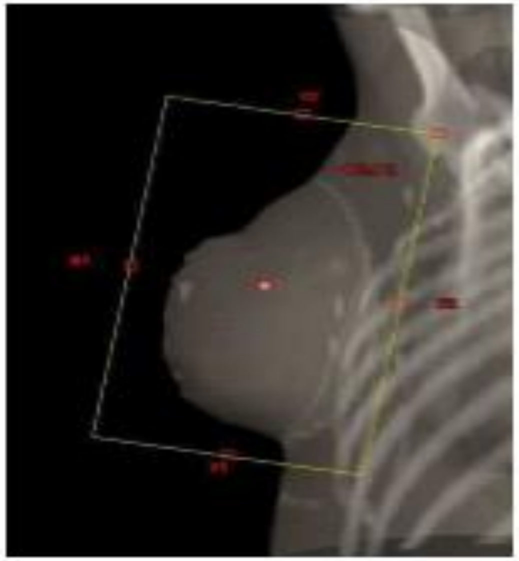
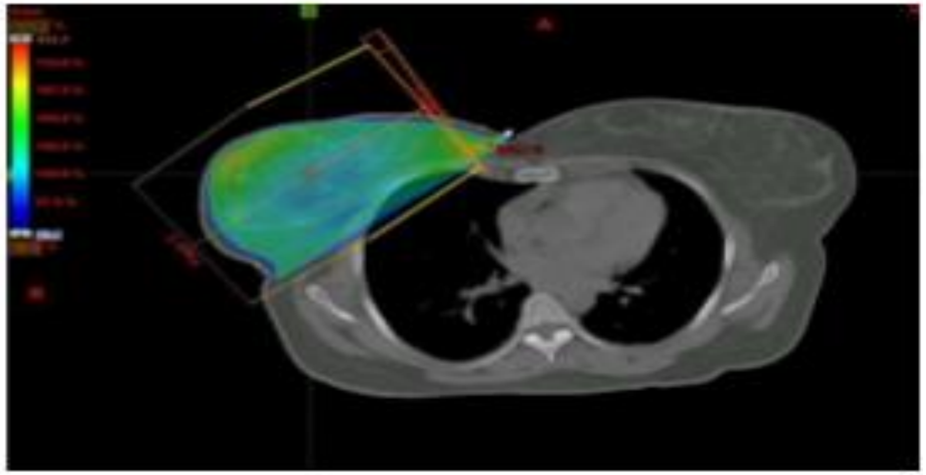
Rationale and techniques of IMRT and organ (including cardiac) sparing approaches in breast cancer radiation therapy





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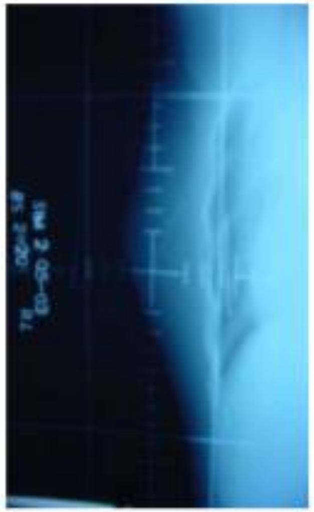
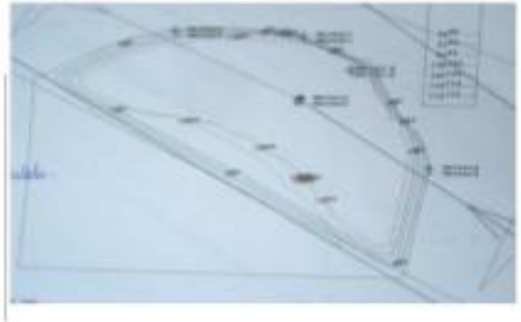
Standard Tangents
2D planning

- Contour taken at central axis and dose distribution evaluated





Advantages

Good technique, simple

Time tested

Reasonably good sparing of lungs and heart

Basics !!!

- Study Pre operative Clinical findings and diagrams well
- Location of tumour Size of tumour
- Tumour involving Nipple areola complex
- Axillary/ SC LNs
- Check for arm’s movement
- If any lymphedema-document it
- Type of Breast -careful palpation
- Pendulous breast -identify and try to reduce folds
- Location of tumour-Tumour in Lower quadrant or inner quadrant need to modify conventional borders

Why do we need Conformal planning?

- RT to breast -reduces local recurrences and improved survival
- Concern-T/t related morbidity in breast and shoulder -Long term risk of heart disease and secondary cancer
- Need to optimize RT to obtain max effect and minimize morbidity
- Transition from 2D to 3D RT–shift from bony land mark based RT to individualised target
- Target volume delineation is the weakest link in quality chain of RT and there are large inter observer variations

Modern RT Techniques

Conventional tangents with simple or customized shielding

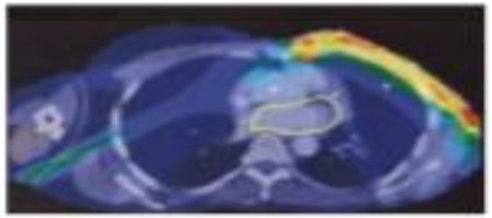
Photon based –3DCRT: wedges, MLCs for shielding heart, overdose volume

IMRT

TomoTherapy

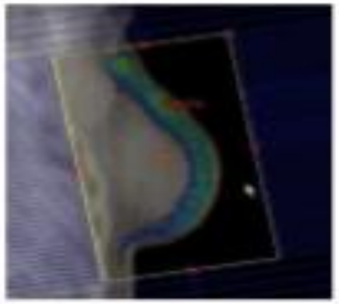
Arc therapy (VMAT)

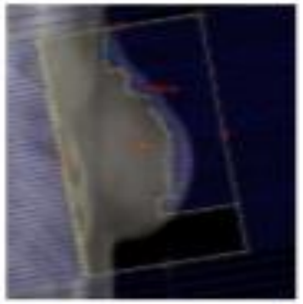
Proton IMRT

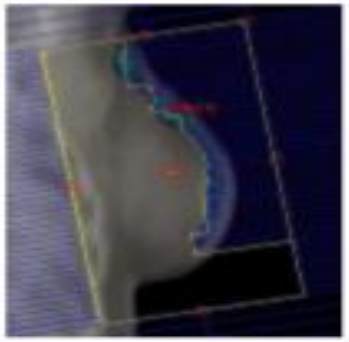


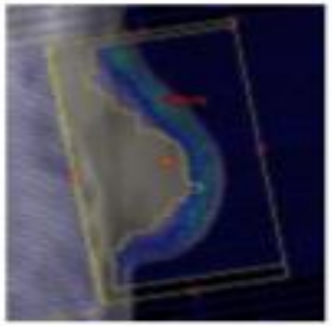
Forward planned IMRT

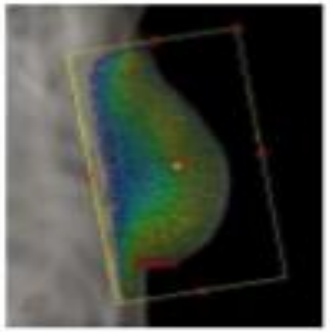
- Modified bi-tangential portals
- Use of multiple segments inside each tangential portal
- Homogenous dose distribution through out the breast
- Possible improvement in the cosmetic outcome

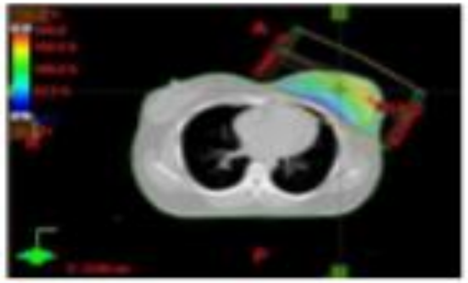












Randomized trial of IMRT vs Tangents

Canadian trial, Multicentre (N=331)

80% medium/large breasts, 50Gy/25#/5weeks±16Gy boost

Endpoint: Acute skin reaction, moist desquamation

	Tangents (161)	IMRT (171)	p value
Skin toxicity grade III and IV	36.0%	27.1%	0.06
Moist desquamation, all breast	47.8%	31.2%	0.002
Moist desquamation, infra mammary area	43.5%	26.5%	0.001

Pignol JP et al JCO 2008

Randomised trial of IMRT vs Tangents

Royal Marsden Hospital trial

306 women with high risk for developing reactions: median breast volume 1046 cc (50Gy/25# + 11.1Gy/5# electron boost)

Primary endpoint: Late, change in breast appearance

5 year late sequelae	**2D RT (156)**	**IMRT (150)**	**p value**
Photographic score at 5 yrs-	58%	40%	0.008
Induration-centre	32%	21%	0.02
Induration-inframammary fold	24%	17%	0.009
Induration-pectoral fold	29%	22%	0.006

Donovan E et al Radiother Oncol 2007 (82): 254–264

Randomised trial of IMRT vs Tangents

Cambridge University Hospital trial (N=815)

All breast sizes (40Gy/15# ± 9Gy/3# electron boost), mean breast volume 1300cc in randomized patients

Primary endpoint: Late, change in breast appearance

5 year Late sequelae	**2D RT (404)**	**IMRT (411)**	**p value**
Telangiectasis	24%	15%	0.031
Overall final cosmesis (good-moderate)	78%	88%	0.038

No difference seen on photographic assessment for breast shrinkage, breast edema, tumor bed induration, or pigmentation

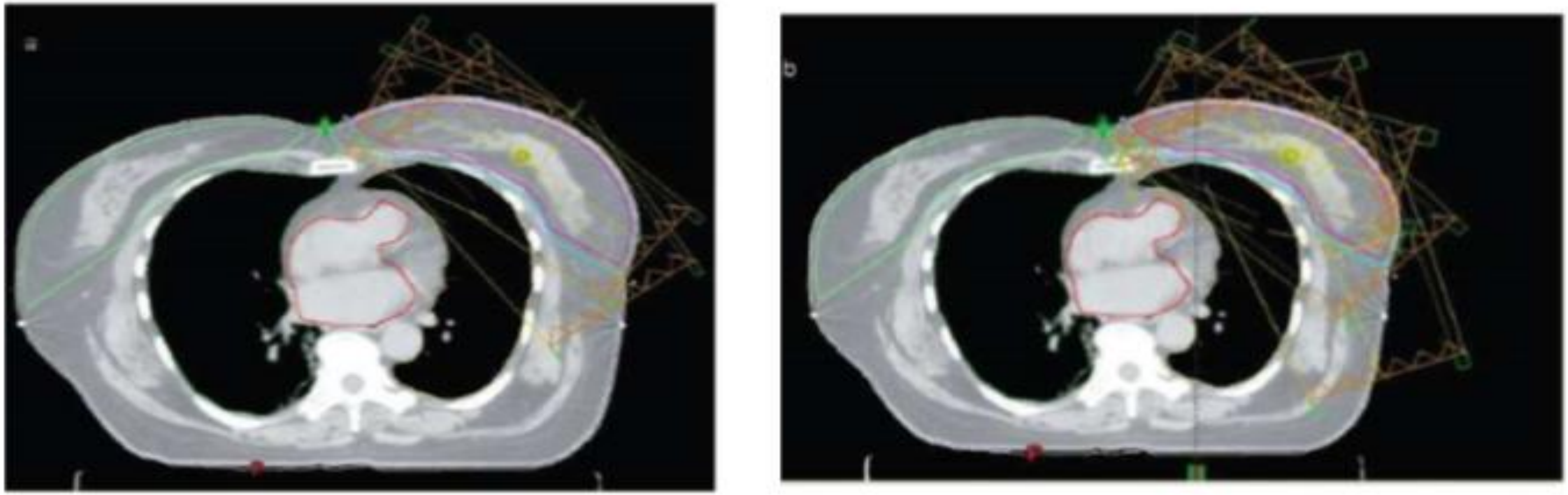
Mukesh et al JCO 2013, 31: 4488-95

Large Phase II data: Fox Chase Cancer Centre

- Early Breast Cancer-Stage 0,I,II
- Study Period: 2003-2010
- N=936
- Technique: Open tangents+ Inverse planned tangents
- Median FU: 31 months (1-97 months)
- 5 year actuarial IBTR rates: 2%
- 5 year actuarial Locoreg rec rates: 2.4%
- Cosemesis: Excellent: 63%, Good: 33%
- Breast Volume> 900cc, boost dose>16Gy, boost volume >34cc: Impact on fair/poor cosmetic outcome

Keller L. IJROBP 2012

Inverse Plan IMRT



Increase in mean doses of ipsilateral lung, heart and opposite breast

What is the Optimal Beam Arrangement for IMRT?

- TANGENTS!!!
- Less low dose: Lung, Heart, Contralateral Breast
- Adequate coverage of Target volume
- Early Breast Cancer women: Do survive long… to see the
- long tem effects of scatter dose

Practical Radiation Oncology (2014) 4, 349-355

Special Article

Choosing Wisely: The American Society for Radiation Oncology's Top 5 list

Carol Hahn MD [a,*,1], Brian Kavanagh MD, MPH [b,1], Ajay Bhatnagar MD, MBA [c], Geraldine Jacobson MD, MBA [d], Stephen Lutz MD [e], Caroline Patton MA [f], Louis Potters MD [g], Michael Steinberg MD [h]

[a]Department of Radiation Oncology, Duke University Medical Center, Durham, North Carolina

5. Don't routinely use intensity modulated radiation therapy (IMRT) to deliver whole-breast radiation therapy as part of breast conservation therapy.	• Clinical trials have suggested lower rates of skin toxicity after using modern 3D conformal techniques relative to older methods of 2D planning. • In these trials, the term "IMRT" has generally been applied to describe methods that are more accurately defined as field-in-field 3D conformal radiation therapy. • While IMRT may be of benefit in select cases where the anatomy is unusual, its routine use has not been demonstrated to provide significant clinical advantage.[28,31-33]

2D, 2-dimensional; 3D, 3-dimensional.

VMAT

- Novel extension of IMRT
- Optimized three-dimensional (3D) dose distribution may be delivered in a single gantry rotation
- Reduction in treatment MUs (30%) and delivery time (55%) due to high dose rates (as compared to cIMRT)
- Arc treatment: Larger low dose scatter-lungs, heart
- Dosimetric advantages of VMAT not confirmed for patients requiring
- adjuvant RT to breast only (Badakhshi et al, BJR 2013)

CT Simulation

- Position-Comfortable and reproducible
- Supine
- Breast wedge
- Both arms above head
- IV Contrast Optional (we use IV Contrast only in patients with Positive SCF nodes)

- Wires-Important Step-Do not hurry!!
- Palpate Breast well, look for skin folds
- Wire around-I/L Breast Scar Opposite Breast Provisional field borders
- Use copper wires to reduce artefacts
- Free Breathing
- 3-5 mm scans from neck to L1-2

Why wires around Breast?

- Large differences are reported b/w CTV localization using standard anatomic borders, palpation and USG
- Hurkmanset al -study in 2001 with palpable breast glandular tissue was marked by lead wire before Planning CT in 6 pts Vs. 4 patients without lead wire
- CTV was delineated by 4 RO
- Deviations in PTV extent were greater in Posterior, Cranial and medial directions
- Interobserver variation in volume was decreased by a factor of 4 on scans with lead wire

IJROBP Vol 50 No5, 2001

OARS

- Heart- Contoured below pulmonary trunk bifurcation
- Coronaries-LAD
- All mediastinal tissue below this level should be contoured including great vessels
- I/L and C/L Lungs
- Opposite Breast
- Head of Humerus

DVH

Evaluate both CTV and PTV –

PTV	Ideal	Acceptable
D95%	95%	
D90%		90%
Dmax	< 115%	<120%

OAR Doses

C/L Breast D max	<3Gy
I/L Lung V 20Gy	<15 -20%
I/L Lung V 10Gy	<35 -40%
I/L Lung V 5Gy	<50 -55%
C/L Lung V5 Gy	<10% -15%
Heart (Left Breast Cancer) V20Gy	<10%
Heart (Left Breast Cancer) V10Gy	<30%
Heart (Right Breast Cancer) V20Gy	0%
Heart (Right Breast Cancer) V10Gy	<10 -15%
Mean	<4 -5Gy

OAR Doses -HF

	CF	HF
I/L Lung	V 20Gy	V 16Gy
	V 10 Gy	V 8 Gy
	V 5Gy	V 4Gy
Heart	V 25Gy	V 20 Gy
	V 20Gy	V 16Gy

Acute & Late Sequelae of Standard Tangents

ACUTE

- Skin toxicity in one third
- Infra-mammary fold
- Treatment break
- Quality of life
- Factors associated:
  - Large breast size
  - Hotspots (>2cm^3 of 107% of PD)

LATE

- Cosmetic outcome (25-40% experience change in breast appearance at one year depending upon breast size)
  - Breast shrinkage
  - Telangiectasia
  - Breast fibrosis
  - Breast edema
- Psychological morbidity

RIHD –Radiation Induced Heart Disease

- Defn: Clinical and pathological conditions of injuries to the heart and large vessels resulting from therapeutic irradiation of malignancies

- Fajardo & Stewart showed that heart and vasculature are radiosensitive organs - Fajardo, L.F., J.R. Stewart, Morphology of radiationinduced heart disease. Arch Pathol, 1968. 86(5): p. 512-9.

Heart and its component affected by RT

- Early reactions rare, mostly late effects
- Radiation induced cardiac injuries

–Pericarditis

–CCF

–Restrictive Cardiomyopathy

–Valvular insufficiency & stenosis

–CAD: ischemia, infarction

Pericardium	Pericardial thickening
	Pericardial effusion
	Cardiac tamponade
	Constrictive pericarditis
Coronary artery disease	Obstructive lesion in the anterior descending artery
	Obstructive lesion in the coronary ostia
Myocardium	Asymptomatic left ventricular diastolic dysfunction
Valves	Valvular thickening without hemodynamic repercussions
	Aortic stenosis
Cardiac electrical and conduction disorders	Right bundle branch block (more frequent)
	Left bundle branch block
	Complete atrioventricular block
	T-wave flattening or inversion
Great vessels of the chest	Increased carotid *intima*-media thickness
	Chronic baroreflex failure: labile hypertension or orthostatic hypotension
	Aortic calcification
	Stenotic lesions of the subclavian arteries

IHD incidence

- Radiotherapy as administered from the 1980s onward is associated with an increased risk of cardiovascular disease. Irradiated breast cancer patients should be advised to refrain from smoking to reduce their risk for cardiovascular disease - Hooning et al JNCi 2007
- Patients who underwent radiotherapy plus adjuvant chemotherapy (CMF regimen) after 1979 had a higher risk of congestive heart failure than patients who were treated with radiotherapy only ($P = 0.002$)
- Risk of death from ischemic heart disease associated with radiation for breast cancer has substantially decreased over time - Giordano et al Risk of Cardiac Death After Adjuvant Radiotherapy for Breast Cancer : JNCI 2005

Normal Tissue Tolerance– Dose volume data

- Summary of historical landmarks to establish the dose-volume parameters and outcomes

TABLE 13.1 HISTORICAL OVERVIEW OF SUMMARIES OF DOSE/VOLUME/OUTCOME INFORMATION

Report	*Key Contributions*	*Key Shortcomings*
Rubin, 1975[3]	Introduced the concept of $TD_{5/5}$ and $TD_{50/5}$	Minimal dose–volume data
Emami, 1991[1]	Concise summary addressing most clinically meaningful endpoints in a uniform manner Based on available data and expert opinion	Dose–volume relationship based on limited data and, thus, much expert opinion
QUANTEC, 2010[2]	Driven largely by the available 3D dose/volume/outcome data. Systematic review addressing many challenges such as organ delineation and confounding factors such as chemotherapy	Because dose/volume/outcome data on all meaningful clinical outcomes are *not* available, the summary is not able to guide all clinical practice

- QUANTEC– introduced the concept of evaluation of DVH parameters like V*x* (the % of organ receiving >/= *x* Gy)

α/β heart is low (about 1 Gy): fractionation results in substantial sparing effect

Source: Eric J. Hall, Seventh Ed. Ch. 20

Radiation Tolerance Doses– Heart

- Data for 2Gy/ #
- Variation with
  - Age
  - Individual sensitivity
  - Vascular status
  - Other treatment factors

OAR	TD5/5 (Gy)	TD50/5 (Gy)	DVH Vx % or mean dose in Gy	Tolerance dose (Gy)
Heart	1/3 60	70	V40 <30	D_{max} <60
	2/3 45	55	V30 <40–45	
	3/3 40	50	V20 <50	
Lung	1/3 45	65	V30 <10–15	
	2/3 30	40	V20 <25	
	3/3 17.5	24.5	Mean 10	

Practical_Radiotherapy_Planning DOBBS 4th ed.

IHD incidence

Table 2. Comparison of percent ischemic heart disease mortality (with 95% confidence intervals) at 15 years of follow-up between women with left-sided and right-sided breast cancers, stratified by stage of disease at time of diagnosis

Cohort by year of diagnosis	All patients			Patients with in situ/localized disease			Patients with regional disease		
	Left-sided, %	Right-sided, %	*P*	Left-sided, %	Right-sided, %	*P*	Left-sided, %	Right-sided, %	*P*
Overall	8.7 (8.0 to 9.3)	7.5 (6.9 to 8.2)	.07	7.6 (6.7 to 8.4)	6.7 (5.9 to 7.5)	.40	10.2 (9.1 to 11.3)	8.6 (7.6 to 9.6)	.09
1973–1979	13.1 (11.6 to 14.6)	10.2 (8.9 to 11.5)	.02	12.7 (10.3 to 15.2)	9.6 (7.5 to 11.8)	.14	13.3 (11.5 to 15.1)	10.6 (8.9 to 12.3)	.06
1980–1984	9.4 (8.1 to 10.6)	8.7 (7.4 to 10.0)	.64	8.9 (7.2 to 10.5)	8.7 (7.1 to 10.4)	.87	10.0 (7.9 to 12.1)	8.8 (6.8 to 10.9)	.38
1985–1989	5.8 (4.8 to 6.7)	5.2 (4.4 to 5.9)	.98	5.7 (4.5 to 6.8)	4.9 (4.0 to 5.8)	.79	6.0 (4.4 to 7.6)	5.7 (4.1 to 7.2)	.76

Incidence of IHD SEER data

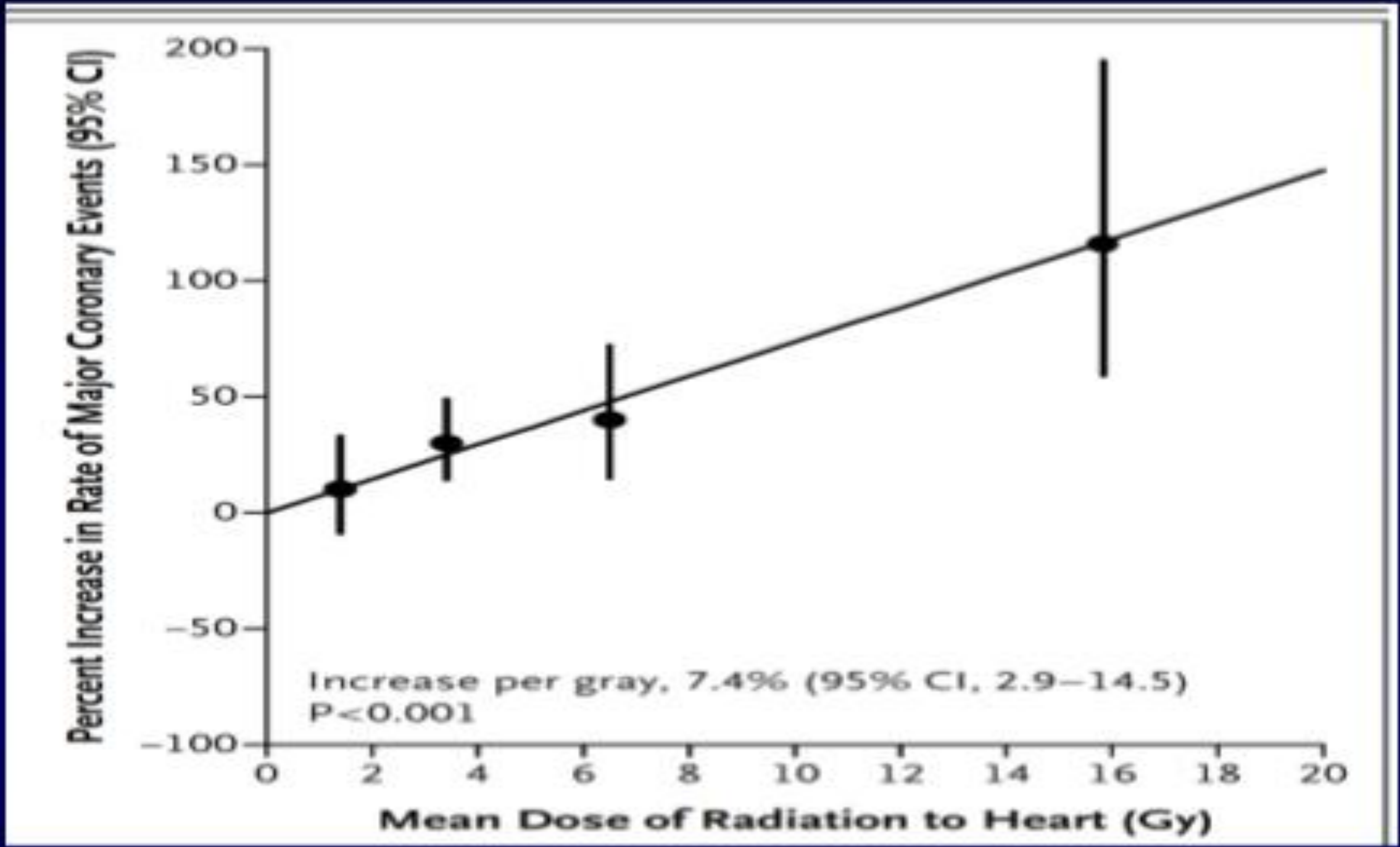
N = 27283 (Left and Right side .13000 each)

Giordano et al Risk of Cardiac Death After Adjuvant Radiotherapy for Breast Cancer : JNCI 2005

Stockholm Breast Cancer Study Group

- Patients: 2168 with major coronary events = 960 (1958 and 2001)
- Matched with population control n = 1205
- Mean dose to Heart
  - Left breast 2.9 Gy
  - Right breast 4.9 Gy
- The percentage increase in risk per gray was similar for women with and those without cardiac risk factors at the time of radiotherapy
- Women irradiated for cancer of the left breast had higher rates of major coronary events than women irradiated for cancer of the right breast (P = 0.002)

Sarah C. Darby et al Risk of Ischemic Heart Disease in Women after Radiotherapy for Breast Cancer NEJM 2013



Mean Heart Dose	% Increase in Major Coronary Event
< 2 Gy	10%
2 - 4 Gy	30%
5 - 9 Gy	40%
> 10 Gy	116%

- Rate of Major Coronary Events According to Mean Radiation Dose to the Heart with no apparent threshold
- Each 1 Gy increase leads to 7.4% increased risk $p < 0.001$

Sarah C. Darby et al Risk of Ischemic Heart Disease in Women after Radiotherapy for Breast Cancer NEJM 2013

Technique of Sparing of Heart

- Breast Board
- Prone position
- Heart block
- 3D conformal radiotherapy (3DCRT)
- Intensity modulated Radiotherapy (IMRT)
- Tomotherapy
- Respiratory maneuvers
- APBI
- Proton therapy

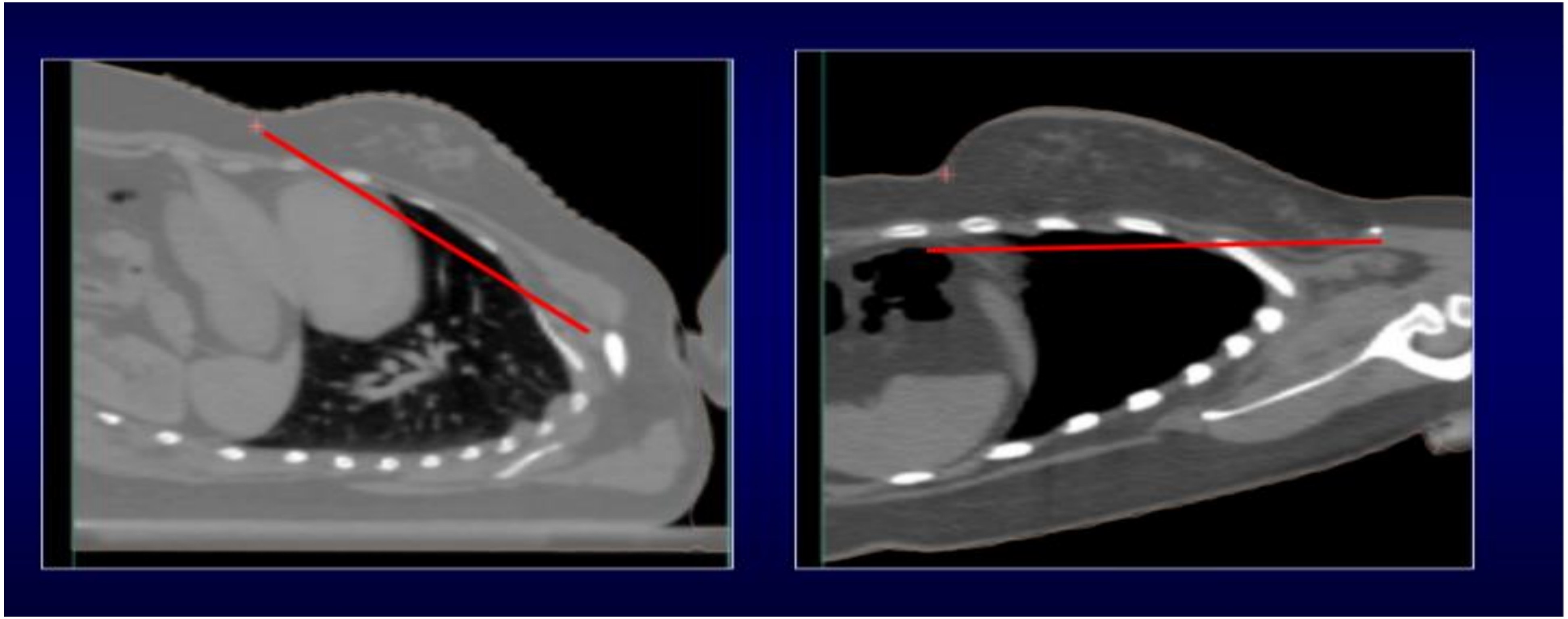
Breast Board

- Improves the angle of treatment along the chestwall to spare the anterior heart
- The tissues of the breast move forward with the slant of the board and higher arm elevation, allowing for less inclusion of tissues deep to the chestwall
- Improvements in the position have been shown to reduce the mean cardiac dose by as much as 60% and the maximum dose to the heart by 30% in comparison to treatment with flat positioning and collimation
- Proper setup and immobilization can decrease cardiac dose.

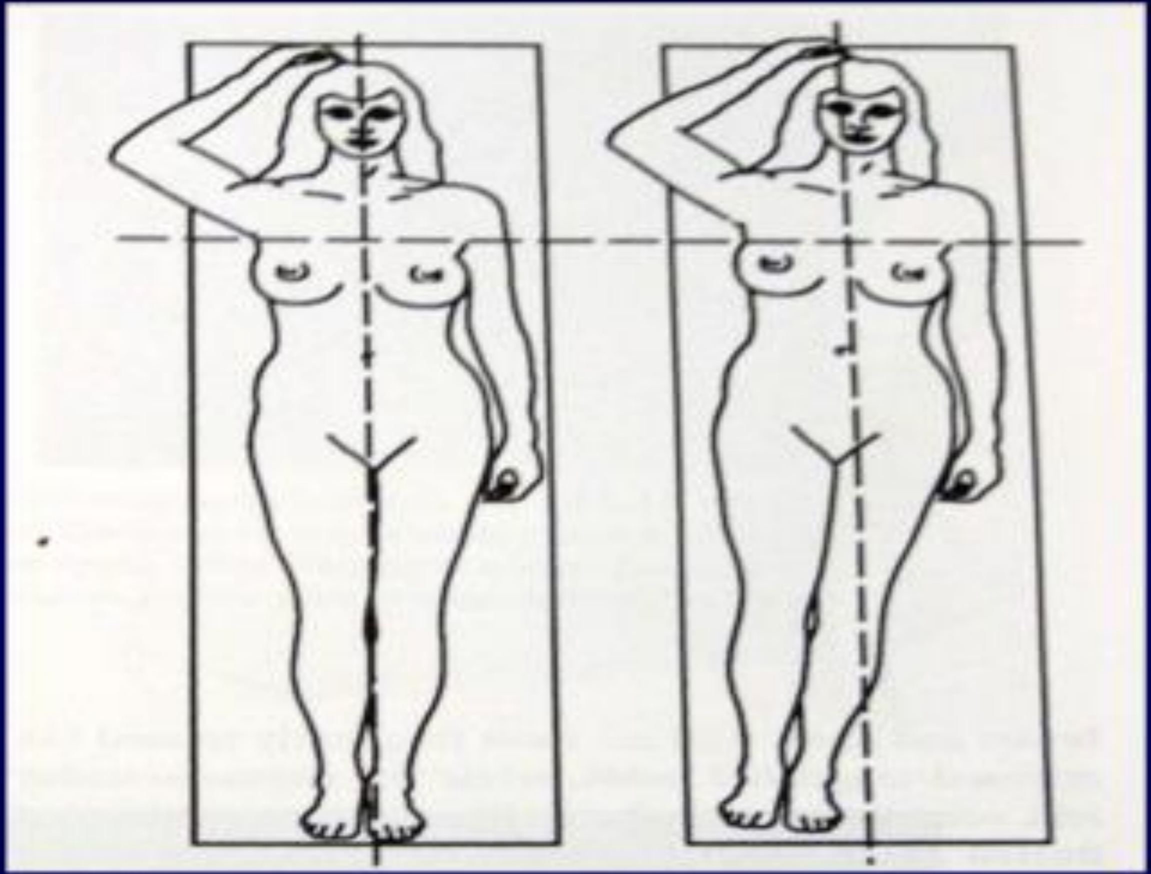
Canney PA et al: Reducing cardiac dose in post-operative irradiation of breast cancer patients: The relative importance of patient positioning and CT scan planning. Br J Radiol 1999

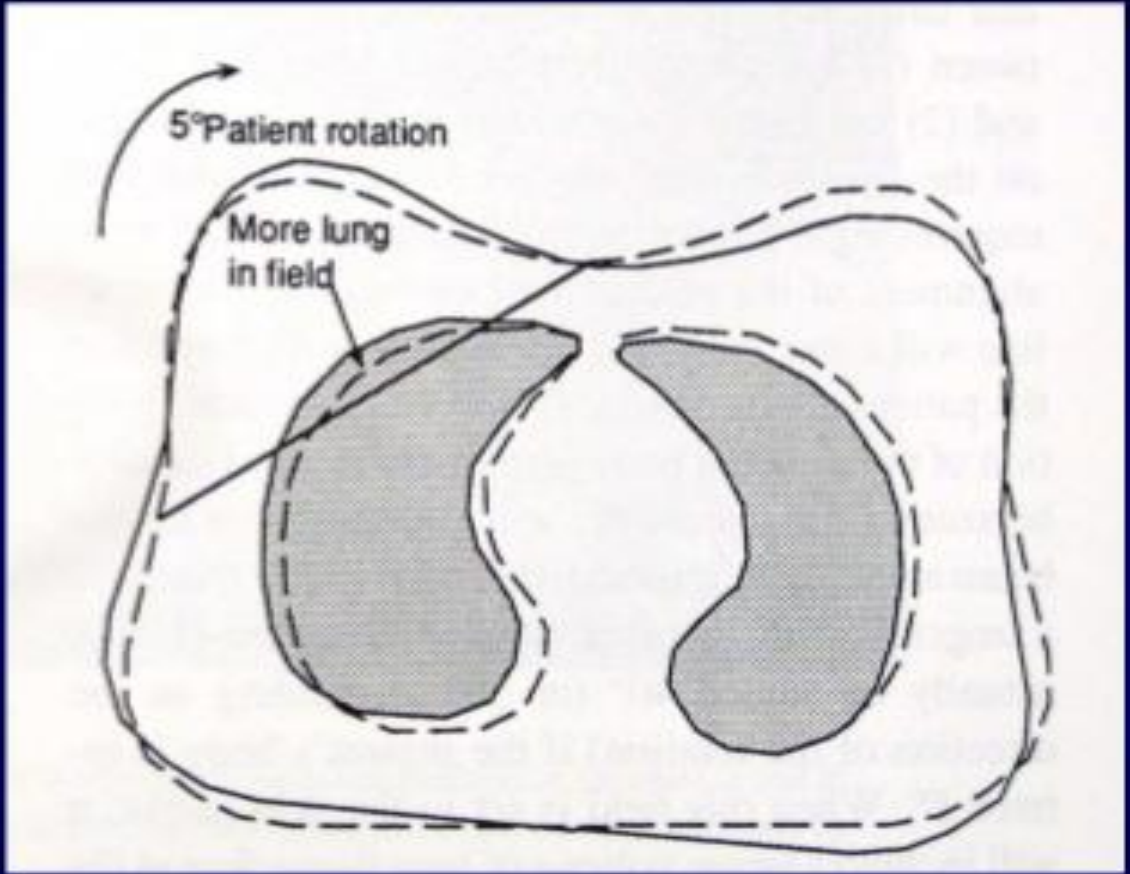
Canney PA et al: Variation in the probability of cardiac complications with radiation technique in early breast cancer. Br J Radiol 2001

Breast Board

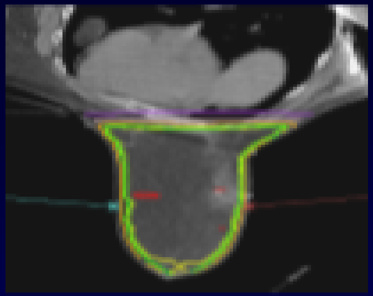


Importance Of Positioning

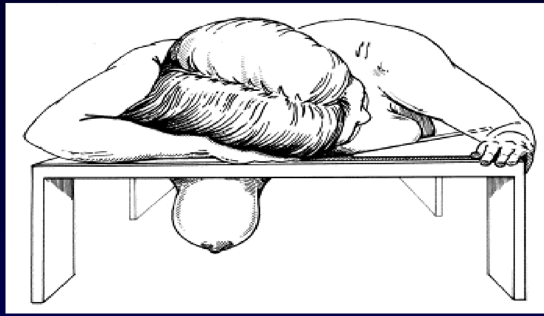




A small misalignment of the pt. on the couch will have the same effect as if the couch were angled



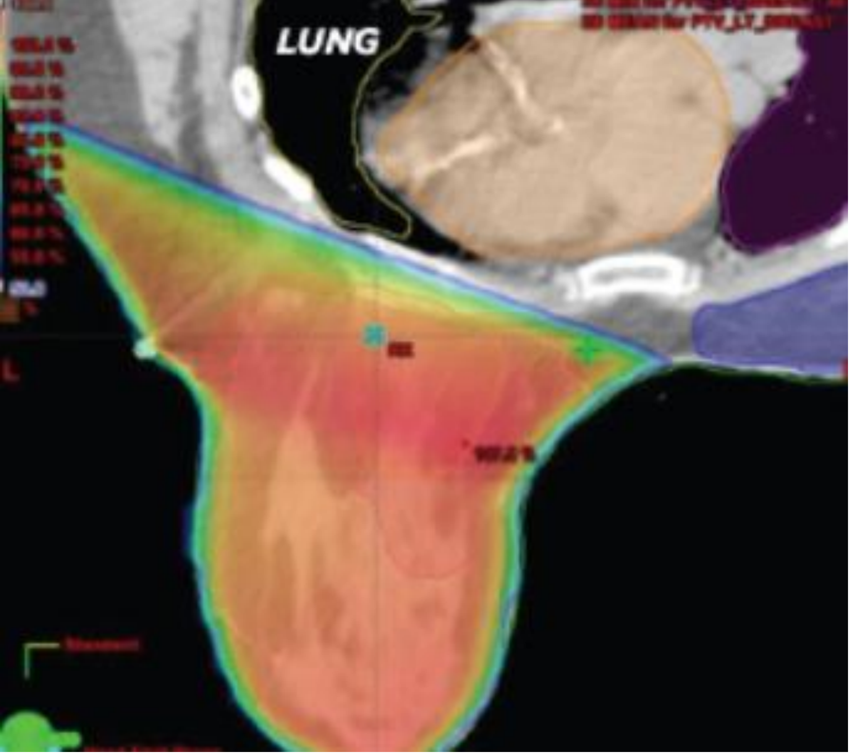
Prone Position

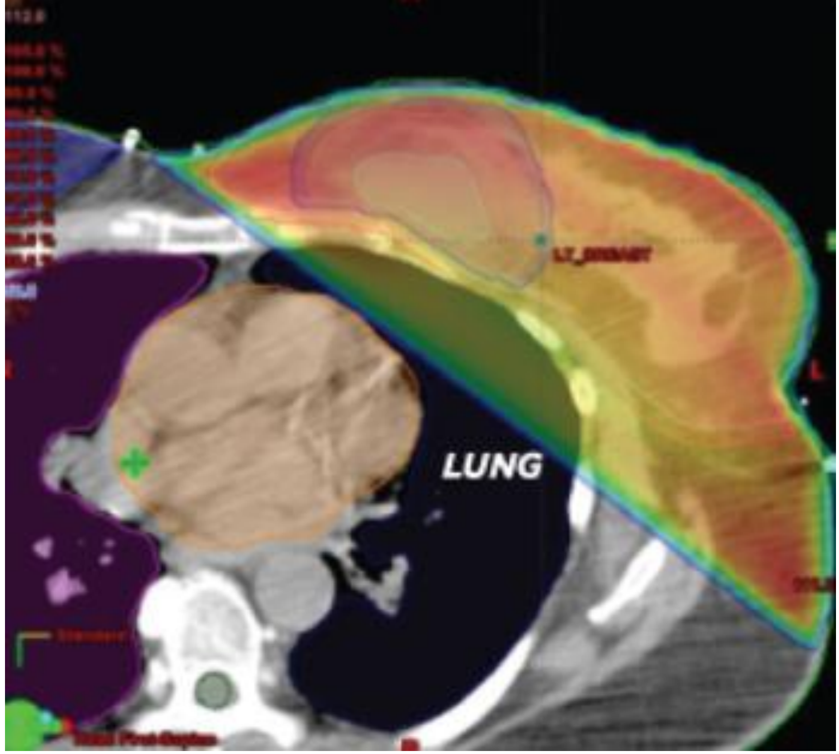


- An alternative to improve cardiac positioning and dose homogeneity throughout the breast.
- Review 200 women simulated with both prone and supine positioning
- Prone positioning decreased the volume of heart in the field for 85% of the patients (with only15% of women having lower cardiac volume with standard supine treatment).
- The reduction in cardiac volumes was 87% (8.8-1.3cm3).
- Although the benefit in women with < 750 cm^3 volume breasts did not reach statistical significance
- Women of all breast volumes had a reduction in cardiac volume with the greatest effect noted in larger breast volumes

Formenti SC et al: Prone vs supine positioning for breast cancer radiotherapy. J Am Med Assoc, 2012

Prone Breast Board





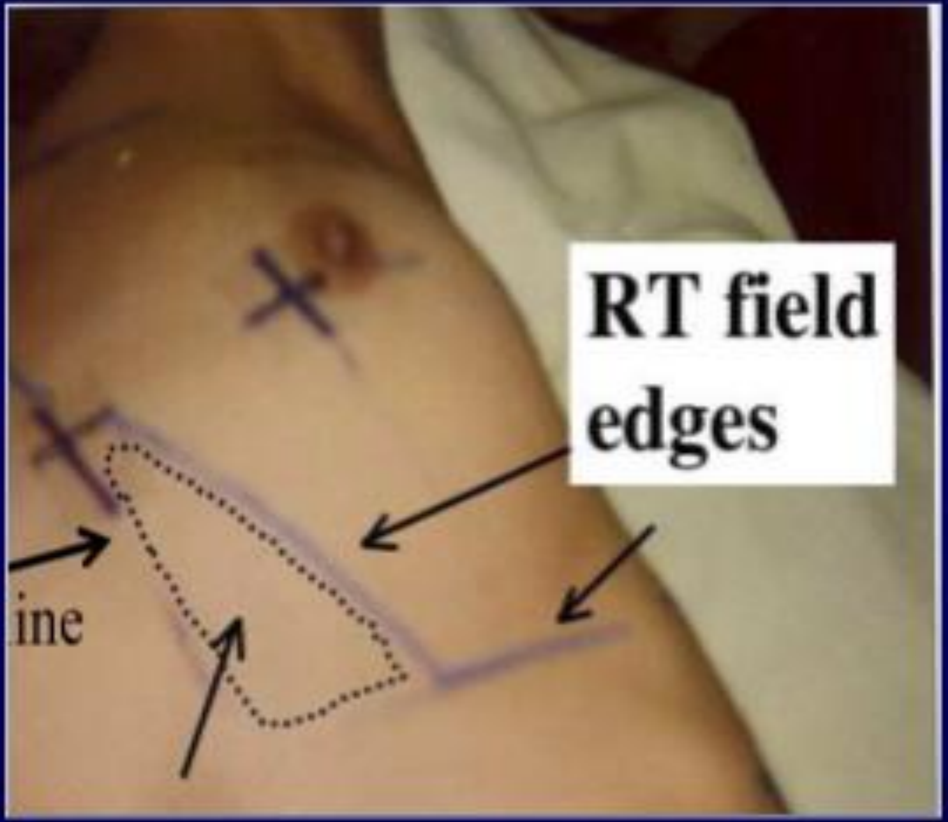
- **<u>LIMITATIONS:</u>**

- Who cannot tolerate prone decubitus- common complaint is pain from tension on neck and spine muscles to maintain position

- CT bore, Patient weight, Knee issues

Heart Block

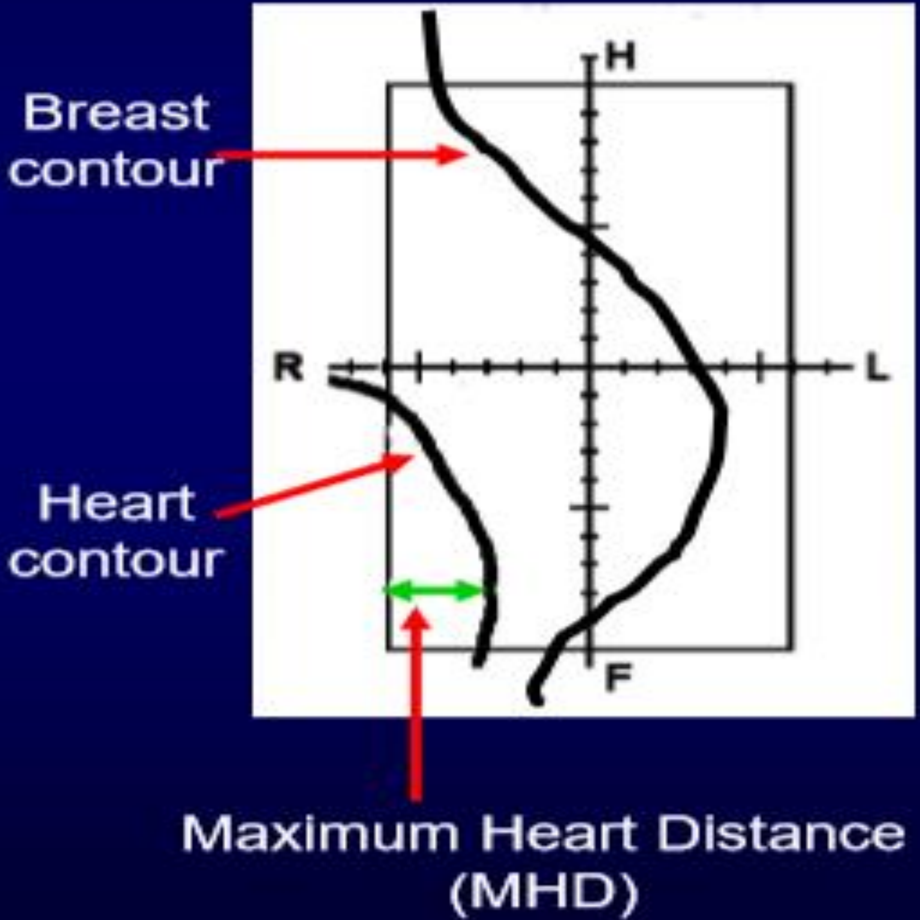
- Customized blocks
- May be appropriate, particularly in patients with well-visualized surgical beds.
- Average percentage of breast tissue that may be under dosed is 2.8%.
- Overall, local recurrence rates were not significantly different between patients with field heart blocks vs those without blocks.

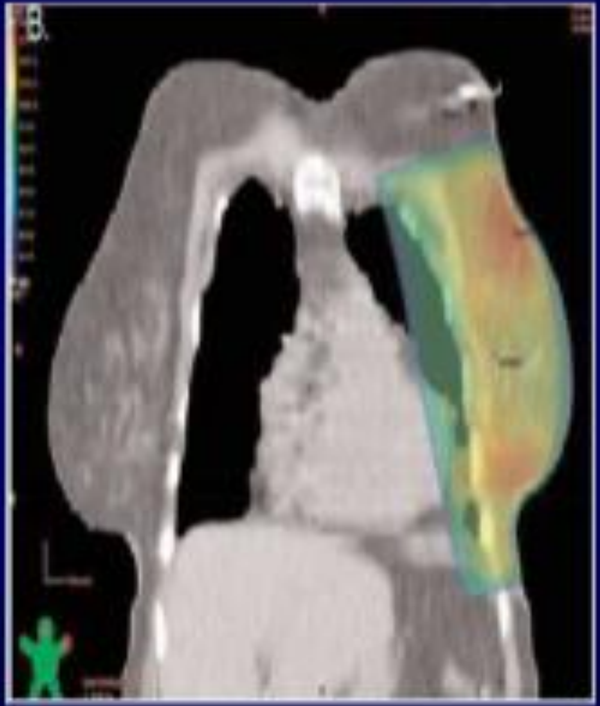


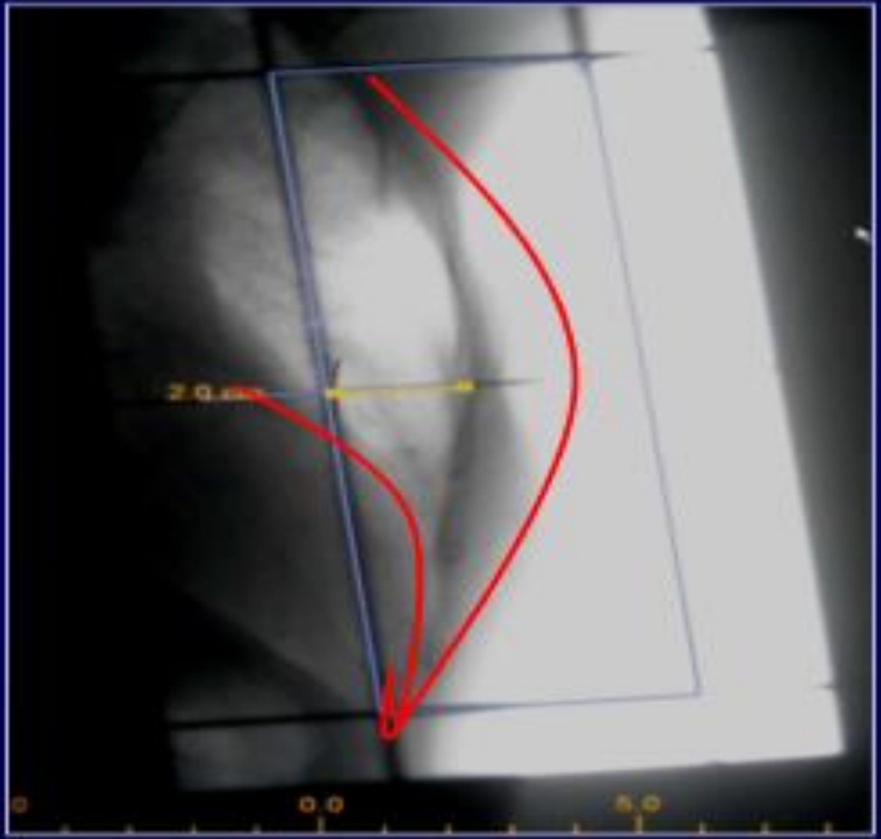
Raj KA et al: Is there an increased risk of local recurrence under the heart block in patients with left-sided breast cancer? Cancer J 1, 2006

Heart Block

field







Heart Block

Marks IJROBP 1994

Left side RT

- Intact Breast
  - Superior tumor
    - Heart Block
  - Inferior Tumor
    - Tangent angle
    - DIBH
    - Electron Patch

- Mastectomy
  - Tangent angle
  - DIBH
  - Electron

Newer RT techniques

- Technological advancements in the RT technique has improved over the time
- Shift from orthovoltage cobalt to MV
- 2D to 3D planning
- Improvement in PTV coverage
- Decrease in OARdoses
- Use of 3DCRT, IMRT, Helical Tomotherapy

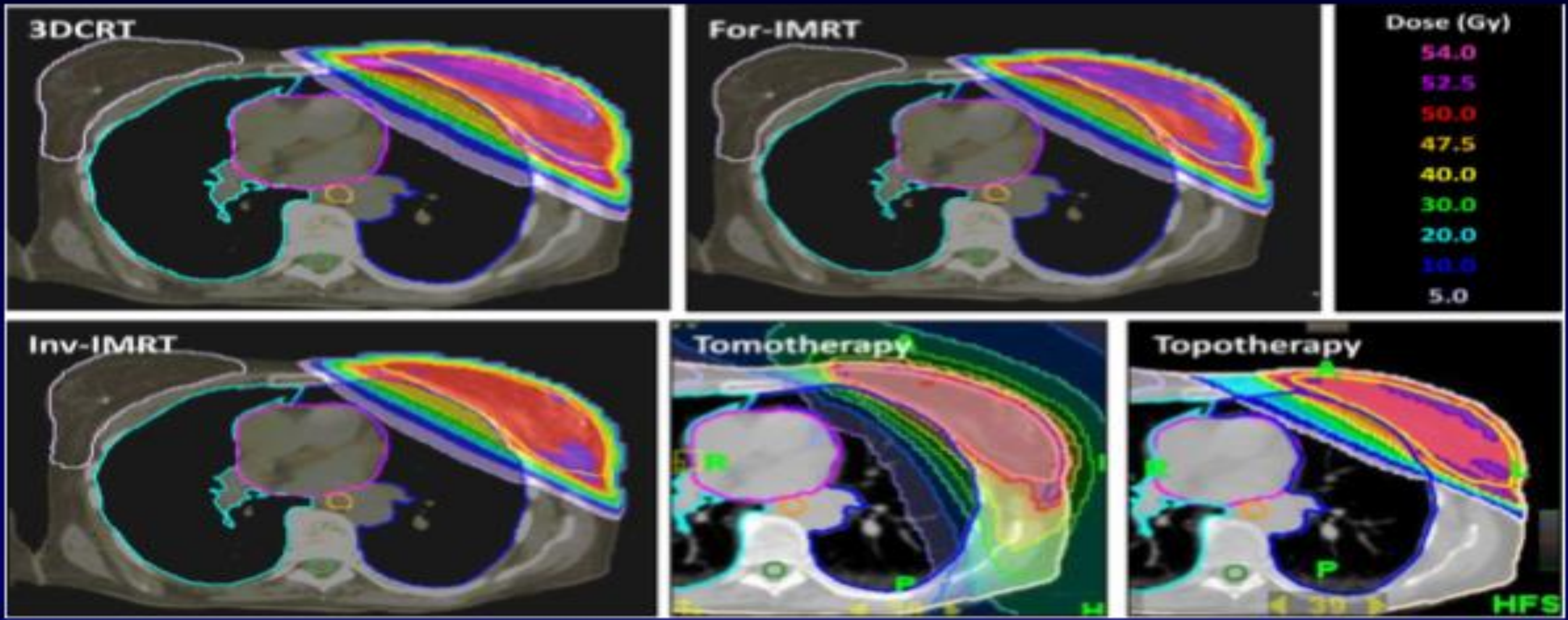
Comparison of different techniques

Comparison of normal tissue dose volume metrics as a function of plan modality.

Metric	3DCRT	For. IMRT	Inv. IMRT	Tomotherapy	Topotherapy	p-Value
Heart						
D_{mean} (Gy)	2.6 ± 0.9	2.3 ± 0.9	1.9 ± 0.8	3.9 ± 1.3	1.9 ± 0.7	0.002
D_{max} (Gy)	50.8 ± 3.5	49.1 ± 5.0	44.0 ± 7.2	33.9 ± 7.7	46.1 ± 5.9	<0.001
V_5 (%)	7.6 ± 3.5	6.6 ± 3.5	5.0 ± 3.1	26.5 ± 18.4	4.7 ± 2.7	0.003
V_{10} (%)	4.2 ± 2.5	3.8 ± 2.4	2.5 ± 2.0	4.8 ± 4.4	3.3 ± 2.2	0.354
V_{20} (%)	2.0 ± 1.6	2.2 ± 1.7	1.2 ± 1.4	0.5 ± 0.4	1.6 ± 1.4	0.010
V_{50} (%)	0.3 ± 0.5	0.1 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.1	<0.001

10 patients with left breast RT

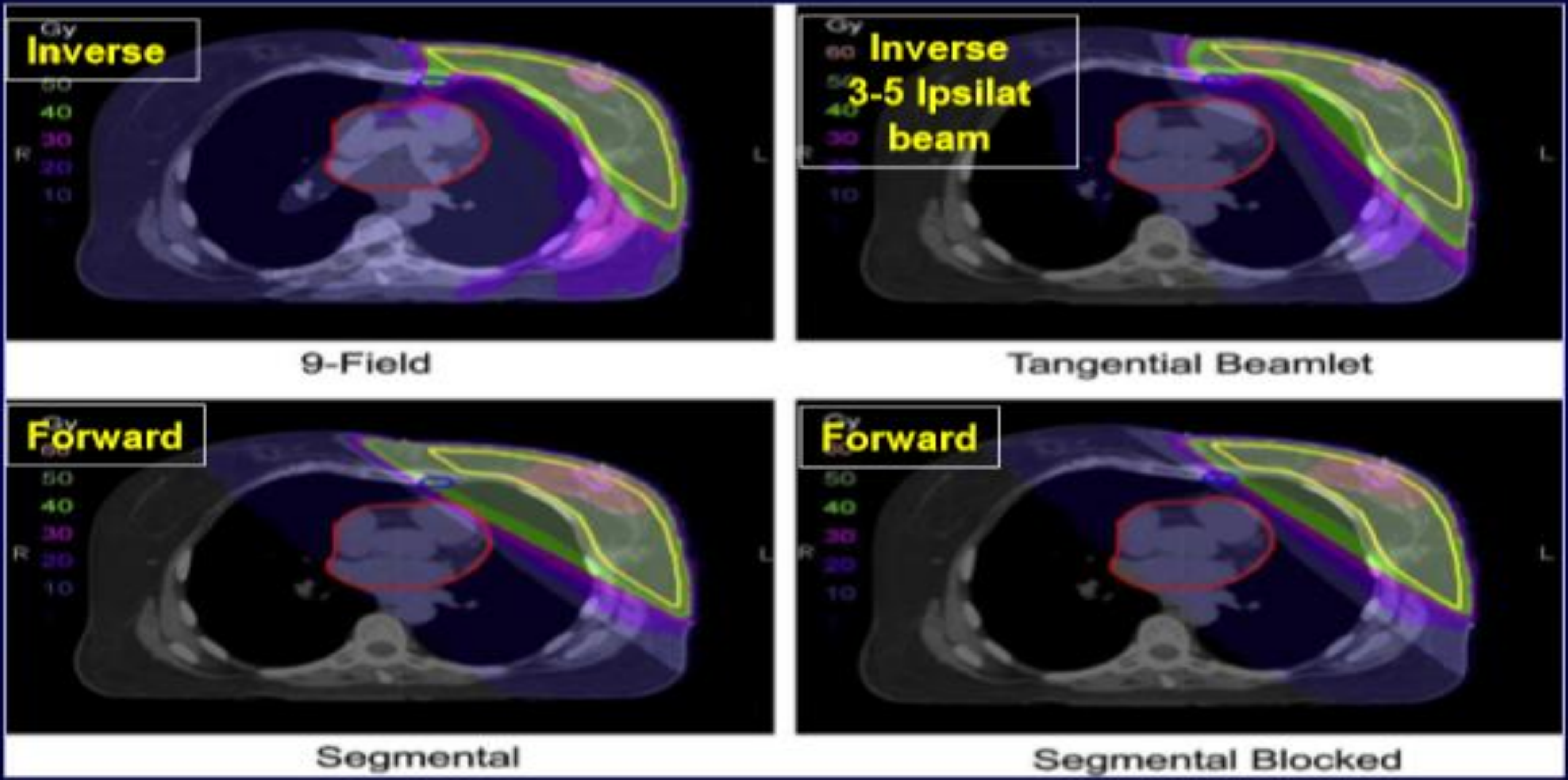
Leah K. Schubert et al Dosimetric comparison of left-sided whole breast irradiation with 3DCRT, forward-planned IMRT, inverse-planned IMRT, helical tomotherapy, and topotherapy, radiotherapy & Oncology 2011



Results: Target max doses were reduced with for-IMRT compared to 3DCRT, which were further reduced with HT, topotherapy, and inv-IMRT. HT resulted in lowest heart and ipsilateral lung max doses, but had higher mean doses. Inv-IMRT and topotherapy reduced ipsilateral lung mean and max doses compared to 3DCRT and for-IMRT.

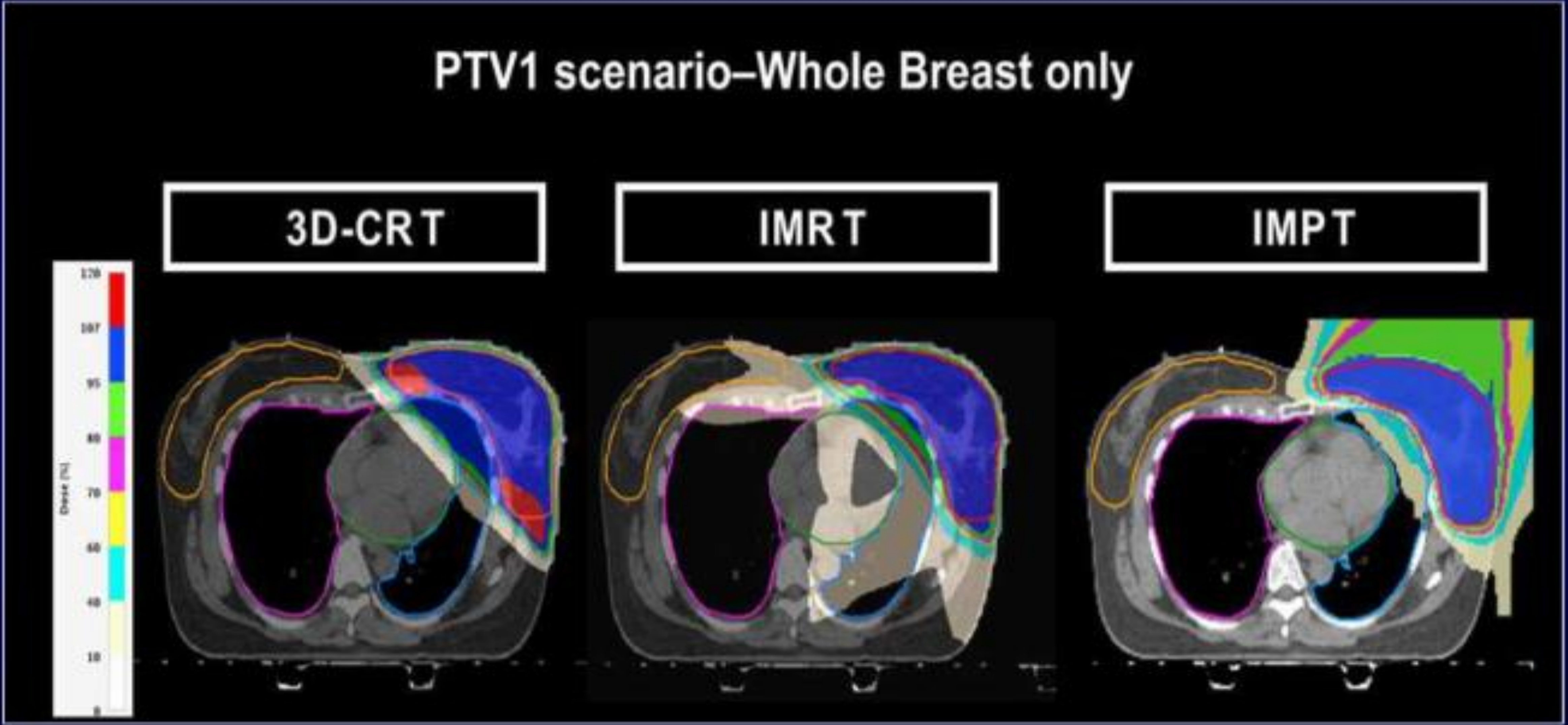
Leah K. Schubert et al Dosimetric comparison of left-sided whole breast irradiation with 3DCRT, forward-planned IMRT, inverse-planned IMRT, helical tomotherapy, and topotherapy, radiotherapy & Oncology 2011

IMRT techniques



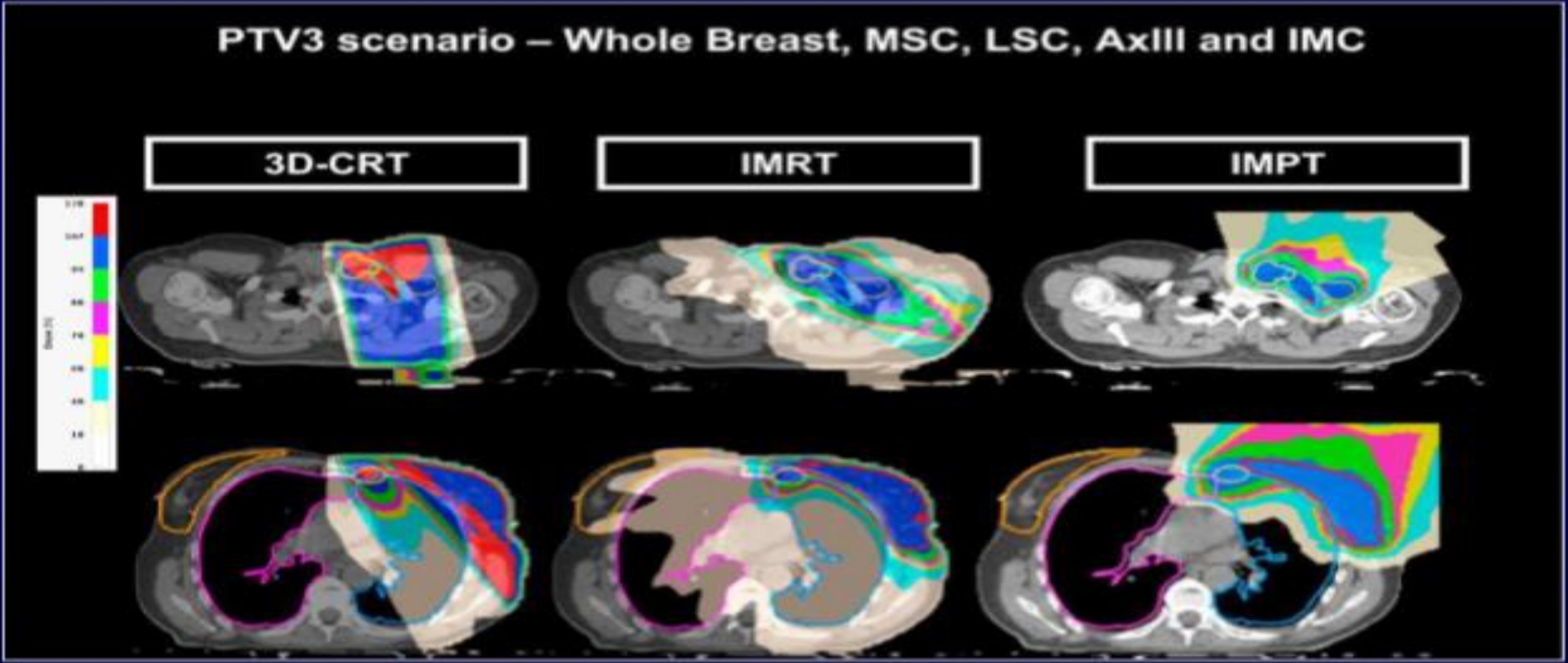
Reshma Jagsi et al; evaluation of 4 different technique of IMRT; IJROBP 2010

Proton Therapy

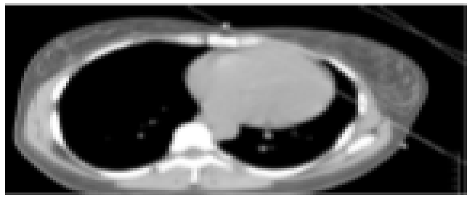


Carmen Ares, Proton Therapy , IJROBP - 2010

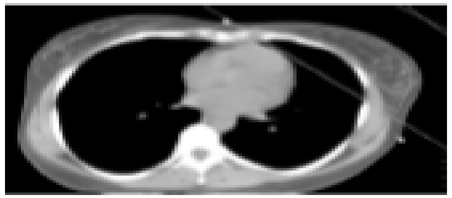
Proton Therapy



Carmen Ares, Proton Therapy , IJROBP - 2010



How to Spare Heart?
Deep Inspiratory Breath Hold



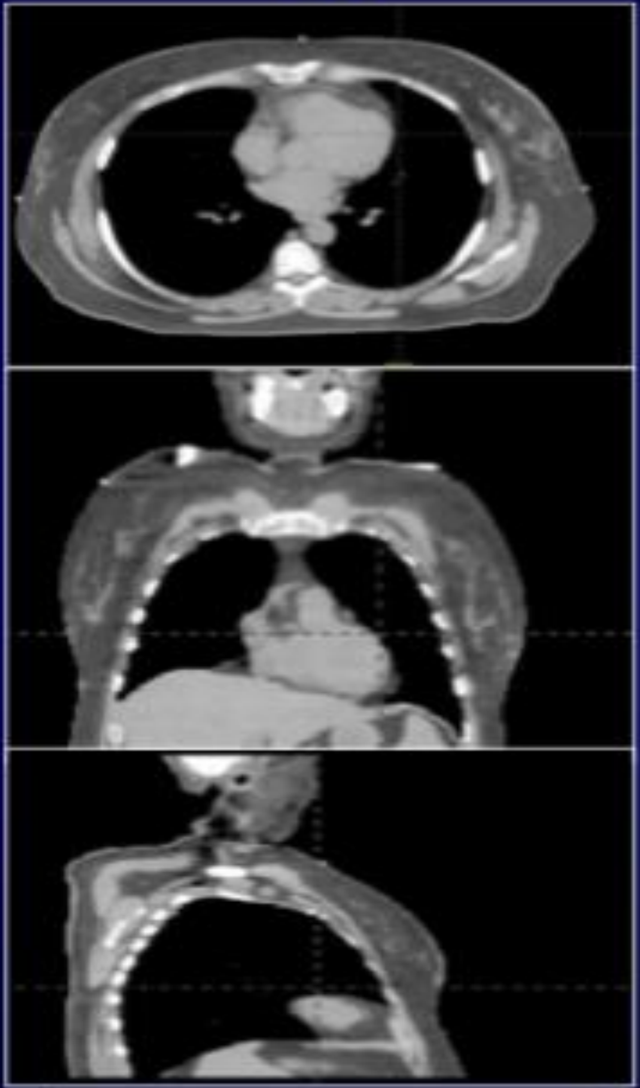
- stage I and II left sided breast cancer and treatment delivered with step and shoot IMRT.

	Heart V30 FB (%)	Heart V30 BH (%)	Maximum Heart Distance (cm) FB	Maximum Heart distance (cm) BH
1	3.6%	0%	1.7	0
2	3.3%	0.6%	1.4	0.7
3	2.3%	0.1%	1.2	0.3
4	5.9%	0.1%	1.8	0.5
5	9.7%	0.1%	2.1	0.2

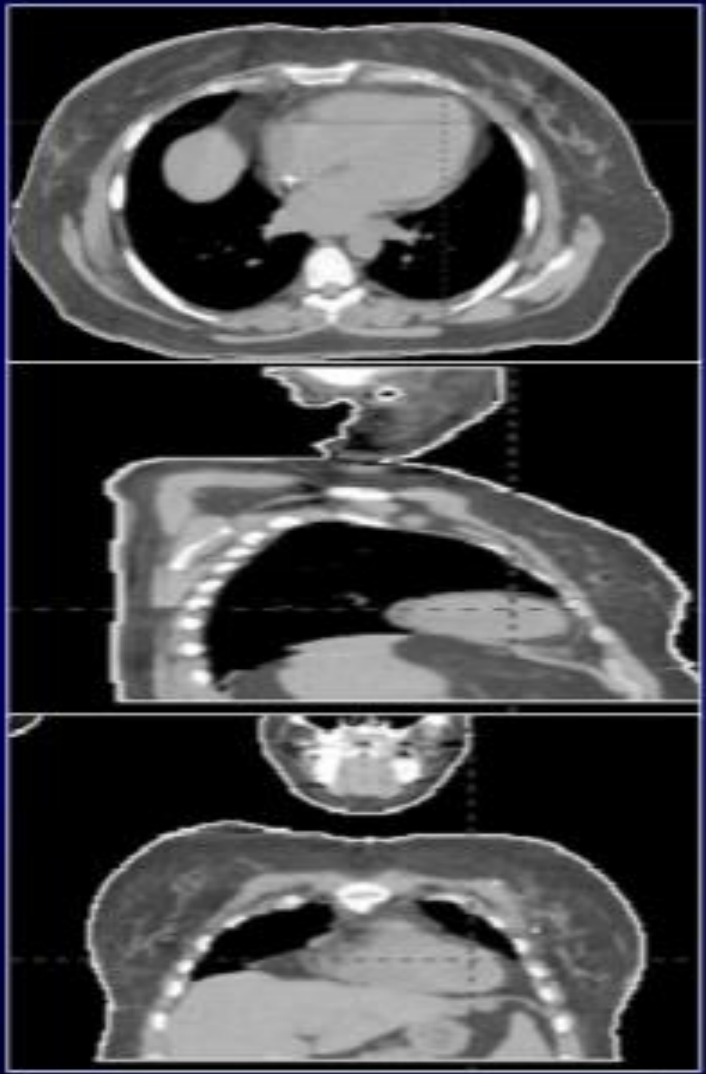
Michigan

Remouchamps VM et al, IJROBP. 2003;56(3):704-15

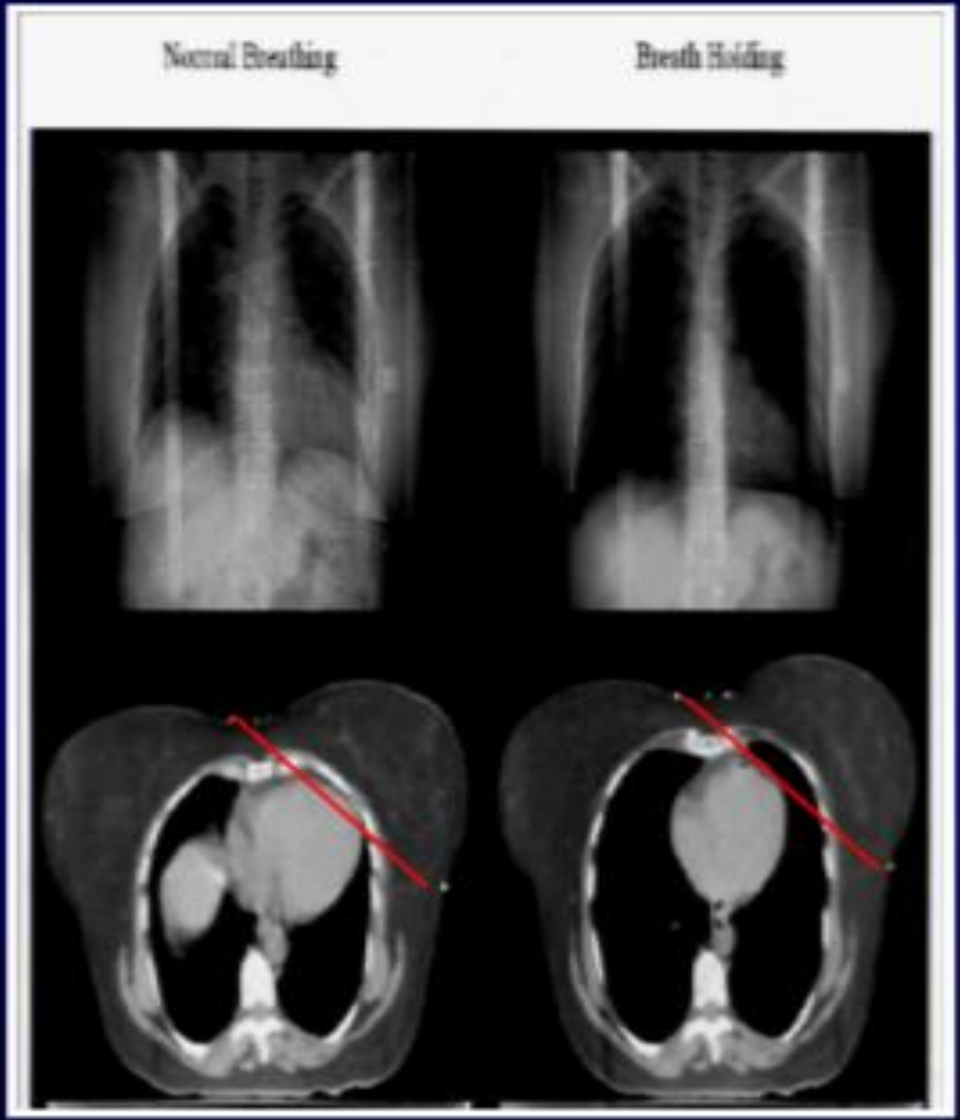
Gating and Deep Inspiration Breathing Techniques



DIBH



Active Breathing



Deep Insipiratory Breath Hold

- Deep insipiratory breath hold is a respiratory motion management technique.
- PURPOSE –
  - Eliminating motion
  - Increasing lung volume [less lung in RT field]
  - Push heart away from chest wall & RT field
  - Smaller ITV
  - No blurring of images as in 4D imaging

Gating and Deep Inspiration Breathing Techniques

- Deep inspiration breathhold (DIBH) involves gating radiation to deliver treatment when the least volume of heart is in the field
- Inferior and posterior displacement of the cardiac silhouette caused by near maximal inspiration
- ~50% cases Heart could been entirely removed from the field and that cardiac volumes were reduced by approximately 80%
- Comparisons of techniques found that median heart volume receiving greater than 50% of the dose was decreased from 19 % to ≤3% with either inspiratory gating or DIBH

Gating and Deep Inspiration Breathing Techniques

- Active breathing may be combined with treatment modalities such as fixed gantry IMRT as well. The reduction in V30 using DIBH for deep tangent IMRT plans was on average 13%-3%
- With active breathing techniques, there is an average reduction of 5% to the volume near the left anterior descending (LAD) receiving 20Gy or more when using fixed gantry angle IMRT over 3D conformal radiation therapy(CRT)

- Remouchamps VM et al: Significant reductions in heart and lung doses using deep inspiration breath hold with active breathing control and intensity-modulated radiation therapy for patients treated with locoregional breast IJROBP 2003
- Mast ME et al: Left-sided breast cancer radiotherapy with and without breath-hold: Does IMRT reduce the cardiac dose even further ? Radiother Oncol 2013

VBH (Voluntary Breath Hold)
vs
Prone

Estimated breast volume of >750 cm3

Frederick R. Bartlett UK Heart Spare Study Radiotherapy and Oncology 2015

VBH (Voluntary Breath Hold)
vs
Prone

- All cardiac dose parameters (Gy) were statistically significantly lower with VBH than prone treatment

- Heart NTDmean 0.44 [0.38–0.51] vs. 0.66 [0.61–0.71] ($p < 0.001$)

- LAD NTDmean 2.9 [1.8–3.9] vs. 7.8 [6.4–9.2] ($p < 0.001$)

- LADmax 21.0 [15.8–26.2] vs. 36.8 [35.2–38.4] ($p < 0.001$)

Frederick R. Bartlett UK Heart Spare Study Radiotherapy and Oncology 2015

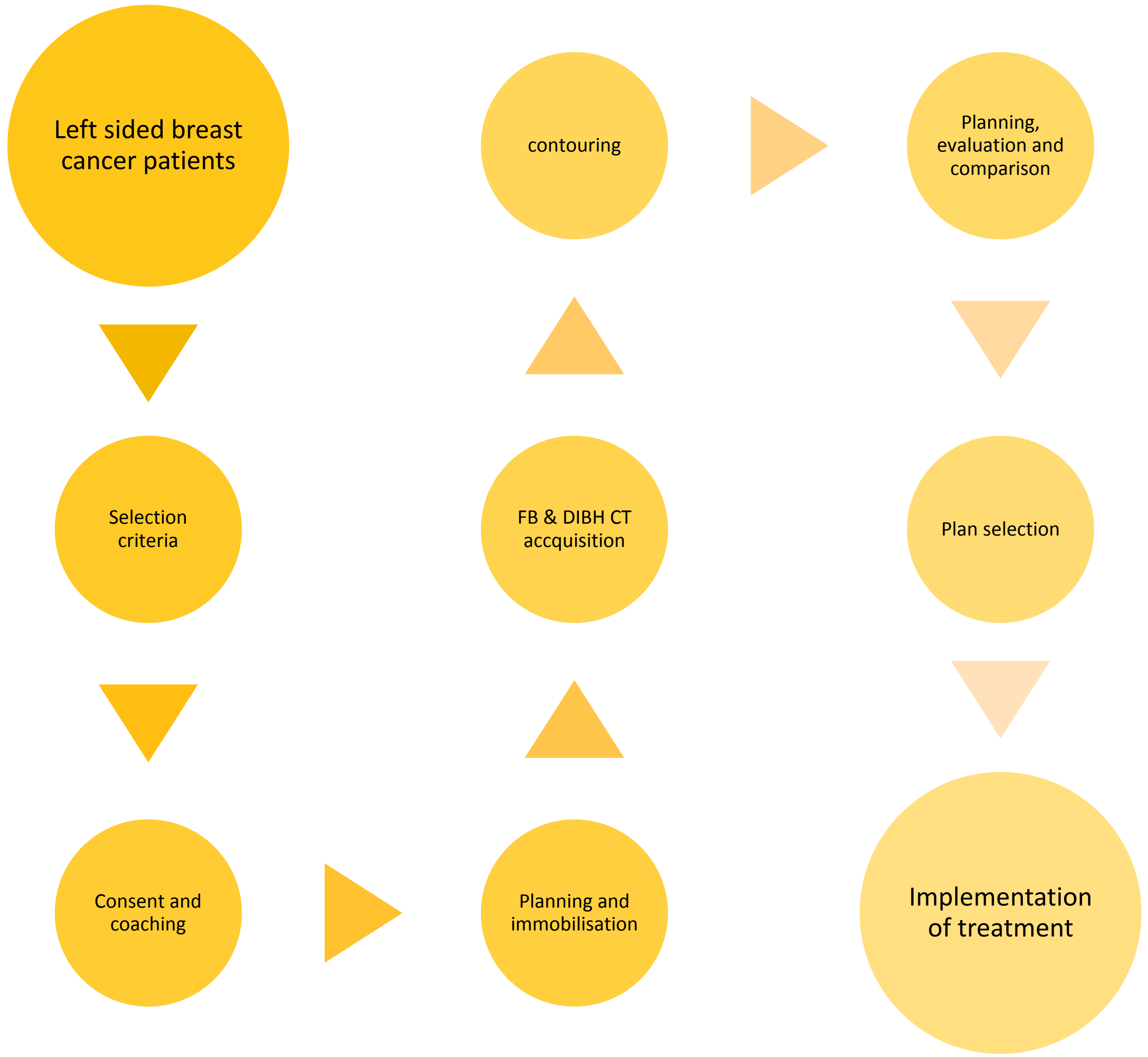
INCLUSION CRITERIA

- Left sided breast cancers [CW +/- SCF, IMN]
- Ability to comprehend
- Ability to breathe and hold a specific volume
- Cardiac dose reduction in plan made on DIBH scan [*Rochet et al* observed the benefit in 75% patients]
- Age <60 years [*Nissen et al, Radiotherapy and Oncology, 2013*]

EXCLUSION CRITERIA

- Poor comprehension/Inability to carry out as instructed
- Lung diseases or respiratory symptoms
- Physical discomfort
- Severe claustrophobia
- Very small volume of inspiratory breath hold <0.8 ml [*Wang etal IJROBP 2012],* heart V30 < 2% [*Swanson et al, Am Journal of Clinical Oncology 2013]*

WORK FLOW


Left sided breast cancer patients
Selection criteria
Consent and coaching
Planning and immobilisation
FB & DIBH CT accquisition
contouring
Planning, evaluation and comparison
Plan selection
Implementation of treatment

TECHNIQUES

Active breath coordinator [ABC] system

- Elekta
- Developed at the William Beaumount hospital, Michigan

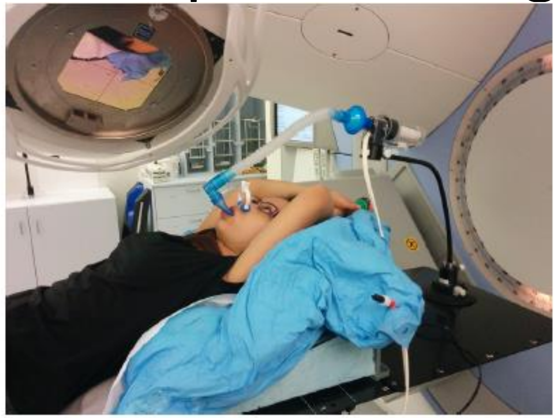


Figure 1. Demonstration of an active breathing coordinator (ABC) set up. The green thumb switch held in the right hand must be pressed during the breath hold manoeuvre; the release of the button signals interruption of breath-hold. Photo courtesy of Nepean Cancer Care Centre.

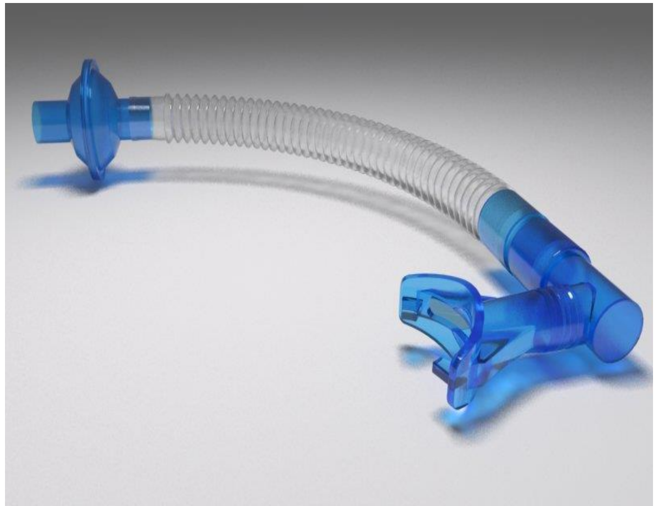
Voluntary breath hold – Real time position management [RPM]

- Varian
- Developed at the University of California Davis Cancer Centre

Figure 2. Demonstration of a real-time position (RPM) set up with the marker box (block) positioned on the xiphoid process. Visual feedback is provided using modified video goggles. Photo courtesy of Crown Princess Mary Cancer Centre.

EQUIPMENT-ABC

- Mouth piece with filter
- Spirometer with closing valve
- Nose clip
- Breath controlling trigger
- ABC software and hardware – screen for patient and health care provider
- Link with linear accelerator to start and stop treatment

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EQUIPMENT – RPM FOR vDIBH

- 6-marker neon localizer box
- Goggle
- Infrared camera
- Infrared lights
- Hardware to observe respiratory pattern
- Link with linear accelerator to start and stop treatment

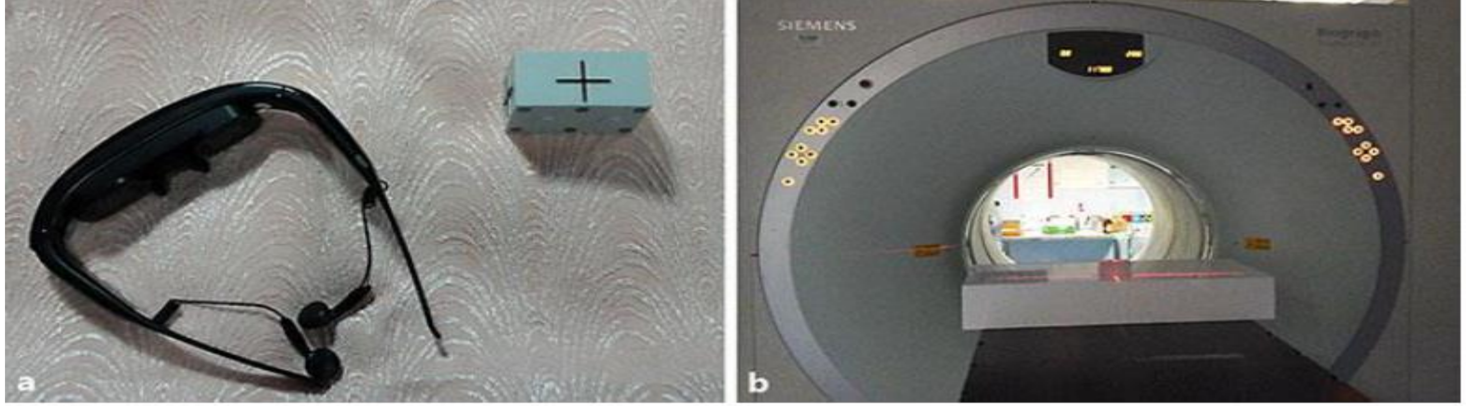
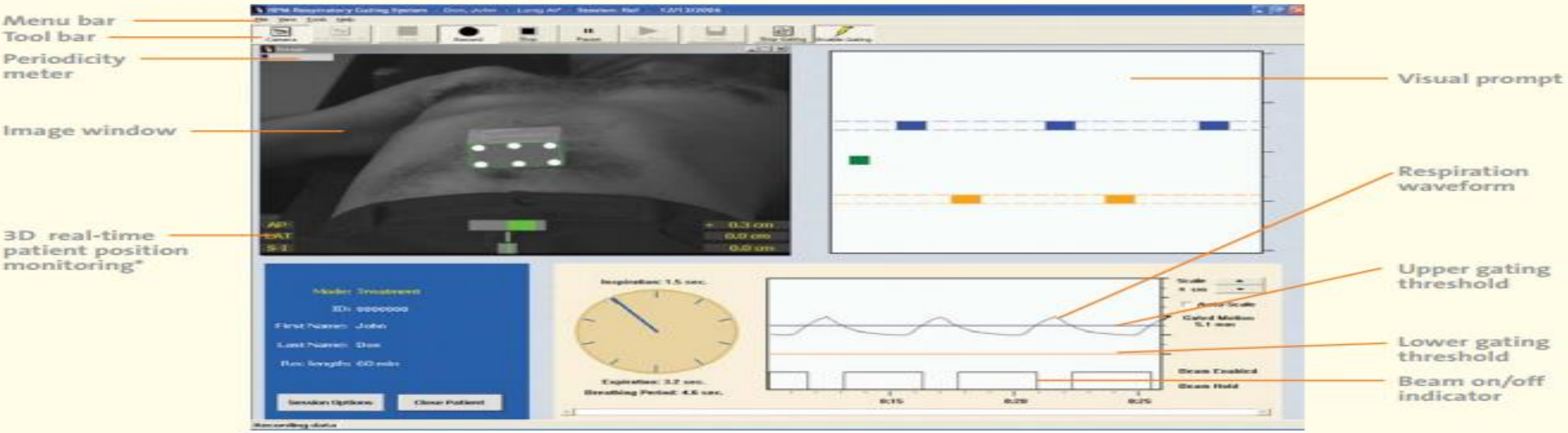


Fig. 2. **a** The 6-marker neon localizer box with crosshairs and goggle. **b** Calibration setup with fi:
couch position using lasers.



RPM software runs on the PC workstation. RPM workstations are networked to a multi-user gating database.

MAJOR COMPONENTS OF THE RPM SYSTEM

Infrared tracking camera

Predictive Filter

Figure 2. Demonstration of a real-time position (RPM) set up with the marker box (block) positioned on the xiphoid process. Visual feedback is provided using modified video goggles. Photo courtesy of Crown Princess Mary Cancer Centre.

COMPARISON - PRO

- ABC has
  - a screen to guide the patient during the process
  - Mouth piece and spirometer helps fix volume as per patient’s capacity
  - Breath control trigger ensures treatment disruption in the event of unexpected situations
  - Higher reproducibility

RPM - Pro

- RPM has
  - Infra red pattern that depicts movement of the chest wall surface at the level its placed
  - Automatically turns on and off the beam when inspiration is in the decided threshold-GATING of the beams

COMPARISON - CONS

- ABC
  - Complicated with multiple pieces
  - Mouth piece and nose clip may be uncomfortable
  - Leaking of air from the sides of the mouth piece
  - Euipment might obstruct the gantry movement
  - Cost factor of the mouth piece.

RPM - Cons

- RPM
  - No mechanism to help patient hold the volume for the duration fixed [mouth piece, balloon valve, nose clip].

  - Reduced duty cycle time

- The reproducibility of the setup and dosimetric benefit are comparable in both vDIBH and ABC

- *Barlett et al*
- *Frederick et al [Radiotherapy and oncology, 2013]*

PATIENT COACHING

- The process, equipment to be used and their participation must be explained to the patient

- They should be made to practise breath hold for 15-20 minutes with the equipment before acquiring scan

- A visual aid for the patient [goggle/screen displaying the volume, threshold and time] helps achieve the right threshold of volume and time

SCAN ACQUISITION

- With the setup, both scans are acquired free breathing and the deep inspiration breath hold positioning and immobilisation
- The volume and duration of breath hold are decided as per individual patient
- Volume – 1-1.8 litres, time – 20-25 seconds
- In ABC, the volume and time threshold are fed into the system to ensure each breath hold is same
- In RPM, the patient is coached to produce and hold the same breathing and DIBH pattern

Remouchamps et al IJROBP 2003

Radiotherapy and Oncology 106 (2013) 28–32

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Breast cancer

Improved heart, lung and target dose with deep inspiration breath hold in a large clinical series of breast cancer patients

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Target coverage

ABSTRACT

Background and purpose: This study aims at evaluating the effect of deep-inspiration breath hold (DIBH) on target coverage and dose to organs at risk in a large series of breast cancer patients.

Materials and methods: Clinical dose plans for 319 breast cancer patients were evaluated: 144 left-sided patients treated with DIBH and 175 free-breathing (FB) patients (83 left-sided and 92 right-sided). All patients received whole breast irradiation with tangential fields, based on a forward-planned intensity-modulated radiation therapy (IMRT) technique. Dose to heart, ipsi-lateral lung and ipsi-lateral breast were assessed and median values compared between patient groups.

Results: Comparing group median values, DIBH plans show large reductions of dose to the heart compared with left-sided FB plans; V_{20Gy} (relative volume receiving $\geqslant$20 Gy) for the heart is reduced from 7.8% to 2.3% (−70%, $p < 0.0001$), V_{40Gy} from 3.4% to 0.3% (−91%, $p < 0.0001$) and mean dose from 5.2 to 2.7 Gy (−48%, $p < 0.0001$). Lung dose also shows a small reduction in V_{20Gy} ($p < 0.04$), while median target coverage is slightly improved ($p = 0.0002$).

Conclusions: In a large series of clinical patients we find that implementation of DIBH in daily clinical practice results in reduced irradiation of heart and lung, without compromising target coverage.

 Radiotherapy and Oncology 106 (2013) 28–32

Int J Radiat Oncol Biol Phys. 2003 Feb 1;55(2):392-406.

Significant reductions in heart and lung doses using deep inspiration breath hold with active breathing control and intensity-modulated radiation therapy for patients treated with locoregional breast irradiation.

Remouchamps VM[1], Vicini FA, Sharpe MB, Kestin LL, Martinez AA, Wong JW.

- DT-IMRT and DT- wedged 3DCRT plans were used
- Heart V 30% was reduced by 81%.
- Heart was completely out of the radiation field in 2 of the 9 patients.
- Lung V20 was reduced from 20.4% to 15.3%

Darapu et al.: Is the Deep Inspiration Breath-Hold Technique Superior to the Free Breathing Technique in Cardiac and Lung Sparing while Treating both Left-Sided Post-Mastectomy Chest Wall and Supraclavicular Regions?

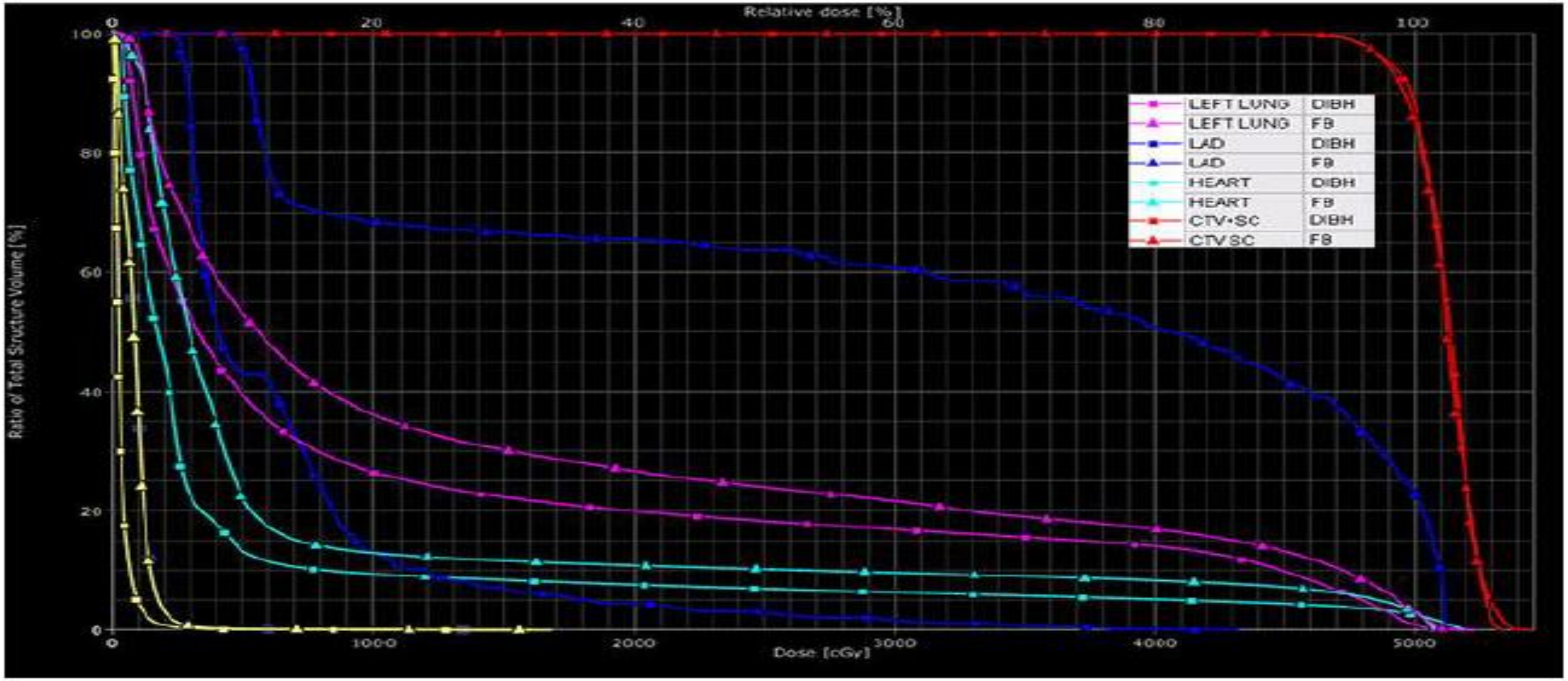

Fig. 6. Plan computed dose-volume histogram of FB (triangles) and DIBH (squares).

Darapu et al, Case Report Oncology, 2017

IMRT for breast cancer - Conclusion

- Small size breast:Not to do IMRT
- Bi-tangential portals: Best beam arrangement
- 3D planning standard in modern era
- However may not be necessary in small and medium size breast
- Large breast > 1000cc IMRT may be considered
- In case IMRT is needed: Forward planned IMRT
- Forward planned IMRT: Better in terms of acute and late effects as compared to standard tangents
- Cardiac sparing is extremely important
- Respiratory gating, Image guidance are important in such situations

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