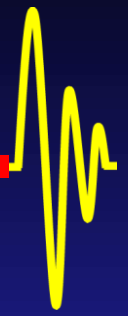
Radiation Therapy: Maximizing Effectiveness and Reducing Side-effects

Ramesh Gopal, MD, PhD
Associate Professor of Radiation Oncology
MD Anderson Cancer Center
Medical Director MD Anderson Radiation Treatment Center at Presbyterian

MD Anderson Cancer Center

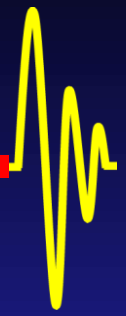
Making Cancer History®

What is Radiation?



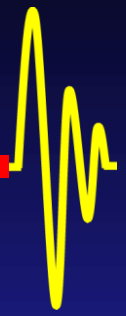
- Electromagnetic waves
  - X-rays
  - Gamma rays
- Sources
  - Radioisotopes
    - Cobalt, Iodine
  - Machines
    - Linear Accelerator

How does radiation work?



- Radiation causes DNA damage
- Cancer cells are not as efficient at DNA repair as normal cells
- Normal cells will repair the damage from a series of moderate radiation doses while cancer cells cannot
- Therefore fractionated radiation therapy is used to treat cancer

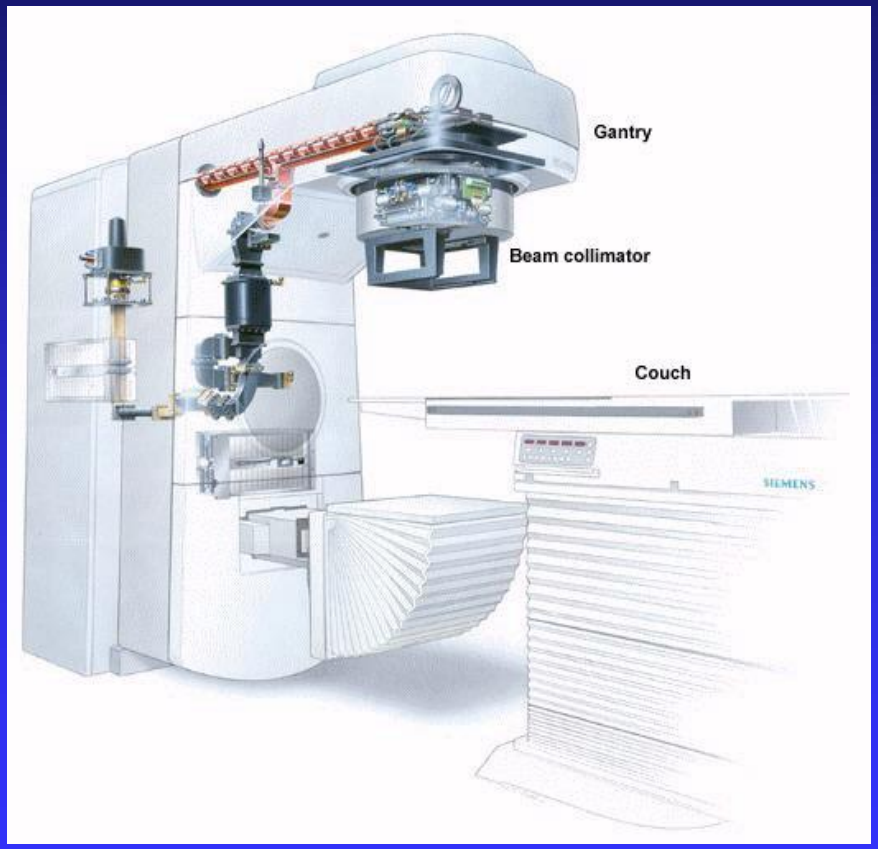
Types of Radiation Therapy



- External beam radiation therapy (teletherapy)
  - Done from the outside
- Brachytherapy
  - Done from the inside

External beam radiation comes from a Linac

- A power source generates electrons
- The electrons are accelerated and...
- Either used for therapy, or...
- Directed at a target to produce photons for therapy



External Beam Radiation

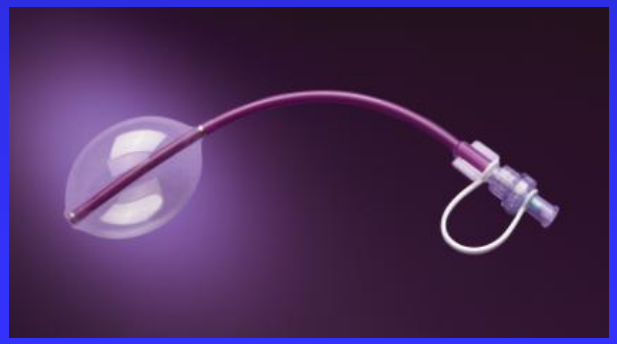
- Non-invasive
- Typical duration: between 4 and 8 weeks of daily, M – F treatments

Brachytherapy is done with an Afterloader

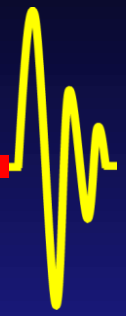
- The active source goes out *after* the appropriate device has been implanted in the site to be treated.
- Typically a Ir-192 source is used.

SAVI® Product Line

- SAVI Applicator
  - 6-1Mini
  - 6-1
  - 8-1
  - 10-1
- SAVI Prep Catheter
- SAVI Prep-01

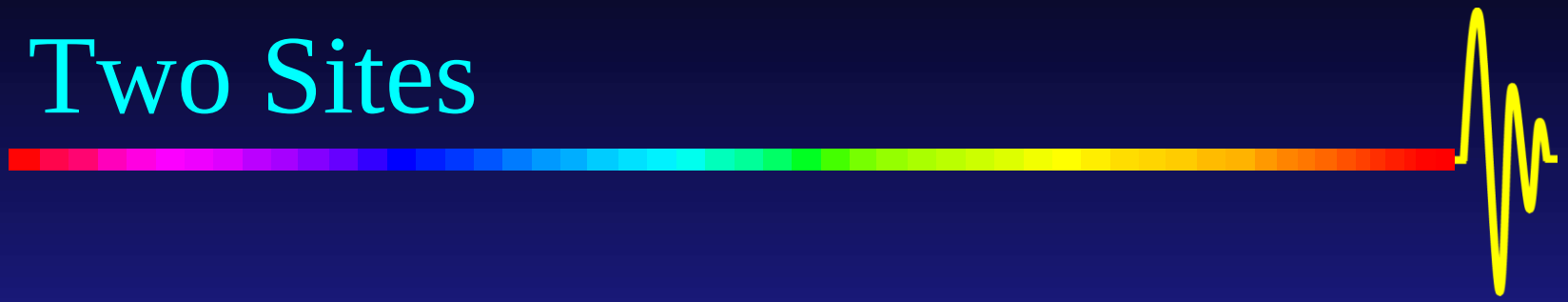


Reducing Side-effects



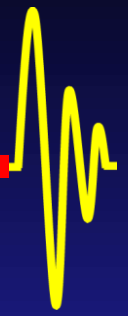
- Treat the target
  - Visible cancer
  - +/- Potential sites of spread
- Minimize the dose to normal tissues

Two Sites



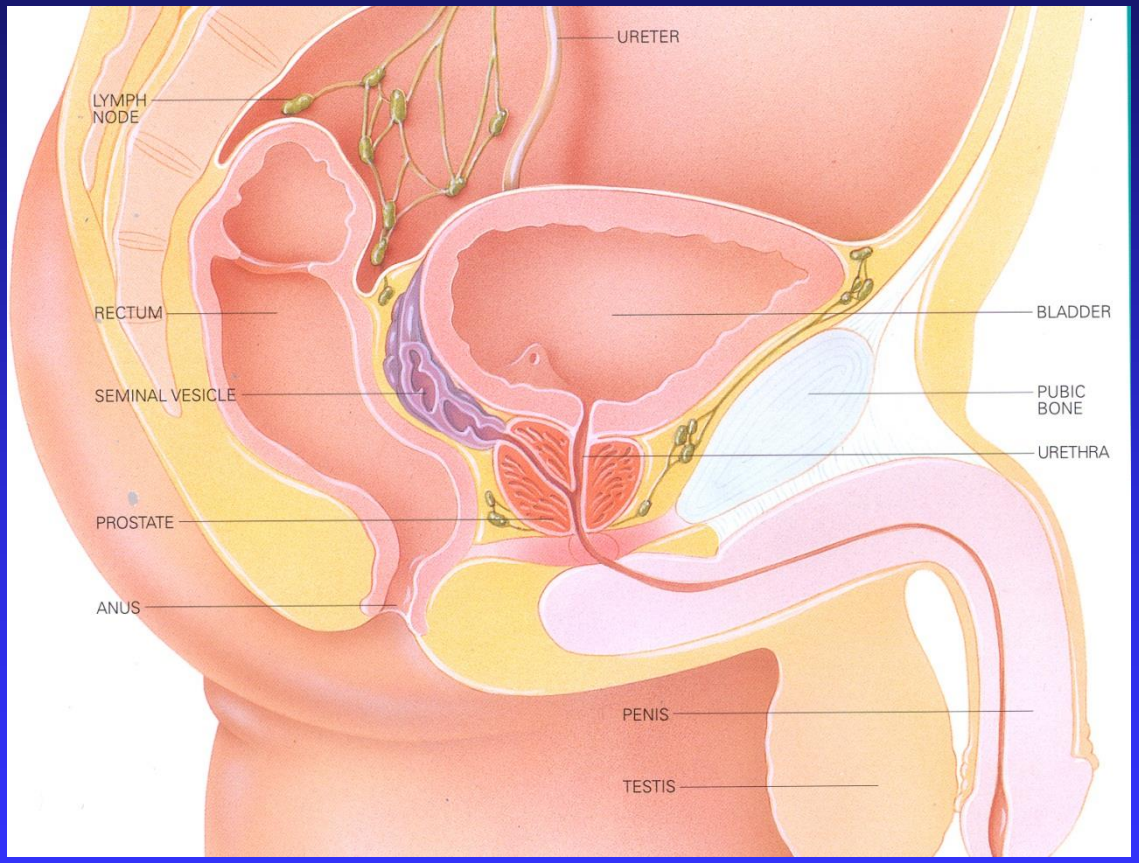
- These principles will be illustrated using 2 common disease sites
  - Prostate
  - Breast

What is the Prostate?



- A gland about the size of a walnut
- Produces the prostatic fluid that carries the sperm
- Located just below the bladder and in front of the rectum

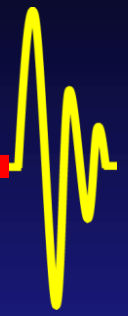
Prostate Anatomy



Treatment techniques

- Conformal radiation therapy
  - Radiation dose to the target is maximized, while dose to normal tissues is minimized
  - Inverse treatment planning is used
  - The goal is to minimize the volumes of rectum and bladder that are irradiated

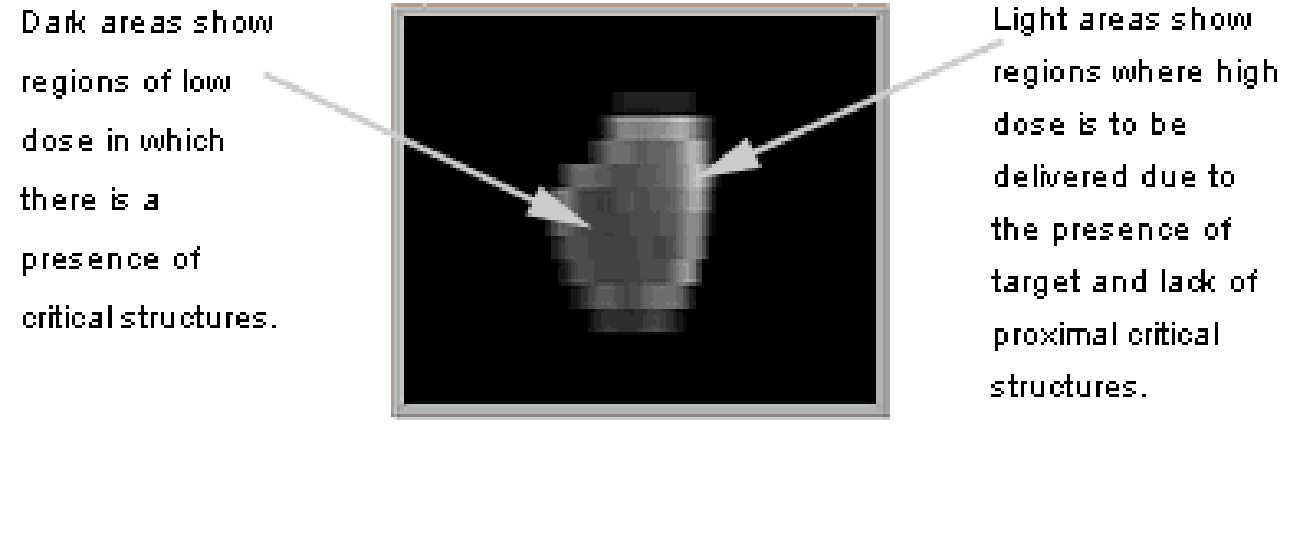
Side-effects



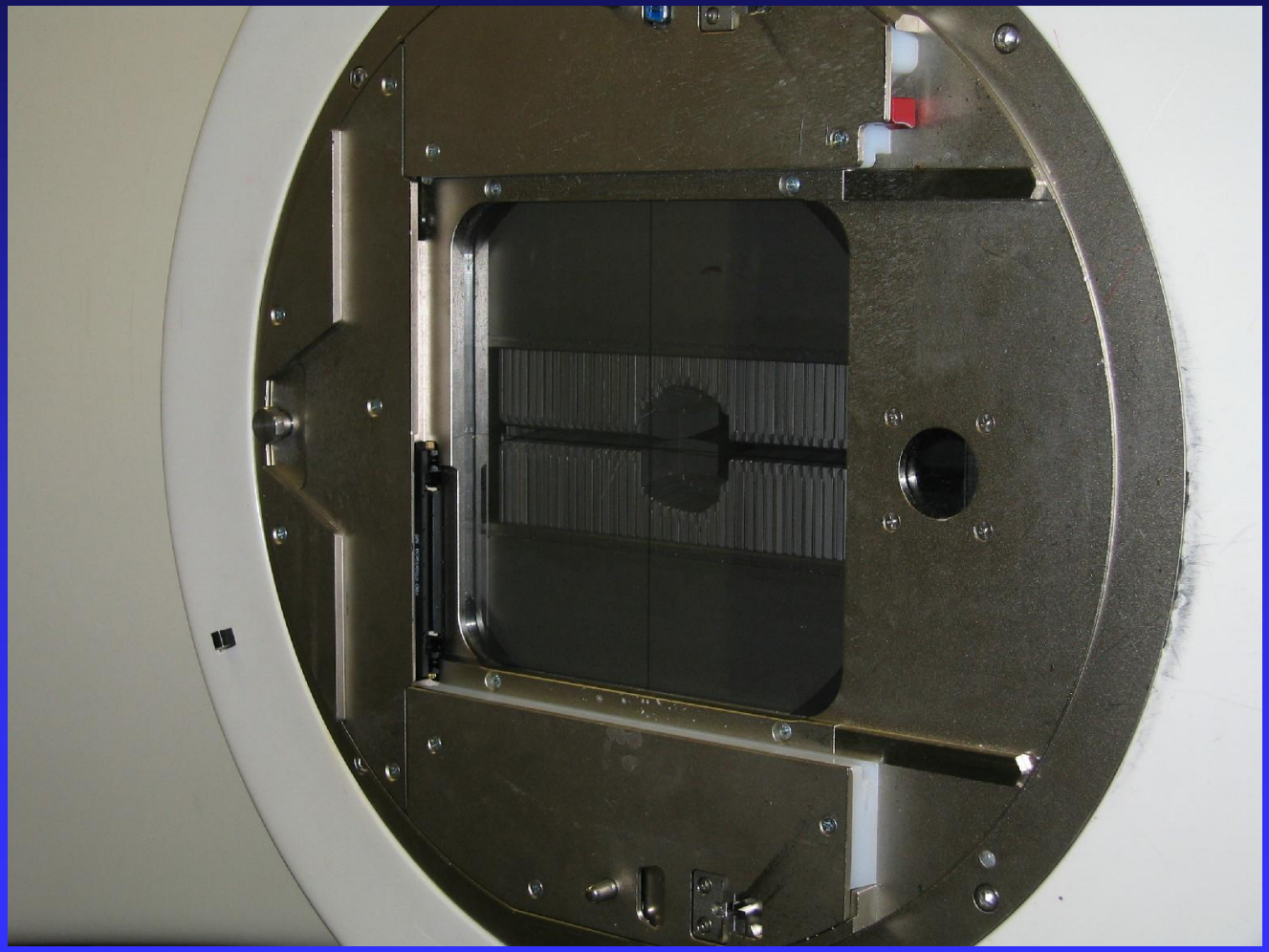
- Urinary
  - Frequency, urgency, burning
  - Weak stream
  - Bleeding
- Rectal
  - Small frequent bowel movements
  - Rectal bleeding

IMRT

- Intensity Modulated Radiation Therapy



The Linac Head

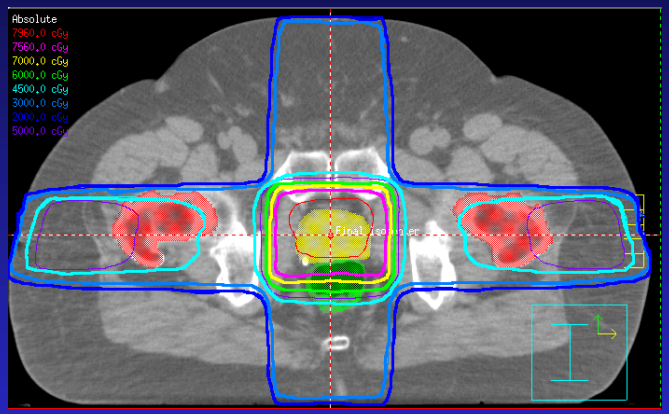


Multi-Leaf Collimators

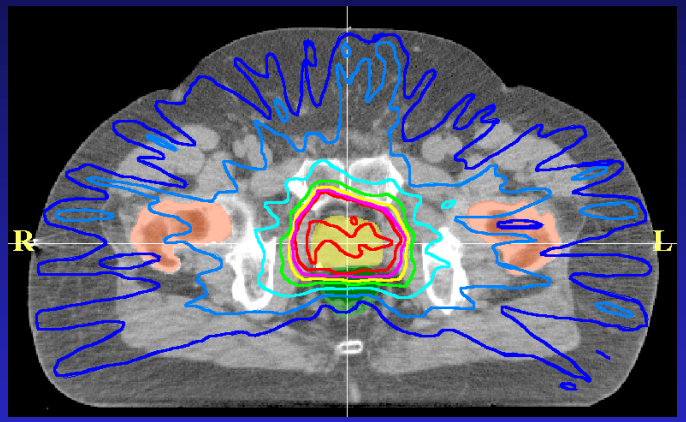
State of the Art

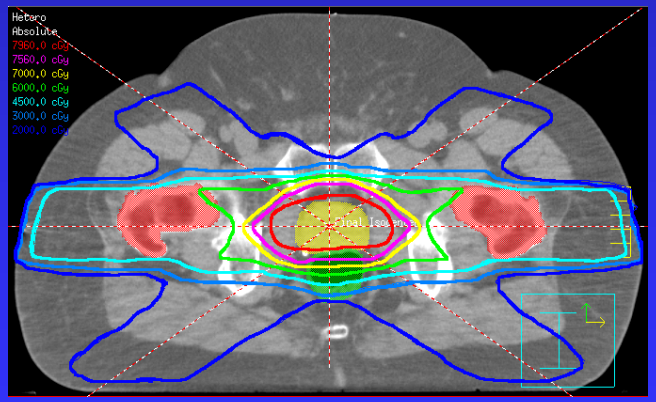
- Dose can literally be “painted” onto the target

Dose distributions

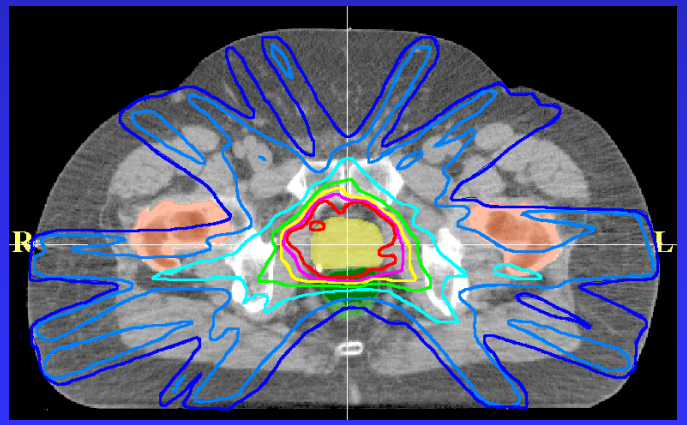


4-Field





7-Field



IMRT

79.6
75.6
70.0
60.0
45.0
30.0
20.0

IMRT

Pinnacle³ RTP System 7.6c

IMRT Prostate Plan

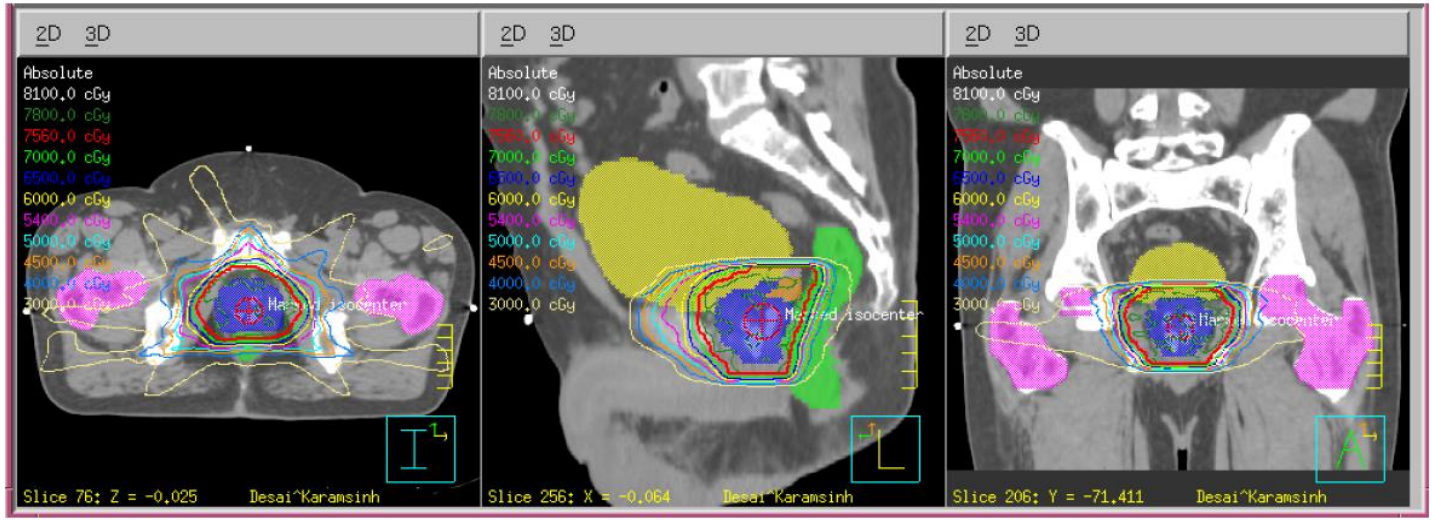
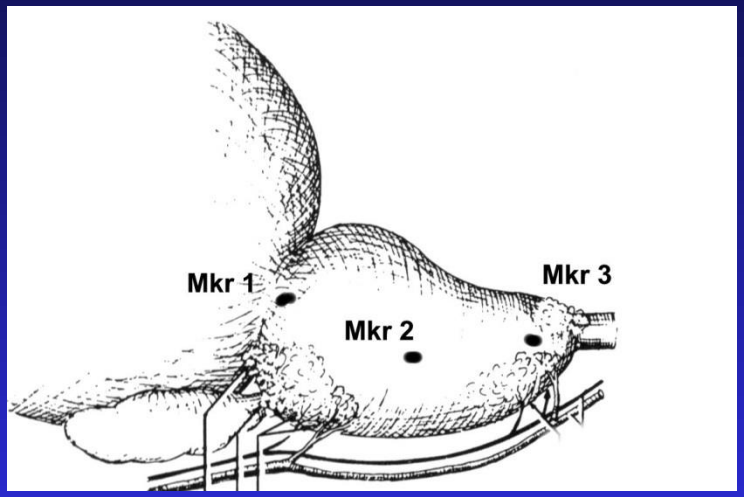
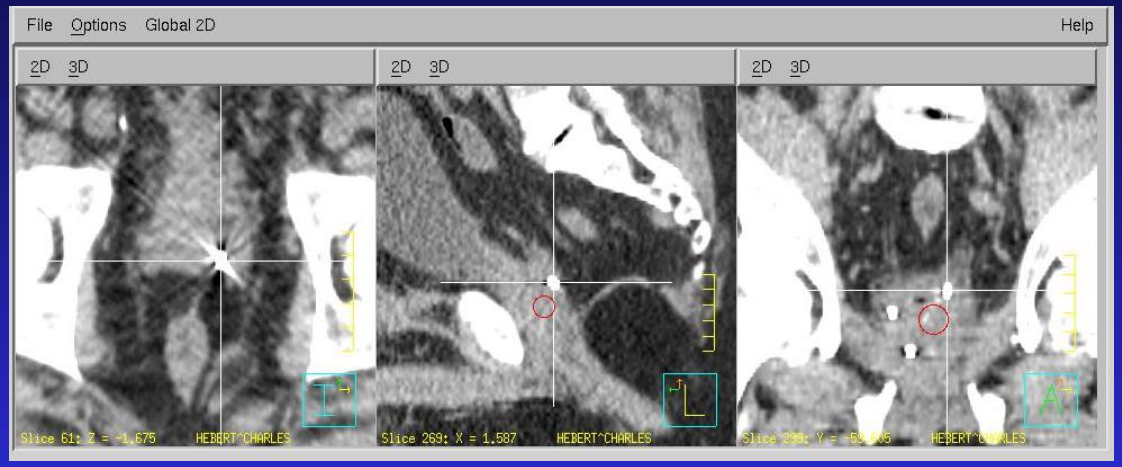


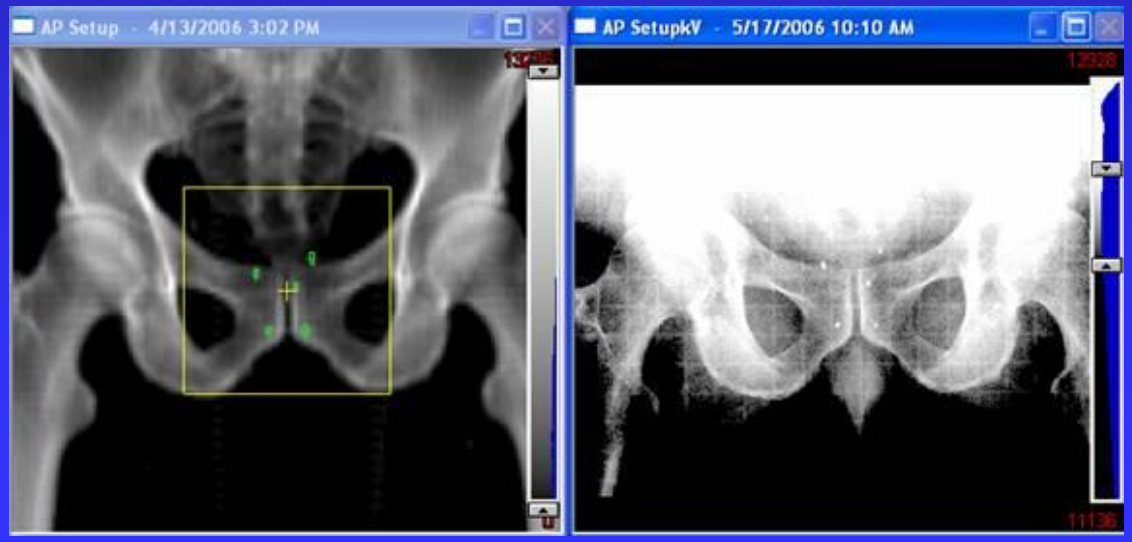
Image Guidance & Fiducial Markers



- Gold seeds implanted directly in the prostate can be visualized and adjustments made.

Markers used for set-up



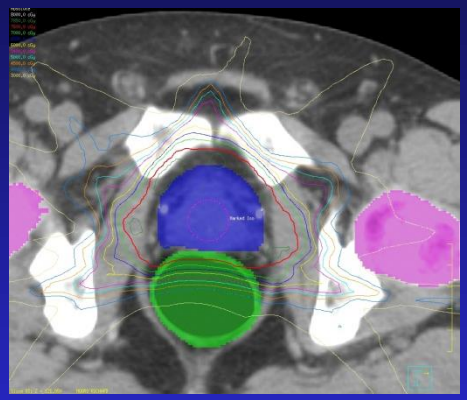


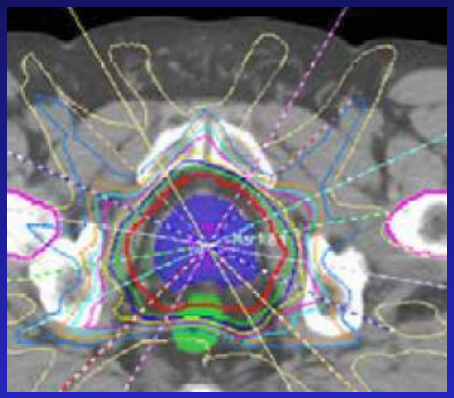
- The markers are visible both on planning CT scans and on daily imaging.
- Used for daily set-up adjustments.

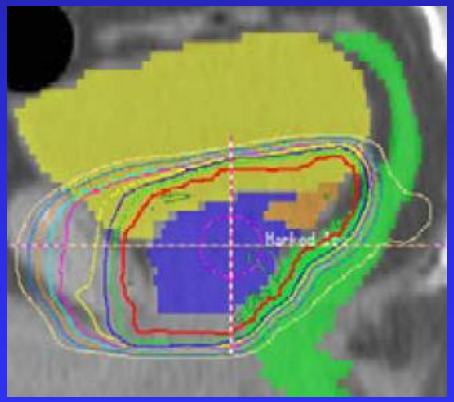
Rectal Balloon

- Stabilizes the prostate.
- Pushes the back of the rectum away from the prostate.
  - Less rectal side-effects.

Rectal Balloon – Radiation Dose

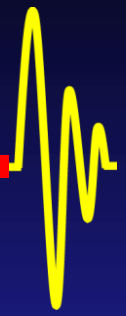






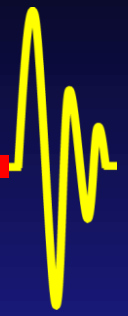
- Less radiation to the back of the rectum

Medical Management of Side-effects



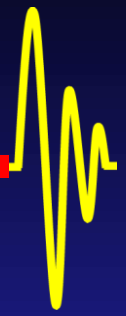
- Prostate relaxers e.g. tamsulosin
- Urinary analgesics e.g. phenazopyridine
- Stool softeners
- Steroid enemas
- Colonoscopy with laser of bleeding blood vessels if needed.

Whole Breast Radiation



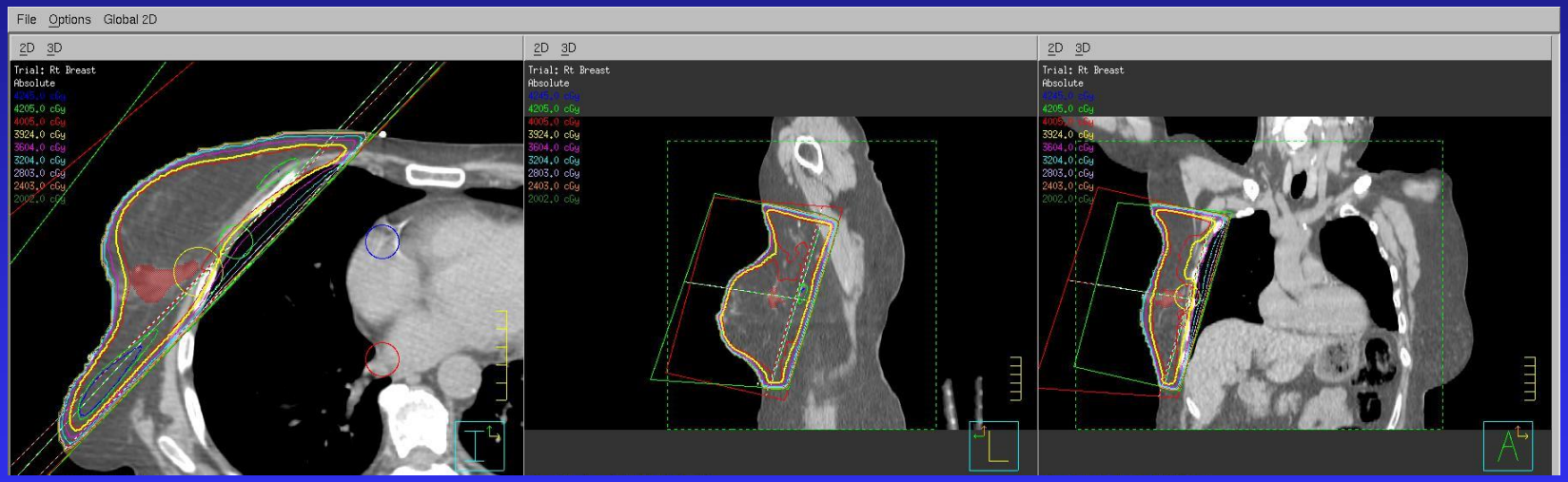
- Twenty daily treatments over 4 weeks if nodes are not treated.
- Thirty daily treatments over 6 weeks if regional nodes require treatment.
- The target is the whole breast +/- regional nodes

Side-effects of breast radiation



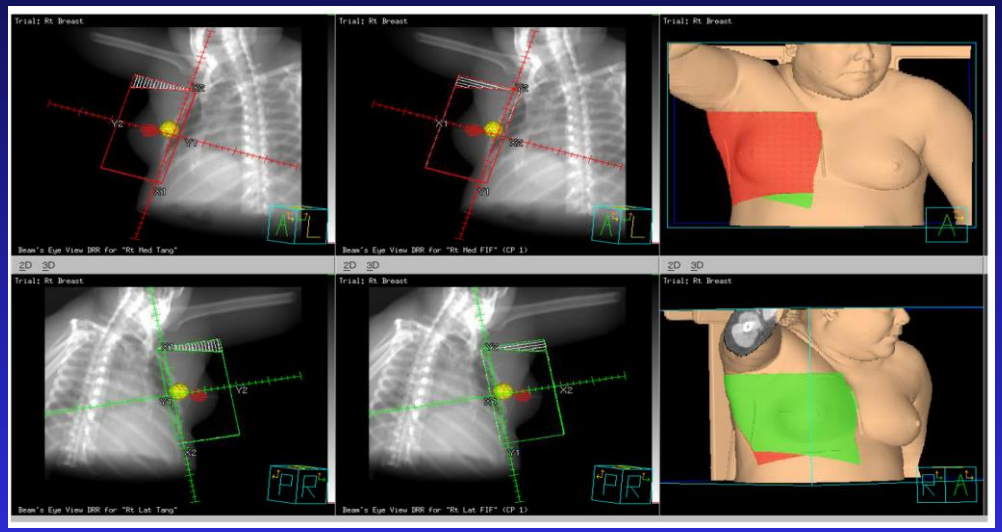
- Breast redness
  - The breast is part of the skin so some skin reaction if to be expected.
- Skin peeling
- Need to minimize heart and lung doses.

Whole Breast Plan

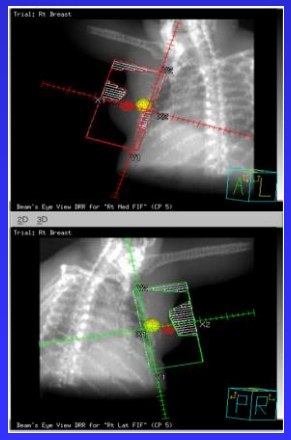


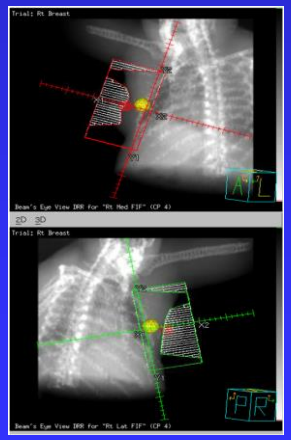
The goal is a homogenous plan

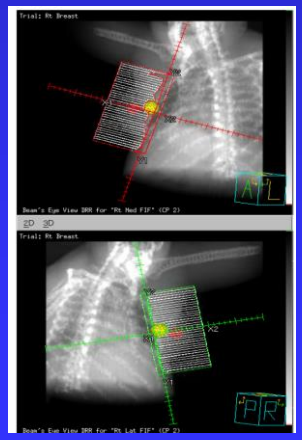
Field-in-field

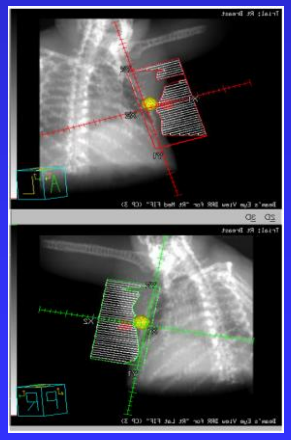


Additional small subsidiary fields are used to smooth out the dose.





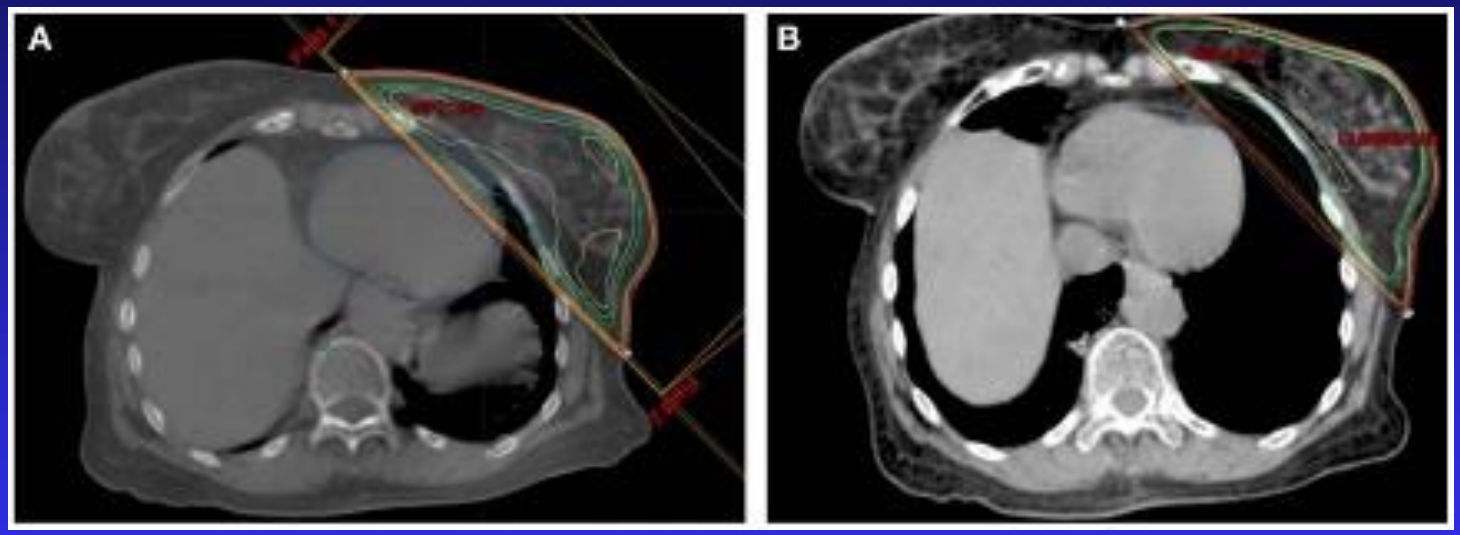




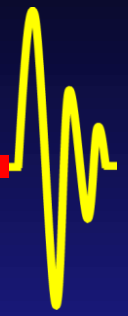
Deep inspiration

Expanding the chest increases the distance between the heart and breast

The heart is out of the way

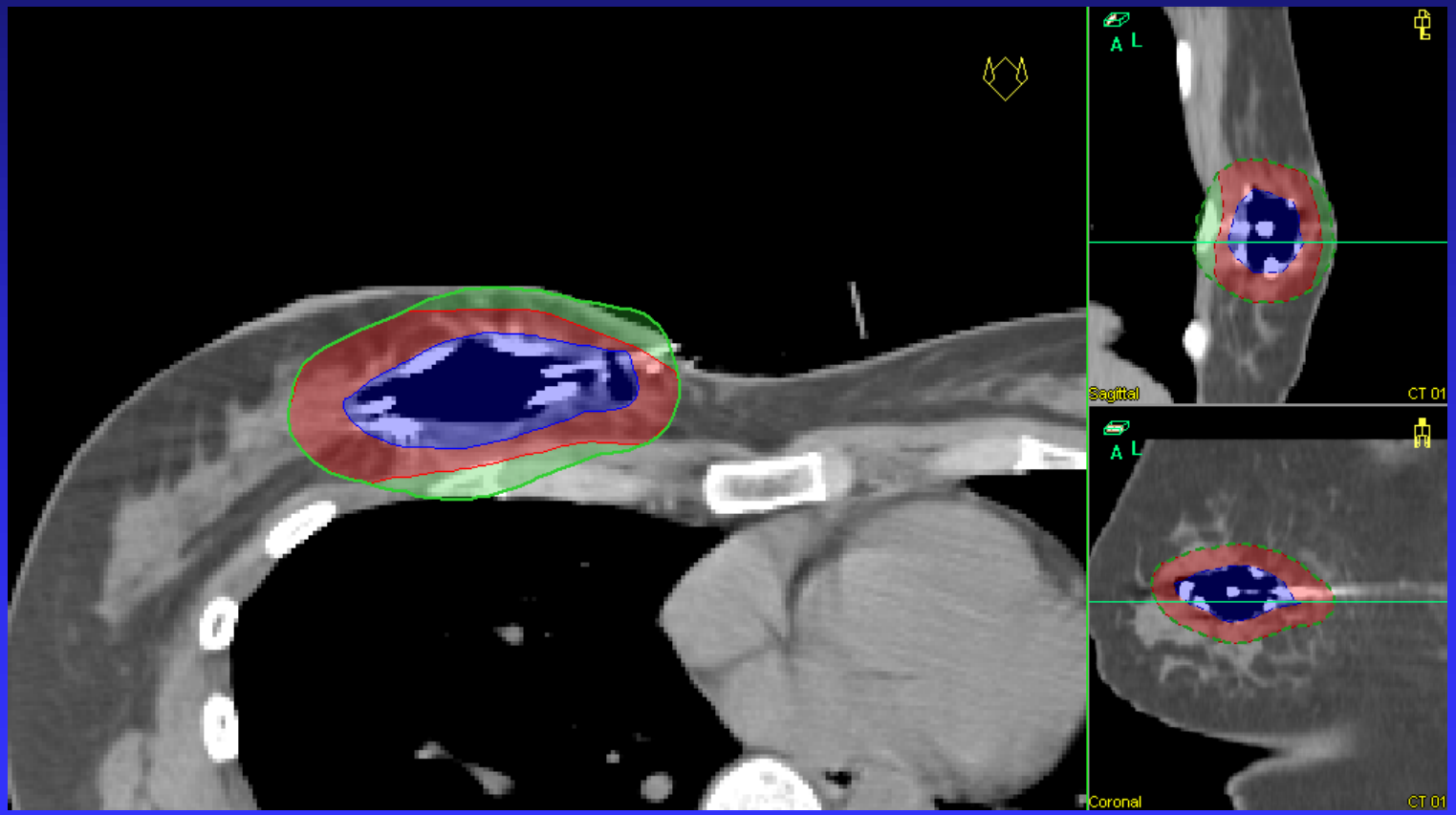


Accelerated Partial Breast Irradiation (APBI)

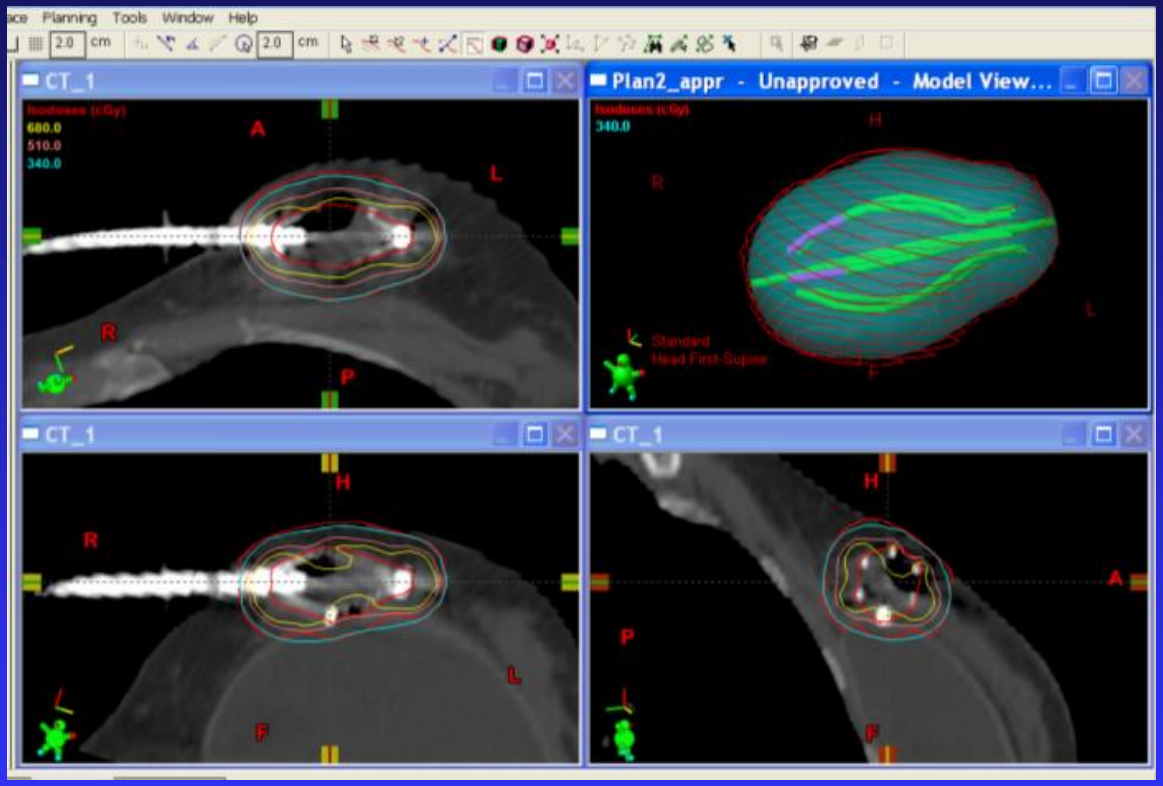


- Treatment of just the tumor bed
- 2x per day for 5 days
- Appropriate for smaller tumors without involved lymph nodes

Partial Breast Irradiation target



Partial breast dose



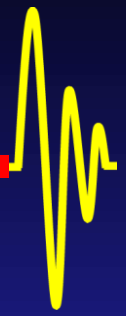
PTV	D95	V200	D_{max} Skin	D_{max} Chest Wall
41.8cc	98.5%	10.0cc	100%	48%

Evaluating a Plan

	ROI Dose [%]	Dose [cGy]	Volume [%]	Volume [ccm]
PTV_EVAL	100.00	340.00	93.48	38.39
PTV_EVAL	83.57	284.14	100.00	41.07
PTV_EVAL	150.00	510.00	46.93	19.27
PTV_EVAL	200.00	680.00	26.07	10.71
PTV_EVAL	90.00	306.00	99.38	40.81
PTV_EVAL	102.92	349.94	90.00	36.96
PTV_EVAL	95.00	323.00	97.44	40.01
PTV_EVAL	98.41	334.60	95.00	39.01
Rib 2	40.64	138.19	4.77	0.10
Rib 2	31.07	105.64	47.70	1.00
Rib 2	125.00	425.00	-	-
Rib 2	145.00	493.00	-	-
Rib	45.45	154.54	3.79	0.10
Rib	36.05	122.59	37.95	1.00
Rib	125.00	425.00	-	-
Rib	145.00	493.00	-	-
Skin	38.98	132.53	0.01	0.10
Skin	34.07	115.84	0.10	1.00
Skin	125.00	425.00	-	-
Skin	145.00	493.00	-	-

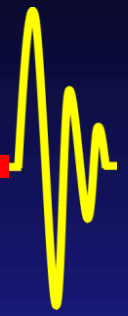
Multiple different parameters are taken into consideration

Stereotactic Radiation



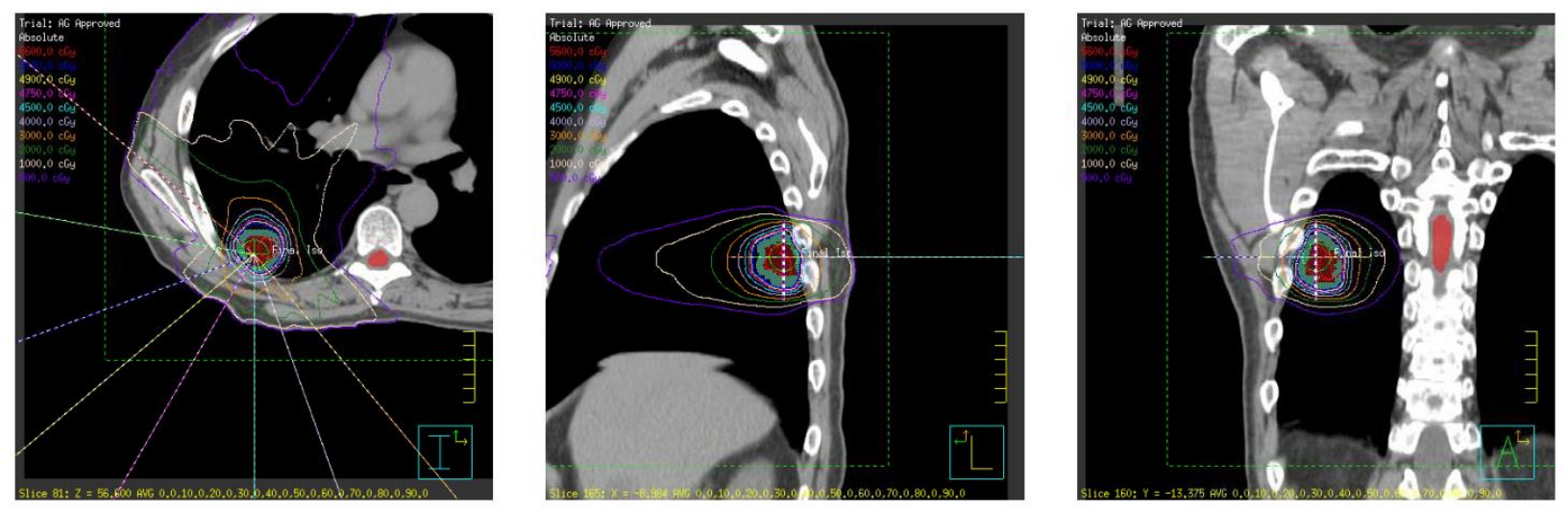
- Stereotactic Body Radiation Therapy (SBRT) is used to administer large doses in a few fractions.
  - 50 Gy in 4 (12.5 Gy fractions)
  - 27 Gy in 3 (9 Gy fractions)
  - 30 Gy in 5 (6 Gy fractions)
- Conventional RT uses ≈ 2 Gy fractions

Advantages



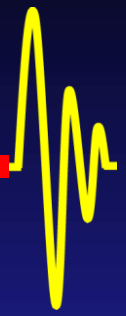
- SBRT is a short course of treatment
- Treatment is considered ‘ablative’
- The goal is to treat the tumor with a very tight margin
  - Very little surrounding normal tissue is treated.

Lung example



A small lung nodule targeted with stereotactic radiation therapy

Summary



- Radiation therapy techniques allow delivery of high doses of radiation with high precision to designated targets.
  - This improves outcomes
- Limiting the dose to adjacent normal tissues reduces side effects.