

Allina Health  VIRGINIA PIPER CANCER INSTITUTE.

THE ELECTROMAGNETIC SPECTRUM

The diagram illustrates the electromagnetic spectrum with various frequency ranges and associated phenomena:

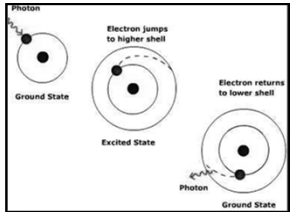
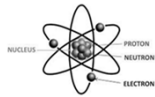
- Static Electric & Magnetic Fields:** 0Hz
- Alternating Electric & Magnetic Fields:** 60Hz
- TV & Radio Broadcast:** 3KHz
- Mobile Phones:** Radio Frequency
- Microwave & Satellite:** 300GHz
- Visible Sunlight:** 300THz
- Ultraviolet:** 3000THz
- X-rays:** 30EHz
- Radioactive Sources:** 30EHz

The spectrum is divided into two main regions:

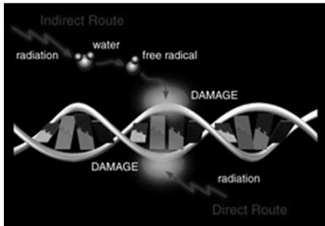
- NON-IONIZING:** Includes Static Electric & Magnetic Fields, Alternating Electric & Magnetic Fields, TV & Radio Broadcast, Mobile Phones, and Microwave & Satellite.
- IONIZING:** Includes Visible Sunlight, Ultraviolet, X-rays, and Radioactive Sources.

What Is Radiation Therapy?

- Particles accelerated to a therapeutic energy
- “Light” particles
 - Photons
 - Electrons
- “Heavy” particles
 - Protons
 - Carbon



How Does Radiation Kill Tumor Cells?



- Normal cells work to repair DNA damage
- Tumor cells have poor DNA repair and die

Radiation in Medicine

For decades, improvement in radiation therapy came mostly in building more powerful radiation machines that spared the skin.



Modern Radiation Therapy

- Uses microwave technology to accelerate electrons in a part of the linac called the waveguide
- Accelerated electrons collide with a heavy metal target
- Photons produced from these collisions

The diagram illustrates the components of a linear accelerator. A wavy line labeled 'Electrons' shows the path of electrons being accelerated through a waveguide. At the end of the waveguide, the electrons collide with a target, producing 'X-rays' which are directed towards the patient area.

Traditional Whole Breast Radiation

Technique: Medial/Lateral tangential fields

Planning: Right Breast

This collage shows three aspects of traditional whole breast radiation: a close-up of the linac head, a 3D model of a breast with radiation fields marked, and a patient lying on a treatment table with their arm raised.

Standard Technique

- Medial and lateral tangential fields to encompass **entire breast**
- 3D CT-based treatment plan, customized to fit individual patient anatomy
- Treat whole breast while sparing adjacent organs like heart and lungs

The image is a 3D CT scan of a breast and chest area. It shows the breast and underlying structures. Labels indicate the 'Medial Tangential Field', 'Lateral Tangential Field', 'Heart', 'Lungs', and 'Spine'. The radiation fields are shown as shaded areas covering the breast while sparing the heart and lungs.

Radiation Set-up and Schedule



- Schedule
 - 3 to 6.5 weeks
 - Start 3-6 weeks after surgery or chemo
 - Monday through Friday
 - In radiation department for about 30 min/day
 - Beams on for 2-4 minutes
- Dose
 - 180 - 266 cGy/day x16 -28 fractions to whole breast
 - 200 - 250 cGy/day x4-5 fractions to lumpectomy cavity
 - Total of 5256 cGy - 6040 cGy in 20 - 33 fractions

Side Effects

- Radiation is focal therapy
 - Fatigue
 - Skin reaction: redness, peeling, itching
 - Fibrosis, soft tissue thickening
 - Lymphedema
 - Pneumonitis
 - Coronary artery disease
 - Small risk of secondary cancer

Risk of Radiation-Induced Cardiac Disease

- Cardiac volume exposed to RT (DVH)
- Use of potentially cardiotoxic systemic therapy
- Presence of independent risk factor (hypertension, DM, lipid disorders, smoking, age, CAD etc...)

A. Recht Editorial 2006

Late Cardiac Mortality and Morbidity in Early-Stage Breast Cancer Patients After BCT.

Harris EE, Correa C et al. JCO, September 2006.

- 961 patients with early stage breast cancer
 - In 2nd decade after radiation:
 - ↑ rate of cardiac deaths in left-sided patients
 - 6.4% for left-sided vs. 3.6% for right-sided patients
 - Statistically higher rates of chest pain, CAD and myocardial infarction reported in left-sided patients

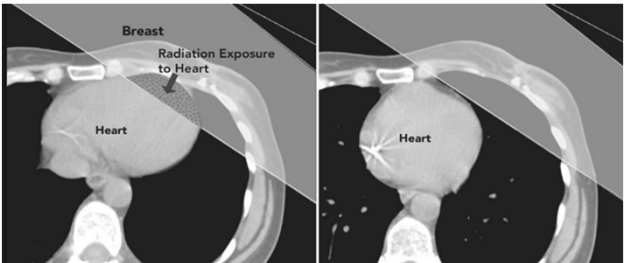
Deep Inspiration Breath Hold - Technique

Deep Inspiration Breath Hold –
Patient is asked to take a very deep breath – usually for 15-25 seconds – so the breast area is as far from the heart as it can be.

Then, during treatment, the patient takes and holds a deep breath in the same way as before, and when the breast area is in the same position as during planning, radiation beam turns on.

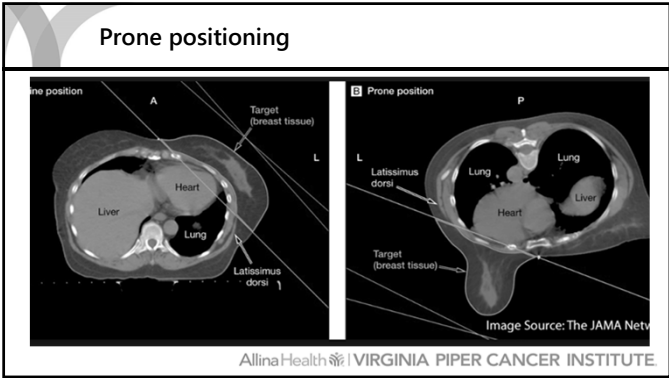


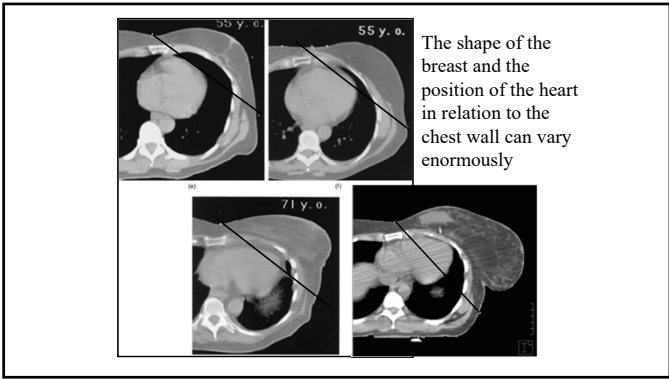
Respiratory Gating - Deep Inspiration Breath Hold



Standard Radiation Therapy

Deep Inspiration Breath Hold





Cardiac dose reduction for tangentially irradiated breast cancer without compromising target coverage

Vikstrom et al, Acta Oncologica 2011

- 17 patients with early left-sided breast cancer
- Compared to free breathing, the deep inspiration breath hold gated patients obtained lower cardiac and pulmonary doses
- With the gated technique, the heart was completely out of the beam portals in 10 patients, while this could not be achieved in any of the 17 patients with free breathing

Stranzl et al, Strahlenther Onkol

- 22 left-sided breast patients
- Significant heart dose reduction using deep inspiration breath hold technique
- Mean dose to entire heart was 2.3 Gy for free breathing vs. 1.3 Gy for gated technique
- For free breathing, 1.4% of the heart received a dose of ≥ 20 Gy, reduced to 0.3% for respiratory gated technique

Korreman et al, Radiother Oncol 2005

- 17 left-sided breast cancer patients
- In left-sided breast cancer patients, the median heart volume receiving $> 50\%$ of the prescribed dose was reduced from 19.2% for free breathing to 2.8% for respiratory gated technique
- Median LAD coronary artery volume was decreased from 88.9% for free breathing to 22.4% for respiratory gated technique

Is radiation really needed after lumpectomy?



Reduction in Local Recurrence

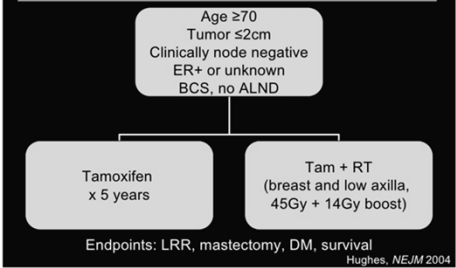
	Lumpectomy	Lumpectomy + RT	Reduction
NSABP 06	36%	12%	67%
Uppsala	24%	9%	63%
Ontario	35%	11%	69%
Milan	24%	6%	75%
Swedish	14%	4%	71%

All trials show a reduction (~ 70%) in local recurrence with the addition of RT

Can We Omit Radiation in Elderly Patients?



Omission of RT for Elderly Patients: CALGB C9343



Omission of RT for Elderly Patients
CALGB C9343

	5 yr LRR	8 yr LRR	10 yr LRR
Tam + RT	1%	1%	2%
Tam	4%	7%	9%

*No difference in overall survival

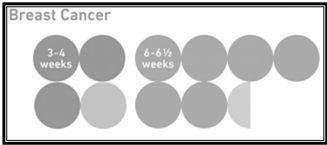
- Bottom Line:**
- Consider omitting RT for:
 - Age ≥ 70 with T1N0 tumors, ER+
 - Fit for and willing to take endocrine therapy for 5 years


Can Whole Breast Radiation Be Given
Faster?



Hypofractionation

- Larger daily fractions given over a shorter period of time
- Possibly increased tumor control (particularly for more radioresistent tumors like melanoma)
- Long-term side effects likely related to fraction size





Ontario Clinical Oncology Group Trial of Accelerated Hypofractionated Whole Breast Irradiation

1,234 patients
T1-2, N0
With clear margins
>50 yo

R


50 Gy/25 fxs – 5 weeks

42.56 Gy/16 fxs – 3 weeks

Median FU 10 years

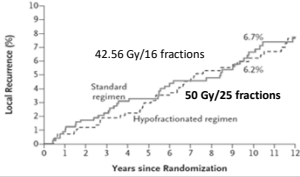
- No boost given
- 11% received chemo
- Breast size ≤ 25cm (large breasted women excluded)
- 2D planning (older technique)

Whelan, JNCI 2002



Results

Cosmesis good/excellent
50 Gy = 71%
42.56 Gy = 70%




Conclusion: The shorter radiation fractionation schedule of 42.56 Gy/16 fractions was as good as a more traditional schedule of 50Gy/25 fractions in terms of local breast cancer recurrence (6.2 vs. 6.7%) and cosmesis at 10 years

Note: Cosmesis rated good/excellent 70% of patients in both arms

Whelan, NEJM 2010

ASTRO Guidelines 2018



Radiation therapy for the whole breast: Executive summary of an American Society for Radiation Oncology (ASTRO) evidence-based guideline

Whelan, JNCI 2002

Factor	2011 Guideline	2018 Guideline
Age	≥50 years	Any
Stage	T1-2 N0	Any stage provided intent is to treat the whole breast without an additional field to cover the regional lymph nodes
Chemotherapy	None	Any chemotherapy
Dose homogeneity	±7% in the central axis	Volume of breast tissue receiving >105% of the prescription dose should be minimized regardless of dose-fractionation

Acute and Short-Term Toxic Effects of Conventionally Fractionated vs. Hypofractionated Whole Breast Irradiation

JAMA ONCOLOGY, August 2015

- Similar results for the following:
 - Somewhat or more lack of energy (HF-WBI, 38% vs. CF-WBI, 39%)
 - Somewhat or more trouble meeting family needs (HF-WBI, 10% vs. CF-WBI, 14%)
- Differing results for the following *during radiation*:
 - Maximum physician-reported acute dermatitis (HF-WBI, 36% vs. CF-WBI, 69%)
 - Pruritis (HF-WBI, 54% vs. CF-WBI, 81%)
 - Breast pain (HF-WBI, 55% vs. CF-WBI, 74%)
 - Hyperpigmentation (HF-WBI, 9% vs. CF-WBI, 20%)
 - Fatigue (HF-WBI, 9% vs. CF-WBI, 17%)

-HF-WBI = Hypofractionated whole breast irradiation
-CF-WBI = Conventionally fractionated whole breast irradiation

Acute and Short-Term Toxic Effects of Conventionally Fractionated vs. Hypofractionated Whole Breast Irradiation

JAMA ONCOLOGY, August 2015

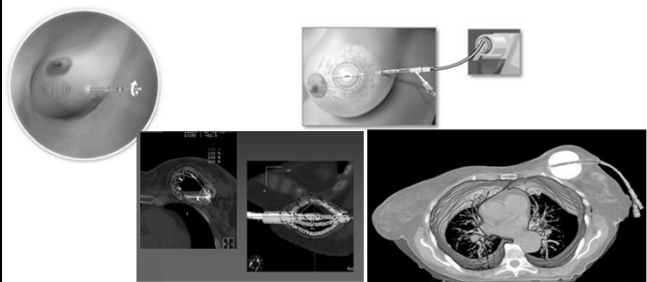
- Results 6 months after RT:
 - Fatigue (HF-WBI, 0% vs. CF-WBI, 6%)
 - Lack of energy (HF-WBI, 23% vs. CF-WBI, 39%)
 - Trouble meeting family's needs (HF-WBI, 3% vs. CF-WBI, 9%)

CONCLUSIONS AND RELEVANCE Treatment with HF-WBI appears to yield lower rates of acute toxic effects than CF-WBI as well as less fatigue and less trouble meeting family needs 6 months after completing radiation therapy. These findings should be communicated to patients as part of shared decision making.

Accelerated Partial Breast Irradiation (APBI)

- The question has arisen as to whether the whole breast needs to be treated or just the lumpectomy bed
- With smaller treatment volume a higher dose could be given, and treatment time could be cut down to just one week
- Can be accomplished by external beam radiation or brachytherapy

Accelerated Partial Breast Irradiation



Rationale for Accelerated Partial Breast Irradiation

- Most recurrences after breast conserving surgery occur in tumor bed region
- “Elsewhere” recurrences in breast are rare after lumpectomy alone or followed by RT
- Whole breast RT may not be necessary in appropriately selected patients

Thank You!



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