at risk (OARs).
- **VMAT:** First it was IMAT, which worked on the gantry rotation to modulate the beam intensities with the same dose rate and when the dose rates were changed along with gantry rotation, it became VMAT.

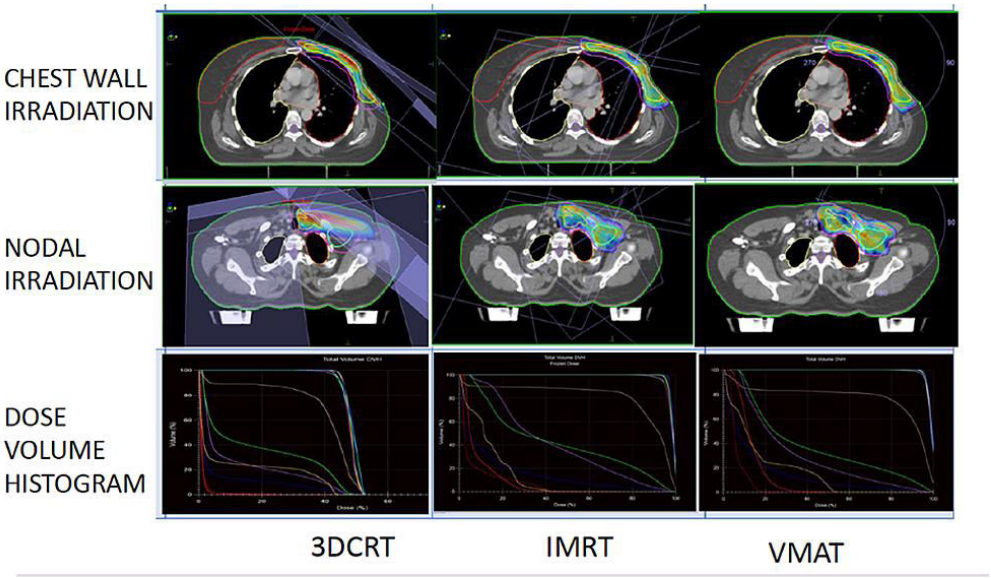

Figure 1: Plan comparison [8]

Techniques: Cardiac morbidity and pulmonary problems are considered as risks in breast treatment. A comparison between irradiated and non-irradiated patients revealed a significant rise in mortality rates, primarily due to heart disease and lung cancer, with rate ratios of 1.27 and 1.78, respectively [9]. Study results imply that the dose of the heart, left anterior descending (LAD) aretery and ipsilateral lung in the deep-inspiration breath-hold (DIBH) group was significantly lower than that in the free-breathing (FB) group as DIBH modifies the volume of considered OARs [10].

- **FB:** Free Breathing, where patients breath normally during treatment that ensures fast treatment delivery.
- **DIBH:** Deep Inspiration Breath Hold, where patient takes a deep breath and holds it, expanding the chest and moving the heart away from the breast/chest wall.

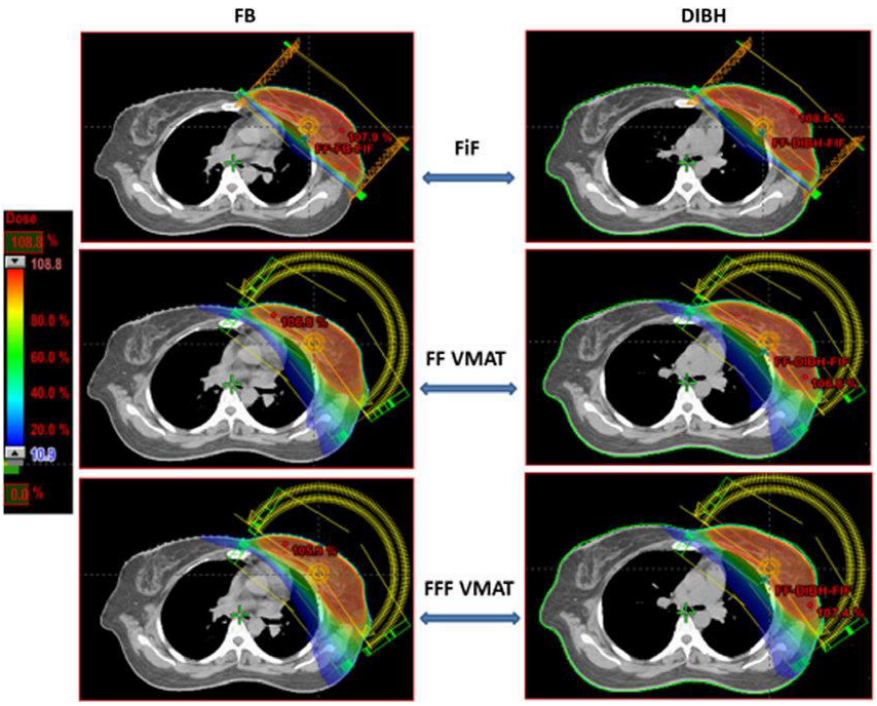

Figure 2: Breathing Comparison [11]

BT: Brachytherapy is a radiation technique where radioactive sources are placed directly into or near the target tissue. Currently, brachytherapy-based accelerated partial breast irradiation (APBI) is the only method with level 1 evidence, supporting its use as a viable alternative to whole breast irradiation (WBI) following breast-conserving surgery (BCS) for patients with low-risk, early-stage breast cancer [12].

Modalities: Among the brachytherapy modalities for breast cancer, intra-operative radiotherapy (IORT) is convenient than the conventional brachytherapy that includes intracavitary and interstitial brachytherapy procedure for low risk breast cancer conserving the breast [13].

- **IORT:** A precise partial breast irradiation (PBI) technique that delivers a single 10-30 Gy dose to the tumor bed during surgery. It can serve as sole RT or a boost, targeting the lumpectomy cavity (1-2 cm margin). Risk-adapted IORT can replace whole-breast radiotherapy (WBRT) for low-risk breast cancer (BC), while high-risk BC may still require WBRT based on histopathology [14].

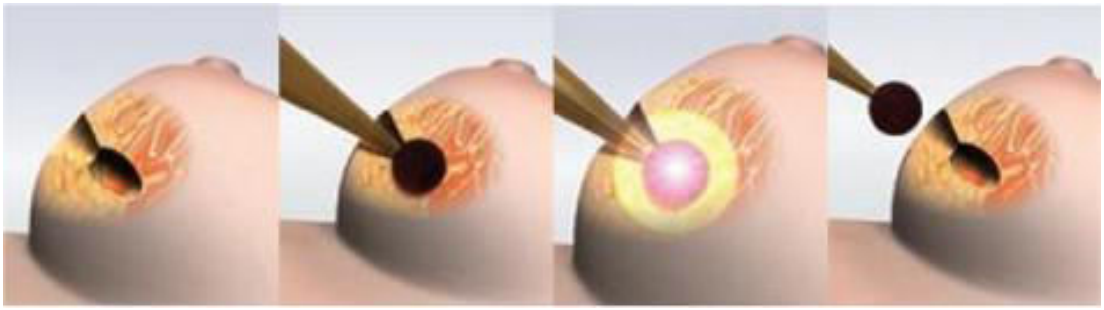

Figure 3: Intraoperative Radiotherapy [14]

Techniques: Compared to WBI of external beam radiation therapy, PBI/APBI showed higher local recurrence rates (HR 1.62), worse cosmesis (OR 1.51), and increased late toxicity, including fibrosis, telangiectasia, and fat necrosis. Acute skin toxicity was lower (OR 0.04), but new ipsilateral breast primaries were more frequent (OR 3.97). Overall survival remained unchanged (HR 0.90), with no significant differences in cause-specific survival, distant metastasis-free survival, relapse-free survival, loco-regional recurrence-free survival, or mastectomy rates. Compliance exceeded 90%, though cost, quality-of-life, and patient preference data were lacking [15].

- **PBI:** Partial Breast Irradiation that delivers radiation to a limited area around the tumor, minimizing side effects and treatment duration.
- **APBI:** Accelerated Partial Breast Irradiation, is a faster version of PBI, typically completed in a shorter timeframe (often within a week).

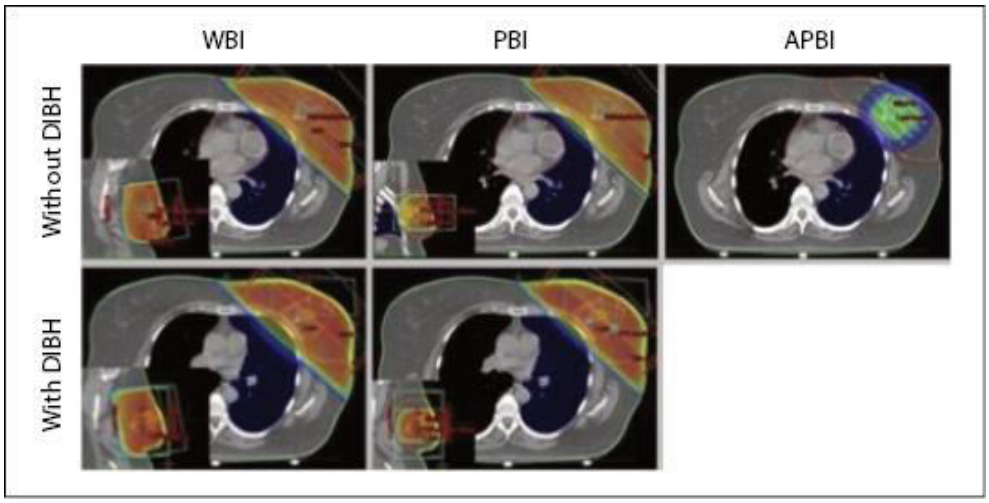

Figure 4: Treatment Area Based Comparison [16]

End-Word: Studies show that women under 40 have higher recurrence rates after radiotherapy due to denser breast tissue, which affects radiation absorption. As fatty tissue increases with age, recurrence rates decline. And treatment effectiveness varies by type, modality, and technique, with tumor characteristics, radiation methods, chemotherapy regimens, and surgical approaches influencing disease control, survival rates, and side effects.

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