Radiotherapy for Breast Cancer: A Medical Physicist's Perspective on Precision, Safety, and Quality

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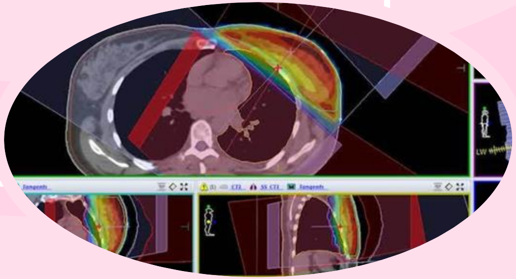

Evolution of Radiotherapy Technology

CHRONOLOGY

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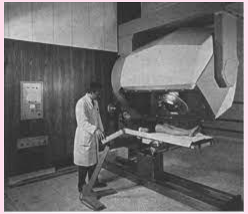
1922
Radiotherapy is established as a medical discipline



3D - TPS
3D - CRT

Discovery of ***X Rays***

Construction of the first accelerator

Betatron

Multi-leaf collimator (MLC) invented for alloy block field shaping

IMRT

VMAT

1895 | 1896 | 1932 | 1934 | 1940 | 1951 | 1965 | 1972 | 1980 | 1990 | 1996 | 2000's | 2012

First TTO.

Fractionation schedule

Cobalt 60 Unit

CT Scanner

PET Scan

IGRT
CBCT
4D-CT
and more

Radiotherapy in Breast Cancer Management

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Breast cancer is the most common cancer among women worldwide, with 2.3 million new cases diagnosed in 2022.

Radiotherapy is used in approximately 50-60% of breast cancer cases as part of the treatment plan.

Hypofractionated radiotherapy has shown to reduce treatment duration by up to 50% while maintaining efficacy.

Home > Japanese Journal of Radiology > Article

Global research trends in radiotherapy for breast cancer: a systematic bibliometric analysis

Original Article | Published: 06 January 2023

Volume 41, pages 648–659, (2023) Cite this article

Review | Open access | Published: 30 March 2020

Recent advances in radiotherapy of breast cancer

Jan Haussmann, Stefanie Corradini, Carolin Nestle-Kraemling, Edwin Bölke, Freddy Joel Djiepmo Njanang, Bálint Tamaskovics, Klaus Orth, Eugen Ruckhaeberle, Tanja Fehm, Svjetlana Mohrmann, Ioannis Simiantonakis, Wilfried Budach & Christiane Matuschek

Radiation Oncology **15**, Article number: 71 (2020) | Cite this article

52k Accesses | **16** Altmetric | Metrics

Radiotherapy in Breast Cancer Management

Core Treatment Modality:

- Integral component of breast cancer treatment alongside surgery and chemotherapy.
- Offers local control of the tumor, reducing the risk of recurrence.

Balancing Efficacy and Safety:

- Strives to maximize tumor eradication while minimizing damage to healthy tissues.
- Essential in both early-stage and advanced breast cancer cases.

Improving Patient Outcomes:

- Contributes to higher survival rates.
- Enhances quality of life by reducing symptoms and treatment-related side effects.

Evolution of Breast Radiotherapy Fractionation

Year	Fractionation Scheme	Regimen	Key Trial/Development
1900s	Conventional (CF)	50 Gy/25 fx/5 wks	Early 20th century
2000s	Hypofractionated (HF)	40 Gy/15 fx/3 wks	START-A, START-B (2008)
2000s	Partial Breast (PBI)	Targeted	Brachytherapy, External Beam
2010s	Ultra-Hypofractionated	28.5-30 Gy/5 fx (weekly)	FAST Trial
2010s	SBRT	Precise targeting	Evolved in the 2000s-2010s
2020s	Ultra-Hypofractionated	26 Gy/5 fx/1 wk	FAST-Forward (2020)
2020s	Preoperative SBRT	15-21 Gy (single-fraction) or 19.5-31.5 Gy (3 fractions)	Recent advancements
Ongoing	RNI	Regional lymph nodes	Ongoing research and trials

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Journey to hypofractionation in radiotherapy for breast cancer: critical reviews for recent updates

Nalee Kim[1], Yong Bae Kim[2]

[1]Department of Radiation Oncology, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea

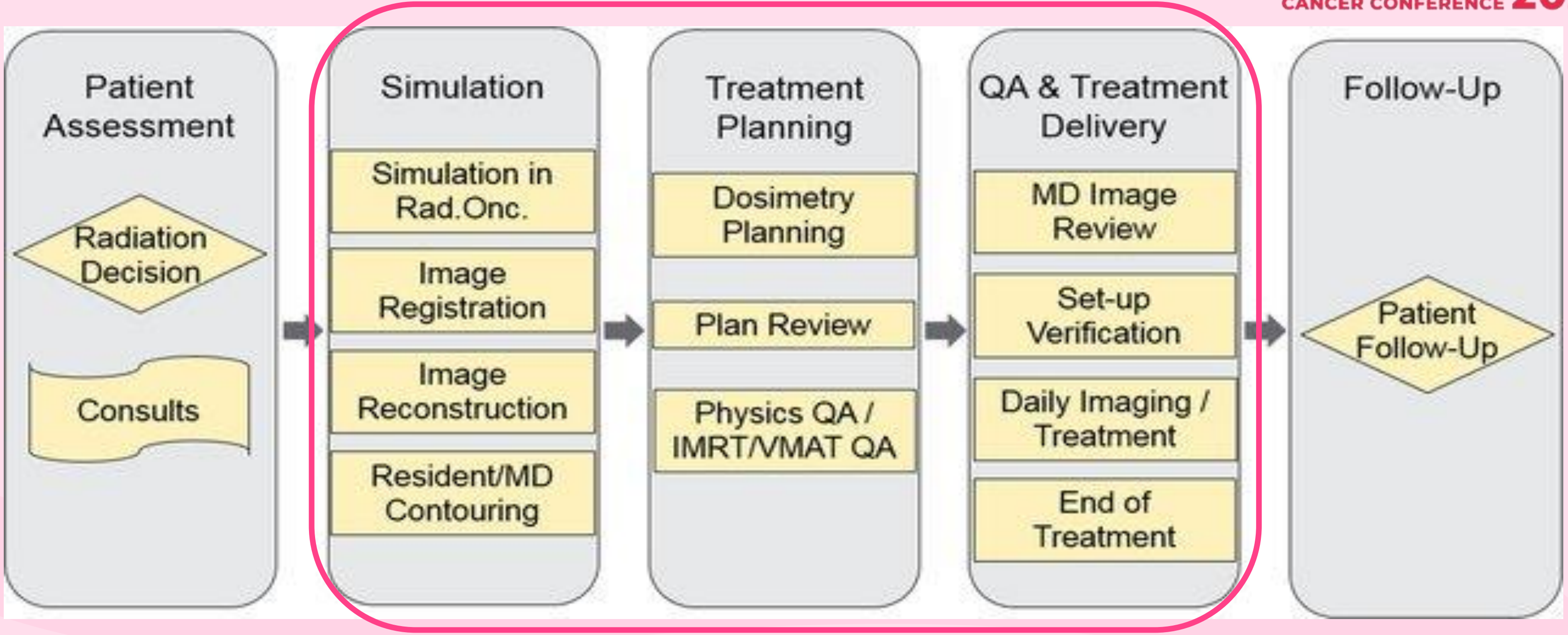
[2]Department of Radiation Oncology, Yonsei Cancer Center, Yonsei University College of Medicine, Seoul, Korea

> Radiat Oncol. 2024 Aug 2;19(1):103. doi: 10.1186/s13014-024-02497-4.

Advances in breast cancer treatment: a systematic review of preoperative stereotactic body radiotherapy (SBRT) for breast cancer

Mateusz Bilski[1 2 3], Katarzyna Konat-Bąska[4], Maria Alessia Zerella[5], Stefanie Corradini[6], Marcin Hetnał[7 8], Maria Cristina Leonardi[5], Martyna Gruba[1], Aleksandra Grzywacz[1], Patrycja Hatala[1], Barbara Alicja Jereczek-Fossa[5 9], Jacek Fijuth[10 11], Łukasz Kuncman[12 13]

Steps Involved in Breast Radiotherapy



Simulation: Setup and Image Quality

A high-quality patient setup is a pre-requisite for a high-quality treatment plan.

Quality Checks

- Patient setup
- Image quality
- Variable anatomy
- Contrast and implanted devices
- Implanted electronic devices
- Image transfer

Patient Setup: Ensure appropriate positioning, orientation, and immobilization per clinical standards.

Reproducibility: Assess whether the setup will be reproducible during treatment.

Image Quality: Review image quality and usability, address CT scan artifacts.

FOV: Ensure scan range covers targets/OARs and the entire patient surface.

Artifacts: Check for metal artifacts from implants or high-density parts; use OMAR if needed.

Anatomy: Identify variable internal (e.g., bladder) and external (e.g., shoulders) anatomy.

Breast Cases: Consider changes in breast, seroma, heart, and liver positions; arms, shoulders, chin can vary.

Implants: Identify and manage metal implants, contrast, and electronic devices per TG-203 guidelines.

CT Set Naming: Name CT sets clearly (e.g., CT_MMDDYY_BH vs. FB).

Simulation: Motion Management

An appropriate motion management strategy improves the accuracy of dose delivery, reduces margins and minimizes dose to normal tissue.

Quality Checks

- **Motion management**
- **4D scan accuracy**

Review that motion management matches the MD directive (e.g. breath hold, gating, 4DCT) and is appropriate for the clinical situation

What to consider for breast patients?

Compare FB vs BH. Q: Is BH worthy?

4D images not usually acquired for breast patients.

Breath Hold Techniques

Breath hold at inspiration can be achieved in several ways:

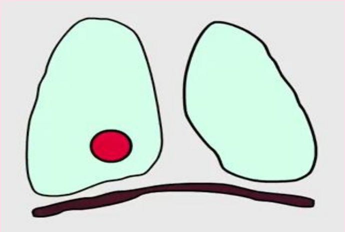
The concepts are discussed in detail in the module on Respiratory Motion

Voluntary Breath Hold: Patient holds breath voluntarily, treatment triggered by a spirometer, switch with patient or by video monitoring of skin marks and light fields.

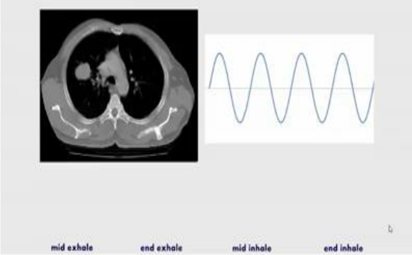
Controlled Breath Hold: Air flow controlled by mechanical pressure from a spirometer assembly (the ABC system®)

Respiratory Gating The beam is triggered at the correct part of the respiratory cycle using phase based or amplitude based techniques.

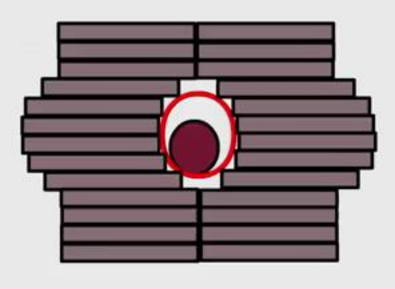
Each of these methods have been used and reported, achieving substantial sparing of heart doses. *Review by Shah et al Radiother Oncol 2014.*



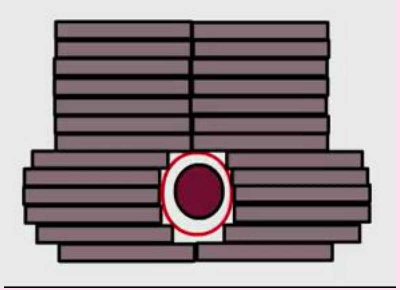
Respiratory Motion



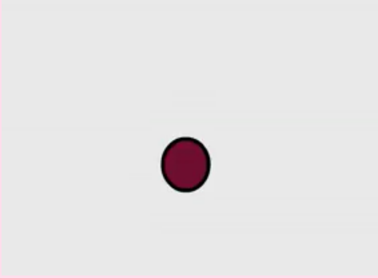
4DCT



Tracking



Breath Hold



Considering ITV

Immobilization Devices for Breast

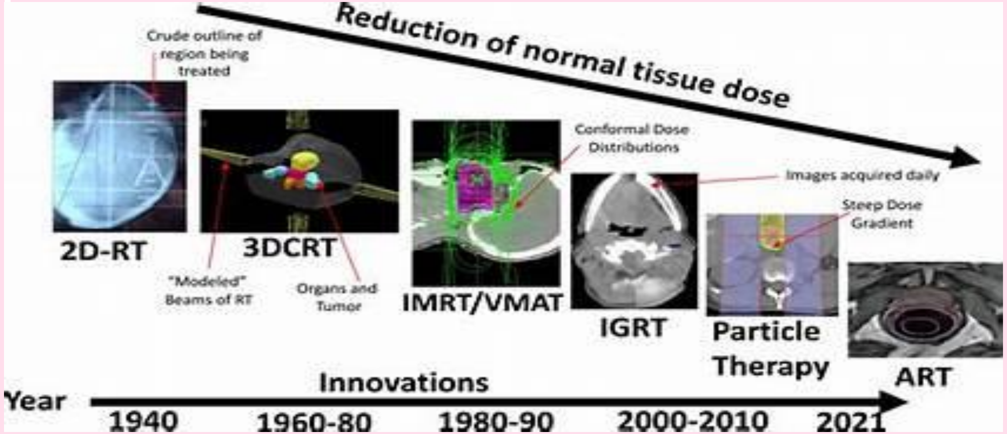







- Arms, elbows, shoulders and chin: avoid beam entry, avoid collision, reproducible and comfortable
- Supine (default) vs prone (pendulous breast without nodes)
- Breast board vs custom immobilization (e.g. vaclock)
- Bubble wrap, breast cup, etc to avoid skin fold and/or to reproduce breast shape.
- Scar, drain site, etc to mark with wires and BBs

Planning Techniques in Breast Radiotherapy



1920s-1950s:
- 2D Planning

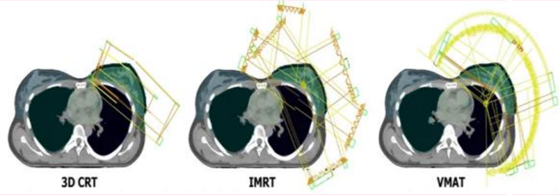
1960s-1980s:
- 3DCR with Wedges

1990s:
- 3DCRT FIF
- Brachytherapy
- Prone Breast Radiotherapy
- IORT

2000s:
- IMRT
- VMAT
- DIBH
- IGRT
- Helical Tomotherapy
- Respiratory Gating

2010s:
- Hybrid Radiotherapy
- SGRT
- ABC

2020s:
- Proton Therapy
- SBRT
- ART



Two-Dimensional (2D) Planning

Overview

- **Definition:** Early radiotherapy technique using 2D imaging for planning.
- **Historical Context:** Widely used before the advent of 3D imaging technologies.

Planning

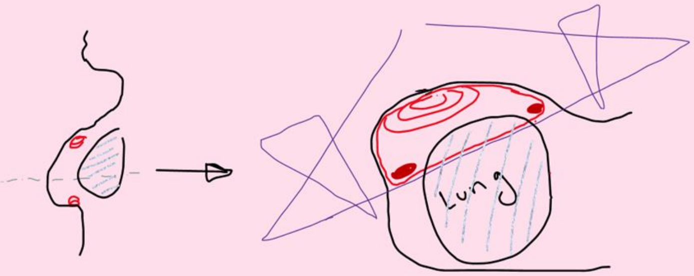
- **Simulation:** X-rays capture images of the treatment area.
- **Field Design:** Radiation fields designed based on 2D images.
- **Dose Calculation:** Calculated for each field, ensuring target coverage.

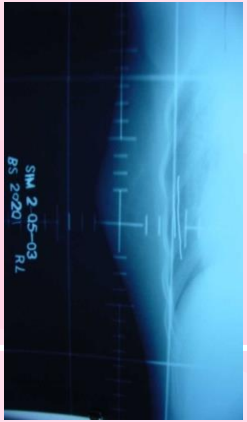
Advantages

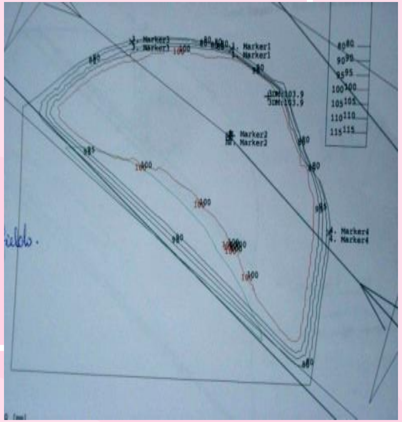
- **Simplicity:** Easy to implement and understand.
- **Accessibility:** Requires minimal technology and resources.

Disadvantages

- **Limited Precision:** Less accurate than 3D and advanced techniques.
- **Higher Risk of Damage:** Increased radiation exposure to healthy tissues.
- **Reduced Customization:** Less ability to tailor treatment to complex tumor shapes.



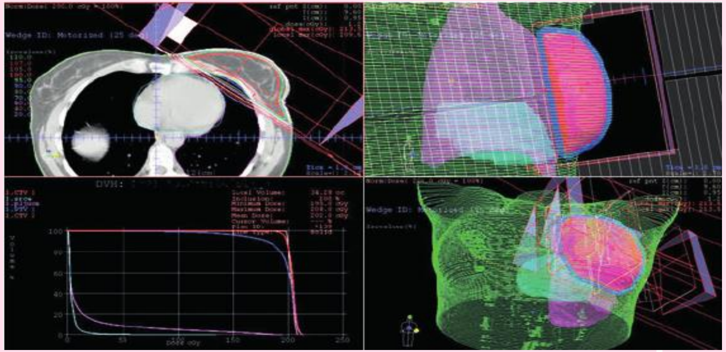




Three-Dimensional Conformal Radiotherapy (3DCRT)

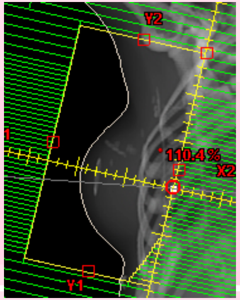
3DCRT with Wedges

- **Overview:** Uses multiple radiation beams shaped to match the tumor's dimensions, with wedge filters to modify dose distribution.
- **Advantages:** Precise targeting, improved dose homogeneity.
- **Disadvantages:**
  - Increased treatment time due to setup and delivery.
  - Complexity in planning and verification.
  - Less adaptable compared to advanced techniques like IMRT.

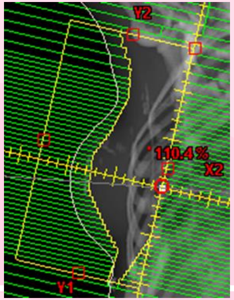


3DCRT Field-in-Field (FiF)

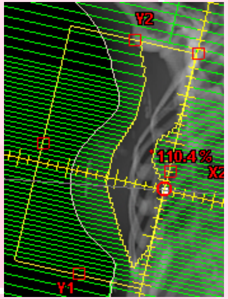
- **Overview:** Uses multiple subfields within each beam to modulate dose, reducing hot spots.
- **Advantages:** Enhanced dose homogeneity, sparing healthy tissues.
- **Disadvantages:**
  - Requires meticulous planning and QA.
  - Limited adaptability for complex tumor shapes.



1 Med Tang = 144 MU



1 Med Tang.1 = 8 MU



1 Med Tang.2 = 8 MU

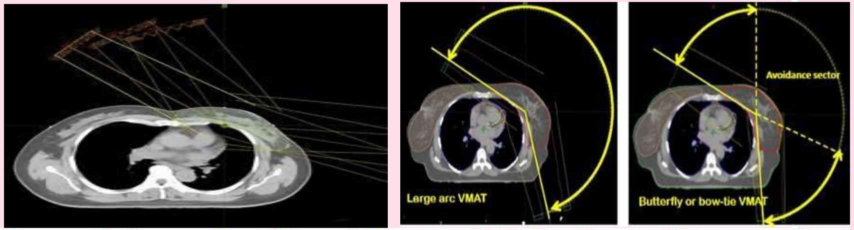
IMRT and VMAT

IMRT: Uses modulated radiation beams to conform to tumor shape.

- High precision targeting.
  - Improved dose homogeneity.
  - Reduces radiation exposure to critical structures.

VMAT Therapy): Delivers radiation in a single or multiple arcs around the patient.

- Faster treatment times.
  - Highly conformal dose distribution.
  - Efficient delivery with minimal exposure to healthy tissues.



An IMRT planning technique for treating whole breast or chest wall with regional lymph nodes on Halcyon and Ethos

Kareem Rayn, Ryan Clark, Klea Hoxha, Anthony Magliari, Jack Neylon, Michael H. Xiang, Dylan P. O'Connell

whole breast or chest wall and regional nodes on an Ethos/Halcyon machine. The IMRT-based planning approach described here offered superior conformity and OAR sparing than a competing hybrid 3D approach, with the tradeoff of increased low dose spill and delivery time. We have also developed and shared tools to

Tangent-based volumetric modulated arc therapy for advanced left breast cancer

Pei-Chieh Yu, Ching-Jung Wu, Hsin-Hua Nien, Louis Tak Lui, Suzun Shaw & Yu-Lun Tsai

TVMAT greatly decreases the radiation doses delivered to the OAR with maintained therapeutic efficacy. It is highly recommended for treating breast cancer, especially for difficult cases with left side disease needing nodal irradiation.

Hybrid Radiotherapy for Breast Cancer

Planning:

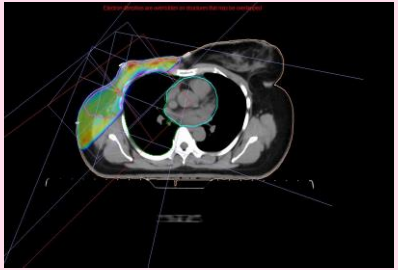
- Utilizes advanced imaging (CT, MRI) for precise tumor delineation.
- Integrates multiple planning algorithms to

Delivery:

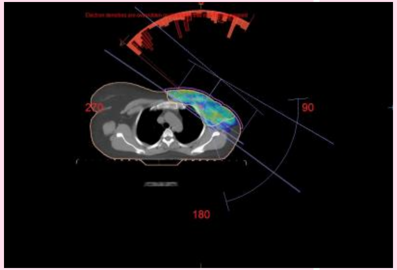
- Combines techniques like IMRT, VMAT, and 3DCRT to achieve optimal coverage.
- Employs IGRT for real-time verification and

Advantages:

- Enhanced dose conformity and homogeneity.
- Reduced toxicity to organs at risk (OARs).
- Flexibility to tailor treatment plans based on patient anatomy and tumor response.



3DCRT with IMRT



3DCRT with VMAT

Hybrid planning techniques for early-stage left-sided breast cancer: dose distribution analysis and estimation of projected secondary cancer-relative risk

Iga Racka, Karolina Majewska, Janusz Winiecki & Karolina Kiluk

Conclusions: The results confirmed that both hybrid techniques provide better target quality and OARs sparing than 3D-CRT. Hybrid VMAT delivers less MU compared to hybrid IMRT but may increase the risk of radiation-induced secondary malignancies.

Stereotactic Radiotherapy for Early Breast Cancer

Planning:

- Utilizes high-resolution imaging (CT, MRI) for accurate tumor localization.
- Employs advanced algorithms to design high-dose conformal plans.

Delivery:

- High precision with sub-millimeter accuracy in targeting.
- Single or few fractionated doses, minimizing overall treatment time.
- Real-time imaging verification to ensure precise delivery.

Advantages:

- High local control rates for early-stage tumors.
- Minimal radiation exposure to surrounding healthy tissues.
- Shorter treatment duration compared to conventional radiotherapy.

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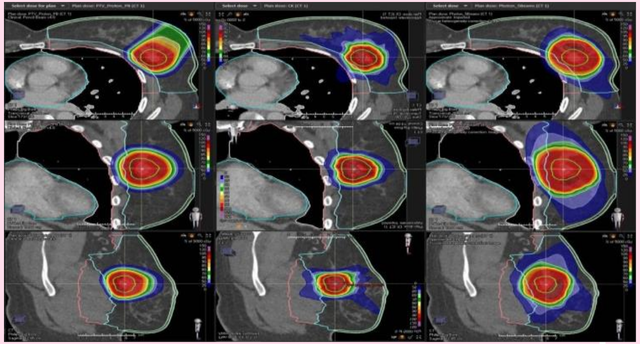

Stereotactic Radiotherapy in Early-Stage Breast Cancer in Neoadjuvant and Exclusive Settings: A Systematic Review

Antonio Piras [1], Antonella Sanfratello [1], Luca Boldrini [2,3], Andrea D'Aviero [4], Gianfranco Pernice [5], Giovanni Sortino [5], Maria Rosaria Valerio [6,7], Roberto Gennari [8], Ildebrando D'Angelo [9], Fabio Marazzi [2], Tommaso Angileri [10], Antonino Daidone [1]

Conclusions: Relative low toxicity rates, the reduced treatment volumes in the neoadjuvant setting, and the possibility to replace surgery when not feasible in exclusive setting resulted to be main advantages for SBRT in BC. Current evidence shows that both the neoadjuvant and the definitive settings seem to be promising clinical scenarios for SBRT, especially for EBC.

Deep Inspiration Breath Hold (DIBH)

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Planning:

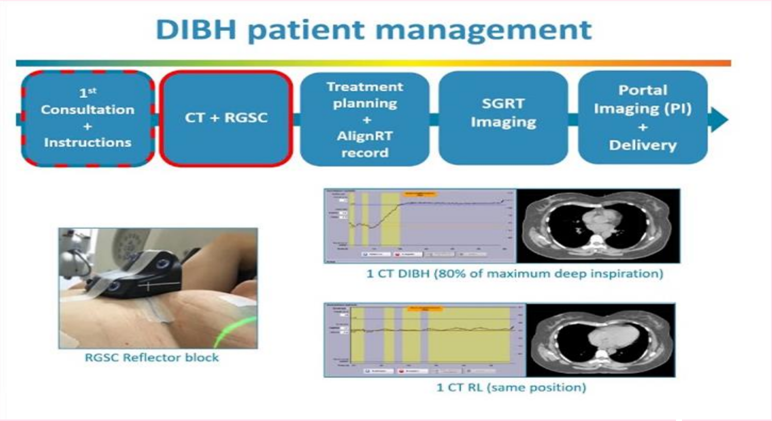
- Utilizes high-resolution imaging (CT, MRI) to map the tumor and surrounding tissues.
- Patients perform a deep breath hold to displace the heart and minimize radiation exposure.

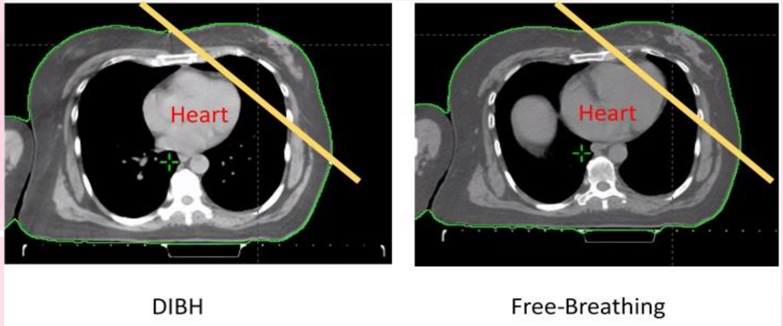
Delivery:

- Radiation is delivered during the breath-hold phase, ensuring precise targeting.
- Real-time monitoring of patient's breath-hold to maintain consistency.

Advantages:

- Significant reduction in radiation dose to the heart and lungs.
- Improved targeting accuracy and reduced risk of cardiac and pulmonary complications.
- Enhanced patient comfort with non-invasive technique.





Deep-inspirational breath-hold (DIBH) technique in left-sided breast cancer: various aspects of clinical utility

Szilvia Gaál, Zsuzsanna Kahán, Viktor Paczona, Renáta Kószó, Rita Drencsényi, Judit Szabó, Ramóna Rónai, Tímea Antal, Bence Deák & Zoltán Varga

DIBH is an excellent heart sparing technique in breast RT, but about one-third of the patients do not benefit from that otherwise laborious procedure or benefit less than from an alternative method.

Prone Breast Radiotherapy

Patient Positioning:

- Patients lie face down on a specially designed breast board.
- This position reduces radiation exposure to the heart and lungs.

Planning:

- Utilizes high-resolution CT or MRI scans to map the breast tissue and surrounding areas.
- Advanced algorithms optimize dose distribution.

Delivery:

- Delivers radiation precisely to the breast while sparing critical structures.
- Employs IMRT or 3DCRT techniques for enhanced dose conformity.

Advantages:

- Reduced cardiac and pulmonary dose.
- Improved dose homogeneity within the breast.
- Enhanced patient comfort and stability during treatment.

Radiation dose to the nodal regions during prone versus supine breast irradiation

Melinda Csenki [1], Dóra Újhidy [1], Adrienn Cserháti, Zsuzsanna Kahán [1], Zoltán Varga [1]

The radiation dose to the axillary and IM lymph nodes during breast radiotherapy is therapeutically insufficient in most cases, and is significantly lower in the prone position than in the supine position.

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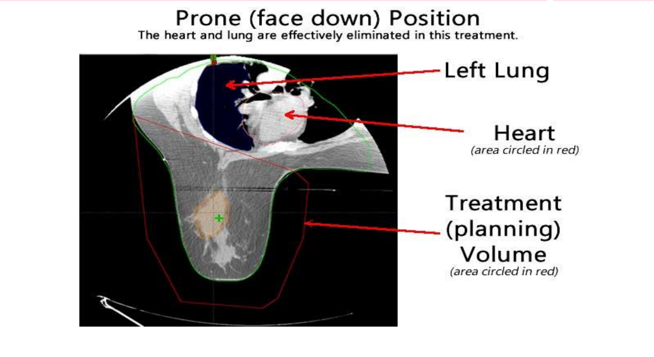


Proton Therapy

Planning:

- Utilizes advanced imaging (CT, MRI) for precise tumor delineation.
- Sophisticated algorithms optimize dose distribution to target the tumor while sparing healthy tissues.

Delivery:

- Protons are accelerated and precisely targeted to the tumor.
- No exit dose, minimizing radiation exposure to surrounding organs like the heart and lungs.

Advantages:

- High precision and accuracy in targeting tumors.
- Reduced risk of cardiac and pulmonary complications.
- Effective for left-sided breast cancer and cases requiring re-irradiation.

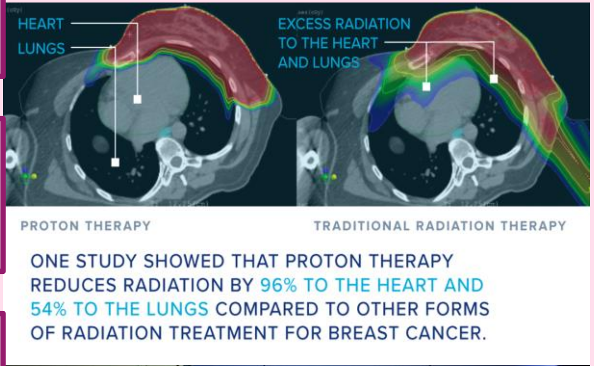
Applications:

- Early-stage and locally advanced breast cancer.
- Patients with tumors near critical structures.
- Suitable for patients with prior radiation exposure.

Proton Therapy in Breast Cancer: A Review of Potential Approaches for Patient Selection

Xiao-Yu Wu [1], Mei Chen [1], Lu Cao [1], Min Li [1], Jia-Yi Chen [1,✉]

PT is a highly promising technology in modern radiotherapy which shows potential to substantially decrease normal tissue irradiation and improve tumor control in high-risk BC patients. However, due to its high cost and limited accessibility, PT should better be offered to highly-selected patients to maximize its clinical benefits. Currently, the most practical way



Surface Guided Radiation Therapy (SGRT)

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Planning:

- Utilizes 3D surface imaging for precise patient positioning.
- Advanced algorithms track patient surface in real-time.

Delivery:

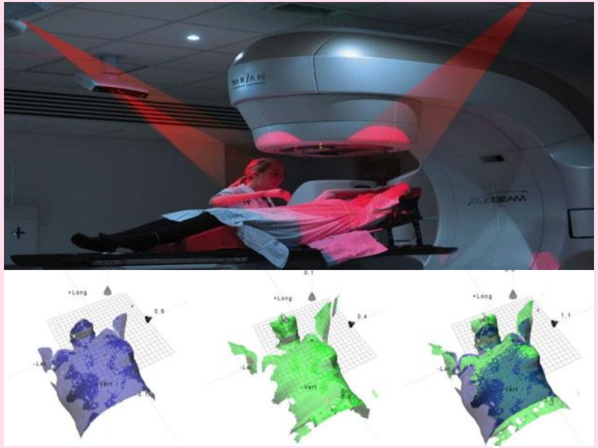
- Non-invasive technique with sub-millimeter accuracy.
- Real-time monitoring and adjustments during treatment.
- Integration with Deep Inspiration Breath Hold (DIBH) for enhanced heart and lung sparing.

Advantages:

- Improved setup accuracy and reproducibility.
- Reduced radiation exposure to healthy tissues.
- Enhanced patient comfort and compliance.

Applications:

- Effective for left-sided breast cancer to protect the heart.
- Suitable for patients requiring precise positioning and motion management.



Surface-guided radiation therapy for breast cancer: more precise positioning

A González-Sanchis [1], L Brualla-González [2], C Fuster-Diana [3], J C Gordo-Partearroyo [4], T Piñeiro-Vidal [4], T García-Hernandez [2], J L López-Torrecilla [4]

Conclusions: SGRT improves patient positioning accuracy compared to skin markers. Optimal breast SGRT can accurately verify the localisation of the tumour bed, ensuring matching with ≥ 3 surgical clips. SGRT can eliminate unwanted radiation from IGRT verification systems.

Brachytherapy in Breast Radiotherapy

Planning:

- Utilizes high-resolution imaging (CT, MRI) for precise tumor localization.
- Advanced algorithms optimize dose distribution to target the tumor while sparing healthy tissues.

Delivery:

- **Interstitial Brachytherapy:** Involves placing several flexible tubes (catheters) in the breast tissue through which a radiation source is placed.
- **Intracavitary Brachytherapy:** Uses a balloon-like device placed in the breast cavity post-lumpectomy to deliver radiation.

Advantages:

- High precision and accuracy in targeting tumors.
- Reduced radiation exposure to surrounding healthy tissues.
- Shorter treatment duration compared to external beam radiation therapy (EBRT).

Applications:

- Early-stage breast cancer post-lumpectomy.
- Reduces tumor size before surgery (neoadjuvant therapy).
- Palliative treatment for advanced or inoperable breast cancer.

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The Role of Brachytherapy in the Treatment of Breast Cancer

Daniela Kauer-Dorner [1,*], Daniel Berger [1]

Radiotherapy plays an essential part in breast-conserving treatment, and external beam irradiation is the most widely used modality. However, BT can deliver radiation doses to the target volume in a highly conformal way, thereby minimizing exposure of normal surrounding structures and OAR. The use of modern imaging technologies like CT, or even

Intraoperative Radiotherapy (IORT)

Technical Aspects

- **Electron IORT:** Uses electron beams for high-dose radiation.
- **Low-Energy X-rays:** Utilizes 50 kV x-rays for precise targeting.
- **Orthovoltage X-rays:** Employs 250-300 kV x-rays for deeper penetration.

Delivery:

- Radiation administered during surgery directly to the tumor bed.
- Real-time imaging verification to ensure precise delivery.
- Shielding of surrounding healthy tissues to minimize exposure.

Advantages:

- High precision and accuracy in targeting residual tumor cells.
- Reduced radiation exposure to surrounding healthy tissues.
- Shorter overall treatment duration compared to conventional radiotherapy.

Applications:

- Early-stage and locally advanced breast cancer.
- Cases requiring high-dose radiation to the tumor bed with minimal delay post-surgery.
- Suitable for patients with prior radiation exposure.

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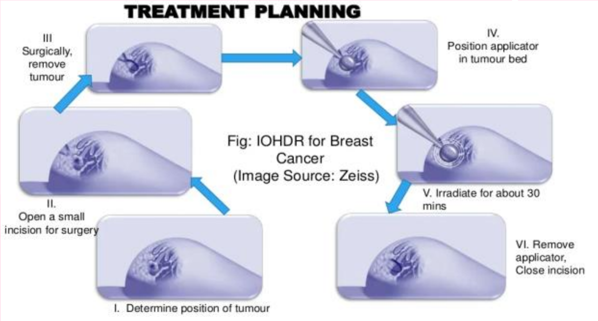


Fig: IOHDR for Breast Cancer (Image Source: Zeiss)

Intraoperative radiation therapy for breast cancer patients: current perspectives

Sunil W Dutta [1], Shayna L Showalter [2], Timothy N Showalter [1], Bruce Libby [1], Daniel M Trifiletti [1,✉]

IORT appeals to patients because of its significant improvement in convenience. Opportunities to increase dose, improve accuracy, and optimize treatment for tailored treatment planning using treatment technologies that exist within RT armamentarium may improve outcomes after IORT. Further refinement of patient selection for APBI in general and IORT in particular will ultimately define its role.

Helical Tomotherapy

Delivery:

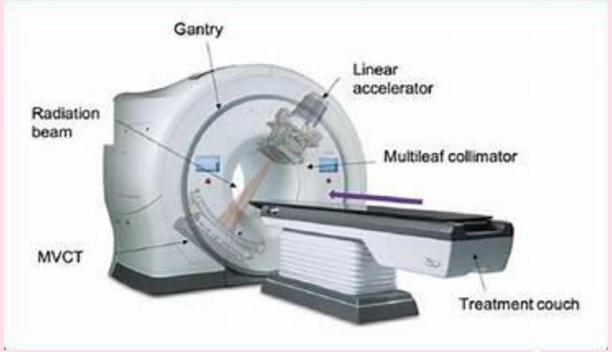
- Combines IMRT and IGRT capabilities into a single integrated platform.
- Delivers radiation via a fan beam using a ring gantry that rotates continuously around the patient.
- Real-time imaging (MVCT) for precise tumor targeting and adaptive radiotherapy.

Special Features:

- **Helical Delivery:** Continuous 360-degree rotation allows seamless and precise dose delivery.
- **Integrated Imaging:** Real-time MVCT ensures accurate positioning and adaptation.
- **Adaptive Radiotherapy:** Capable of adjusting plans based on daily changes in patient anatomy.
- **Highly Conformal Dose Distribution:** Optimizes dose delivery to complex tumor shapes while sparing critical structures.

Advantages:

- High precision and accuracy in targeting tumors.
- Reduced radiation exposure to surrounding healthy tissues.
- Effective for complex tumor shapes and locations.



Left-Sided Whole Breast Irradiation with Hybrid-IMRT and Helical Tomotherapy Dosimetric Comparison

An-Cheng Shiau [1,2,3], Chen-Hsi Hsieh [1], Hui-Ju Tien [1], Hsin-Pei Yeh [1], Chi-Ta Lin [1], Pei-Wei Shueng [1,4,*], Le-Jung Wu

In conclusion, hIMRT and lTomo provide similar dosimetric target coverage. The concave dose distribution shape conforms to the breast tissue in the lTomo plan, resulting in significant dose reductions to the heart and lung. By properly

Adaptive Radiotherapy (ART)

Planning:

- Utilizes advanced imaging (CT, MRI, PET) to monitor anatomical changes.
- Adjusts treatment plans based on observed changes during the course of radiotherapy.

Delivery:

- Online ART: Adjustments made during treatment sessions.
- Offline ART: Adjustments made between treatment sessions.
- Employs IGRT for real-time verification and adaptation.

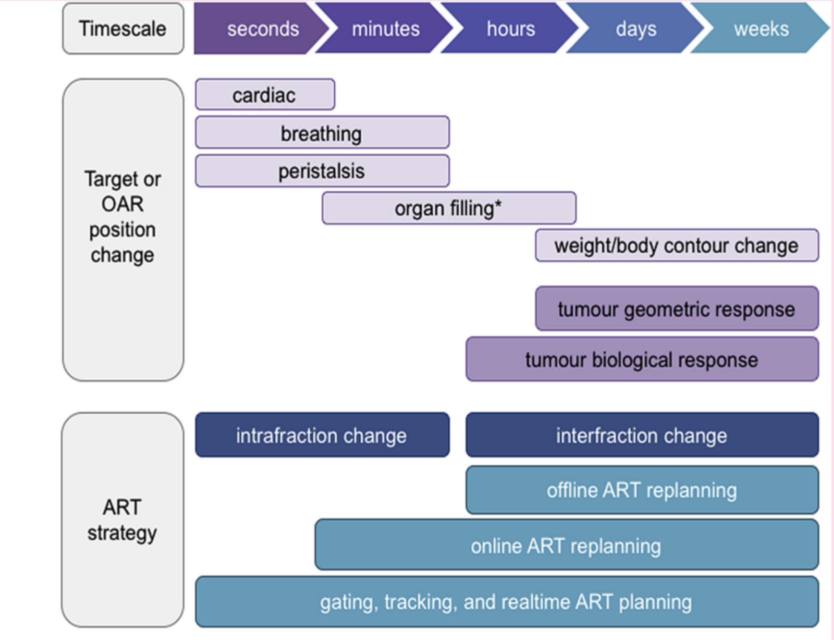
Advantages:

- Enhanced precision and accuracy in targeting tumors.
- Personalized treatment plans that adapt to patient-specific changes.
- Reduced toxicity to organs at risk (OARs) by maintaining optimal dose distribution.

Adaptive radiotherapy for breast cancer

C. De-Colle [a], A. Kirby [b], N. Russell [c], S.F. Shaitelman [d], A. Currey [e], E. Donovan [f], E. Hahn [g], K. Han [g], C.N. Anandadas [h], F. Mahmood [i], E.L. Lorenzen [i], D. van den Bongard [j], M.L. Groot Koerkamp [k], A.C. Houweling [k], M. Nachbar [l], D. Thorwarth [l m], D. Zips [a m]

ART could be of benefit to breast cancer patients in several clinical scenarios, particularly PBI, in which ART could minimize margins and thereby reduce the volume of normal tissue irradiated. Autonomous AI-driven technologies are expected to further enable ART in the near future. Initial clinical experiences are promising and numerous studies are currently recruiting such that further data on likely clinical benefit are expected in the coming years.



* Organs subject to filling and deformation including bladder, rectum, cervix, and stomach etc

Image-Guided Radiotherapy (IGRT)

Imaging:

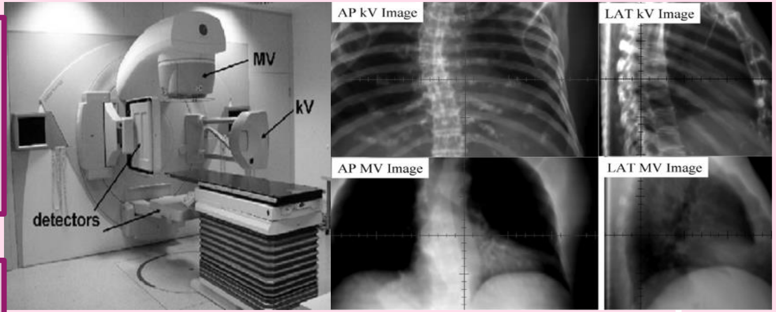
- Utilizes advanced imaging technologies (CT, MRI, PET) for precise tumor localization.
- Real-time imaging before and during treatment to ensure accurate targeting.

Delivery:

- Integration with linear accelerators equipped with imaging systems.
- Frequent imaging sessions to monitor and adapt to tumor and patient positioning.
- Use of fiducial markers or surface markers for enhanced precision.

Advantages:

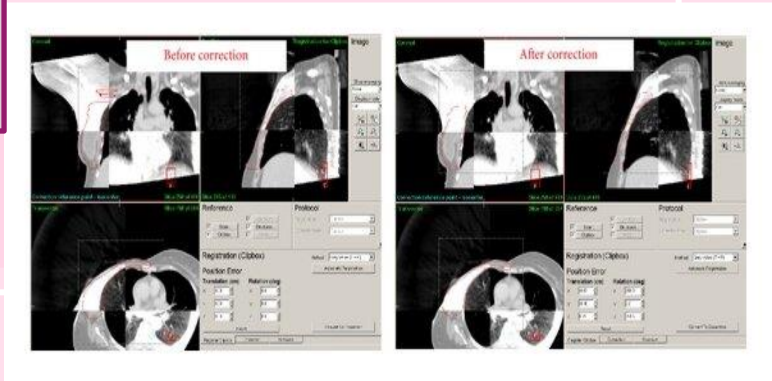
- High precision and accuracy in targeting tumors.
- Reduced radiation exposure to surrounding healthy tissues.
- Ability to use higher radiation doses for improved treatment efficacy.



Effectiveness of Image-Guided Radiotherapy in Adjuvant Radiotherapy on Survival for Localized Breast Cancer: A Population-Based Analysis

Ji-An Liang [1,2,*], Po-Chang Lee [3,*], Chun-Ping Ku [3,*], William Tzu-Liang Chen [2,3,*], Chih-Yuan Chung [4], Yu-Cheng Kuo [1,2], Szu-Hsien Chou [5], Chia-Chin Li [6], Chun-Ru Chien [1,2,6,✉]

We found that OS of LBC patients treated with adjuvant CFRT was not statistically different between those treated with IGRT versus without IGRT. This was the first study in this regard to our knowledge but randomized controlled trials were needed to confirm our finding.



Challenges in Treatment Planning

5TH BBCC
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Field-in-Field (FIF) 3DCRT Plans and Segments:

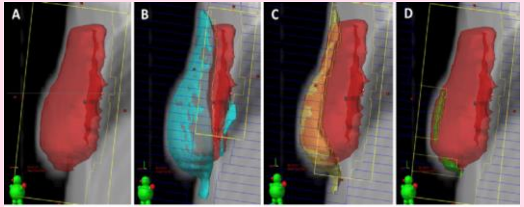
- Complexity: Requires meticulous planning to achieve optimal dose distribution.
- Homogeneity: Ensuring dose homogeneity can be challenging.
- Segments: Managing multiple segments increases planning and delivery complexity.

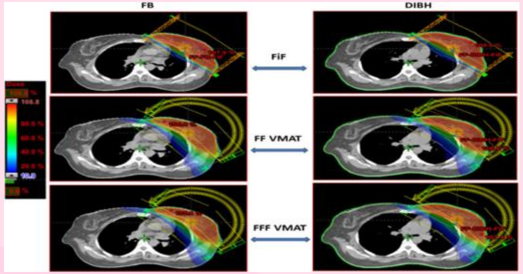
Centers Without DIBH for IMRT and VMAT Planning:

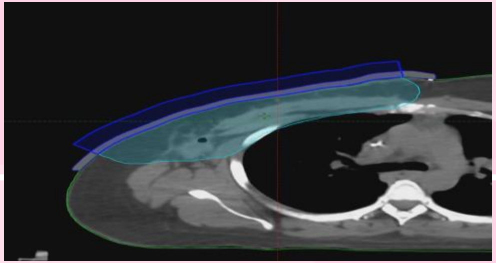
- Cardiac Sparing: Difficulty in minimizing radiation exposure to the heart, especially for left-sided breast cancer.
- Motion Management: Challenges in managing respiratory motion without DIBH.
- Accuracy: Reduced precision in targeting tumors due to lack of breath-hold techniques.

Importance of Auto Flash Margin:

- Superficial Dose: Ensures adequate dose coverage for superficial tissues.
- Motion Compensation: Compensates for patient movement and setup variations.
- Plan Robustness: Enhances the robustness of treatment plans, ensuring consistent dose delivery.







Treatment Planning: Technical Aspects

The prescription should match the physician's planning directive, and the plan normalization method should match institutional protocols.

Quality Checks

- **Prescription and normalization**

Specific Guidelines

- Verify that the plan prescription and normalization methods are appropriate

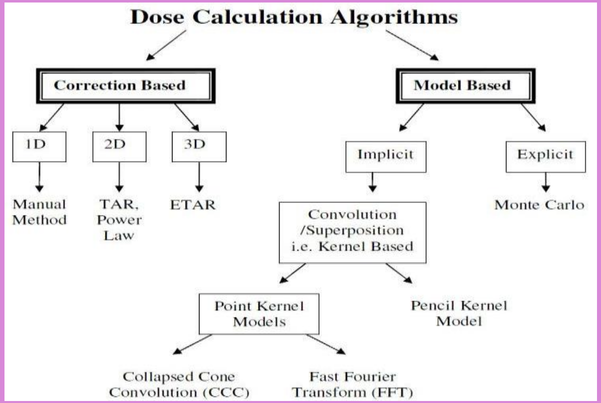
- What to consider for breast patients
  - Value normalization recommended.
  - Do not use volume normalization (e.g. 95% of target to be covered by 95% of prescription dose)
  - Why?
    - Breast (or chest wall) PTV eval does not always get included in the beams.
    - Build up region
    - Lung/heart interface
  - Partial breast (tumor bed) plan can be normalized for volume coverage.

Treatment Planning: Technical Aspects

The dose calculation algorithm and dose grid size should be appropriate for the planning scenario.

Quality Checks

- **Algorithm and dose grid**



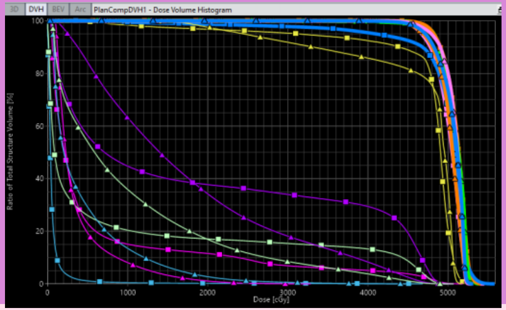
Specific Guidelines

- Verify that the dose calculation algorithm and grid size are appropriate and follow institutional guidelines
- Follow institutional standard
- Pencil beam, AAA, AcurosXB or Monte Carlo
- 0.2 to 0.3 slice thickness for CT
- 0.2 to 0.5 cm dose grid

Treatment Planning: Technical Aspects

Develop institutional standard for dose metrics

Quality Checks

- …
- **Target coverage and conformity**
- **Hot spots**
- **Dose gradients**
- **OAR sparing**
- **DVH metrics**
- 

Specific Guidelines

- Review target dose conformity and coverage, including the use of quantitative metrics when possible
- Review the magnitude and location of the hot spot and high dose streaking
- Review high, medium, and low dose levels with expected gradients in mind
- Confirm that organs at risk are spared as much as possible in order of clinical priority
- Review DVH metrics and relevant clinical goals in the context of national and institutional normal tissue dosimetric goals

Treatment Planning: Technical Aspects

Verify the plan is safe by reviewing the accumulated dose from all courses of radiation therapy.

Quality Checks

- **Composite with prior radiotherapy**

Specific Guidelines

- Confirm that prior radiation is accounted for in the treatment plan
- Verify that the composite plan considers biological dose when combining different fractionation schemes

- What to consider for breast patient?
- Beam overlap with previous treatment
- Register previous CT with current CT: based on sternum, focus on new treating side (or split difference) for chest wall area.

Clinical Example: **Dose distribution**

Develop institutional standard for dose metrics: Excel worksheets

Consolidated constraints

Breast Fast(Forward)			
Structure	V or D	Constraint	Note
PTV Eval	V95%	> 95-90%	
PTV Eval	CI	105%	
PTV Eval	CI	107%	
Body	Max	<107-110%	
Ipsi Lung	V30%	<15-17%	
Heart	V25%	<5%	
Heart	V5%	<25%	
Note: 520 cGy x 5fx or 570 cGy x 5fx			

Breast/CW Tang only			
Structure	V or D	Constraint	Note
Brst_PTVeval	V95%	> 95 - 90%	
TB_PTVeval	V95%	> 95%	
Body	Max	<110-120%	
Body	V105%	< 200cc	
Body	V107%	<10cc	
Heart	Dmean	< 100-300cl	Lt: 2-3Gy// Rt: 1Gy
Ipsi Lung	V20Gy	< 15-20%	
Ipsi Lung	V5Gy	< 50%	
note: 200cGy x 25fx= 5000cGy, 266cGy x 16fx= 4256cGy, 267cGy			

PS Breast/CW+Nodes 50Gy			
Structure	V or D	Constraint	Note
CW_PTVeval	V95%	>95-90%	
SCV_PTV	V95%	>95-90%	
IMN_PTV	V90%	>90-80%	Aim for V95%>90%
Axilla_PTV	V95%	>95-90%	
Body	Max	<110-120%	
Body	V107%	<10cc	
Body	V115%	<0.03-10cc	
Heart	Mean	<200-500cl	Lt: 4Gy-5Gy// Rt: 2Gy
Heart	V2500cGy	<2-10%	Lt: <10%// Rt: < 2%
Ipsi Lung	V2000cGy	<35-40%	
Ipsi Lung	V500cGy	<75%	
Contra Lung	V500cGy	<10-15%	
Lungs	V2000cGy	<20%	
Lungs	V500cGy	<50%	
Contra Breast	D10%	<300-1000cGy	
Contra Breast	Mean	<600cGy	
BrachialPlexus	Max	<5300cGy	
Left Ventricle	Mean	<300cGy	
LAD	Max	<1000-3500	mean < 1000cGy
Esophagus	Max	<3400cGy	
Larynx	Mean	<500cGy	
Liver	Mean	<800cGy	
Stomach	Mean	<500cGy	
Thyroid	Mean	<2000cGy	
Cord	Max	<2000cGy	
Notes: 200cGy x 25fx= 5000cGy			

- Targets V95% > 90-95%
- IMN V90% > 90%

- Dmax < 110%

- Heart Dmean < 2Gy – 5Gy
- Ipsi-Lung V20 < 35-40%
- Ipsi-Lung V5 <70-75%
- Contra-Lung V5 < 10-15%

Clinical Example: **Dose distribution**

Develop institutional standard for dose metrics: Word documents

Treatment Sites	

Prescription	Dose= XX cGy x # fx = YY Gy	Note
Primary	**200 cGy x 25 = 5000 cGy**	
Boost	**200 cGy x 5 = 1000 cGy**	
Targets	**V XX% > YY Gy**	**Note**
Breast or CW PTV eval	V 95% > 4750 cGy	Acceptable V90% > 4500 cGy
SCV PTV	V 95% > 4750 cGy	Acceptable V90% > 4500 cGy
IMN PTV	V 90% > 4500 cGy	Acceptable V90% > 4000 cGy
Axilla PTV	V 95% > 4750 cGy	Acceptable V90% > 4500 cGy

OAR Constraints	
Ipsilateral lung	V20Gy < 35%, acceptable V20 Gy <40%
	V10Gy < 65% ideal, acceptable V5Gy < 75%
Contralateral lung	V5Gy < 10%, acceptable V5 Gy < 15%
Total lung	V20Gy < 20%
	V5Gy < 50%
Heart	ALARA; Dmean < 4-5 Gy for left-sided cancer, mean < 2Gy for right
	V25Gy <10% (left) V25Gy<2% (right)
LAD	ALARA, ideal max <10-25 Gy; acceptable max <35 Gy Mean <10 Gy; V15<10%; V30 <2%; V40 <1%
Left Ventricle	Mean <3 Gy; V5<17%; V23 <5%
Contralateral breast	Ideal V 3Gy < 10%, acceptable V10 Gy <10%; mean <6 Gy
Plexus	Max <53 Gy
Esophagus	Max <34 Gy
Larynx	Mean < 5 Gy
Liver	Mean < 8 Gy
Stomach	Mean < 5 Gy
Thyroid	Mean <20 Gy
Cord	Max <20 Gy
Notes	0.5cm Bolus: 15 fx with and 10fx without. Hot spots: - Max <110% ideal, <115-120% acceptable (SCV max ideal <115%) - Goal: V107<10cc; V115 <0.03 cc - Acceptable V115<10cc, V120 <0.03cc

Treatment Sites	

Prescription	Dose= XX cGy x # fx = YY Gy	Note
Primary	**266 cGy x 16 = 4256 cGy**	
Boost	**250 cGy x 4 = 1000 cGy**	
Targets	**V XX% > YY Gy**	**Note**
Breast or CW PTV eval	V 95% > 4043 cGy	Acceptable V90% > 3830 cGy
SCV PTV	V 95% > 4043 cGy	Acceptable V90% > 3830 cGy
IMN PTV	V 90% > 3830 cGy	Acceptable V90% > 3404 cGy
Axilla PTV	V 95% > 4043 cGy	Acceptable V90% > 3830 cGy

OAR Constraints	
Ipsilateral lung	V18Gy < 35%, acceptable V18 Gy <40%
	V10Gy < 65% ideal, acceptable V4.8Gy < 75%
Contralateral lung	V4.8Gy < 10%, acceptable V4.8 Gy < 15%
Total lung	18Gy < 20%
	V4.8Gy < 50%
Heart	ALARA; Dmean < 3-5Gy for left-sided cancer, mean <2 Gy for right
	V22.5 Gy <10%
LAD	ALARA, ideal max <10-24 Gy; acceptable max <34 Gy
Left Ventricle	
Contralateral breast	Ideal V 3Gy < 10%, acceptable V10 Gy <10%; mean <6 Gy
Plexus	Max <50 Gy
Esophagus	Max <34 Gy
Larynx	Mean < 5 Gy
Liver	Mean < 8 Gy
Stomach	Mean < 5 Gy
Thyroid	Mean < 20 Gy
Cord	Max < 20 Gy
Notes	0.5cm Bolus: 8 fx with and 8 fx without Hot spots: - Max <110% ideal, <115-120% acceptable (SCV max ideal <115%) - Goal: V107<10cc; V115 <0.03 cc Acceptable V115<10cc, V120 <0.03cc

Clinical Example: **Dose distribution**

Develop institutional standard for dose metrics

Clinical Goal Template Manager

Approved | breast

ID	Description
Breast/CW Tang only	200cGy x 25fx= 5000cGy, 266cGy x 16fx= 4256cGy, 267cGy x 15fx= ...
Breast APBI 600x5	CTV=1cm around clips (3mm from skin surface)PTV=1cm from C...
Breast-FastForward	Fast Forward Breast Planning Protocol (520cGy*5 or 570cGy*5)
PS Breast/CW+Nodes 50Gy	Notes: 200cGy x 25fx= 5000cGy
PS Breast/CW+Nodes 40Gy	Notes: 267 cGy x 15 = 4005cGy; 266cGy x 16= 4256cGy or 265cGy x...

Clinical Goals

Plan			1P_Brst_Rt
Total Dose			4005.0 cGy
Clinical Goal Summary			0 / 1 / 7
Brst_PTVeval	R	V 95.0 % > 95.0 %	92.89 %
TB_PTVeval	R	V 95.0 % > 95.0 %	99.98 %
BODY	R	Dmax < 110.0 %	107.00 %
	R	V 105.0 % < 200.0 cm^3	89.07 cm^3
	R	V 107.0 % < 10.0 cm^3	0.00 cm^3
Heart	R	Dmean < 100 cGy	29.33 cGy
Lung_R	R	V 2000 cGy < 15.0 %	8.67 %
	R	V 500 cGy < 50.0 %	23.40 %

Clinical Goals

Plan			test3
Total Dose			5000.0 cGy
Clinical Goal Summary			10 / 3 / 11
Axilla_PTV	R	V 95.0 % > 95.0 %	99.42 %
IMN_PTV	R	V 90.0 % > 90.0 %	99.08 %
SCV_PTV	R	V 95.0 % > 95.0 %	96.43 %
BODY	R	Dmax < 110.0 %	112.68 %
	R	V 107.0 % < 10.0 cm^3	353.20 cm^3
	R	V 115.0 % < 0.1 cm^3	0.00 cm^3
BrachialPlexus_L	R	Dmax < 5300 cGy	5180.70 cGy
Breast_R	R	V 95.0 % > 95.0 %	0.00 %
	R	D 10.0 % < 300 cGy	1396.71 cGy
	R	Dmean < 600 cGy	721.30 cGy
Cord	R	Dmax < 2000 cGy	2052.34 cGy
Esophagus	R	Dmax < 3400 cGy	4498.16 cGy
Heart	R	Dmean < 200 cGy	348.38 cGy
	R	V 2500 cGy < 2.0 %	0.18 %
LAD	R	Dmean < 300 cGy	706.57 cGy
	R	Dmax < 1000 cGy	1606.31 cGy
	R	Dmean < 1000 cGy	706.57 cGy
Larynx	R	Dmean < 500 cGy	833.55 cGy
Lung_L	R	V 500 cGy < 10.0 %	65.14 %
Lung_R	R	V 2000 cGy < 35.0 %	0.95 %
	R	V 500 cGy < 75.0 %	42.62 %
Lungs	R	V 2000 cGy < 20.0 %	13.27 %
	R	V 500 cGy < 50.0 %	53.33 %
Thyroid	R	Dmean < 2000 cGy	1890.26 cGy

Eclipse clinical goal: Build templates with standard dose metrics for various prescription scheme.

Clinical Example: **Dose distribution**

Develop institutional standard for dose metrics

Template Selection

Folder: Breast/CW

Tag:

Filter

Template	Add To Patient
DUMC Breast SBRT 21Gy	+
Breast Fast(Fwd)	+
Breast PRAD	+
Breast/CW Tang only	+
Breast APBI 600x5	+
PS Breast/CW+Nodes 4005	+
PS Breast/CW+Nodes 4256	+
PS Breast/CW+Nodes 5000	+

Prescription	Total Dose (cGy)
1P_Brst_Rt 100%	4005

Breast/CW Tang only (Breast/CW) Constraints

Priority	Structure Template	Structure Plan	Type	Constraint	Goal	1P_Brst_Rt	Pass/Fail
1	Brst_PTVeval	Brst_PTVeval	Target	V95% ≥	95-90%	92.886%	△
2	TB_PTVeval	TB_PTVeval	Target	V95% ≥ (Aim for V100%>95%)	95%	99.975%	✓
3	Body	BODY	OAR	Max ≤	110-120%	107%	✓
4	Body	BODY	OAR	V105% ≤	200cc	89.092cc	✓
5	Body	BODY	OAR	V107% ≤	10cc	0.003cc	✓
6	Heart	Heart	OAR	Mean ≤ (Lt: 2Gy-3Gy// Rt: 1Gy)	100-300cGy	29.3cGy	✓
7	Ipsi-Lung	Lung_R	OAR	V1600cGy ≤ (V2000 for 50Gy in 25fx)	15-20%	9.698%	✓
8	Ipsi-Lung	Lung_R	OAR	V400cGy ≤ (V500cGy for 50Gy in 25fx)	50%	28.668%	✓

Prescription	Total Dose (cGy)
200	5000

PS Breast/CW+Nodes 5000 (Breast/CW) Constraints

Priority	Structure Template	Structure Plan	Type	Prescription	Constraint	Goal	test3	Pass/Fail
1	CW_PTVeval	CW_PTVeval	Target	200: 5000cGy	V95% ≥	95-90%	99.055%	✓
2	SCV_PTV	SCV_PTV	Target	200: 5000cGy	V95% ≥	95-90%	96.434%	✓
3	IMN_PTV	IMN_PTV	Target	200: 5000cGy	V90% ≥ (Aim for V95%>90%)	90-80%	99.083%	✓
4	Axilla_PTV	Axilla_PTV	Target	200: 5000cGy	V95% ≥	95-90%	99.417%	✓
5	Body	BODY	OAR	200: 5000cGy	Max ≤	110-120%	112.684%	△
6	Body	BODY	OAR	200: 5000cGy	V107% ≤	10cc	353.38cc	✗
7	Body	BODY	OAR	200: 5000cGy	V115% ≤	0.03-10cc	0cc	✓
8	Heart	Heart	OAR		Mean ≤ (Lt: 4Gy-5Gy// Rt: 2Gy)	200-500cGy	348.4cGy	△
9	Heart	Heart	OAR		V2500cGy ≤ (Lt: <10%// Rt: < 2%)	2-10%	0.184%	✓
10	Ipsi-Lung	Lung_L	OAR		V2000cGy ≤	35-40%	26.867%	✓
11	Ipsi-Lung	Lung_L	OAR		V500cGy ≤	75%	65.135%	✓
12	Contra-Lung	Lung_R	OAR		V500cGy ≤	10-15%	42.617%	✗
13	Lungs	Lungs	OAR		V2000cGy ≤	20%	13.267%	✓
14	Lungs	Lungs	OAR		V500cGy ≤	50%	53.332%	✗
15	Contra-Breast	Breast_R	OAR		D10% ≤	300-1000cGy	1396.7cGy	✗
16	Contra-Breast	Breast_R	OAR		Mean ≤	600cGy	721.3cGy	✗
17	BrachialPlexus	BrachialPlexus_L	OAR		Max ≤	5300cGy	5180.7cGy	✓
18	Left Ventricle	LAD	OAR		Mean ≤ (V500cGy<17% // V2300cGy<5%)	300cGy	706.6cGy	✗
19	LAD	LAD	OAR		Max ≤ (Mean < 1000 cGy)	1000-3500cGy	1606.3cGy	△
20	Esophagus	Esophagus	OAR		Max ≤	3400cGy	4498.2cGy	✗
21	Larynx	Larynx	OAR		Mean ≤	500cGy	833.6cGy	✗
22	Thyroid	Thyroid	OAR		Mean ≤	2000cGy	1890.3cGy	✓
23	Cord	Cord	OAR		Max ≤	2000cGy	2052.3cGy	✗

Build templates with standard dose metrics for various prescription scheme.

Conclusion

- **Precision and Safety:** Modern techniques enhance precision and reduce side effects.
- **Innovative Evolution:** Continuous advancements drive improved patient outcomes.
- **Technological Integration:** AI and machine learning enable personalized treatments.
- **Patient-Centric Approaches:** Focus on patient comfort and overall well-being.
- **Role of Medical Physicists:** Medical physicists play a crucial role in treatment planning, quality assurance, and ensuring the accuracy and safety of radiotherapy.
- **Collaborative Efforts:** Multidisciplinary teams, including medical physicists, ensure successful treatment planning and delivery.


Thank You