Treatment Planning Fundamentals

Basics of Breast Planning

Cases Involving
Regional Lymph Node Irradiation

Rebecca M. Howell, PhD, DABR
Associate Professor

THE UNIVERSITY OF TEXAS
MD Anderson Cancer Center

Making Cancer History®

Background

- **Recent studies have demonstrated a clear benefit from regional node irradiation (RNI) in terms of absolute reductions in both recurrence and mortality in post-mastectomy breast cancer patients with node positive disease, even those with ≤ 3 +nodes (Darby *et al.* Lancet 2014).**

- **Similar benefits from RNI are suggested by recent, but unpublished studies, for patients who underwent breast conserving surgery (MA.20 EORTC 22922).**

Rationale and Objective

- **While, the topic of RNI remains hotly debated within the radiation oncology community, there is a trend toward more frequent inclusion of RNI in breast and chest wall radiotherapy.**

Objective:

To discuss the fundamentals of breast treatment planning for cases requiring RNI focusing on beam design and methods to reduce lung and heart dose.

Left sided breast and chest wall cases?

How is dose to heart minimized?

Deep Inspiration Breath Hold (DIBH)

Deep Inspiration Breath Hold (DIBH)

Many Techniques

- Active-breathing control
- Self-held breath control
  - without respiratory monitoring
  - with respiratory monitoring
  - with respiratory monitoring and feedback guidance

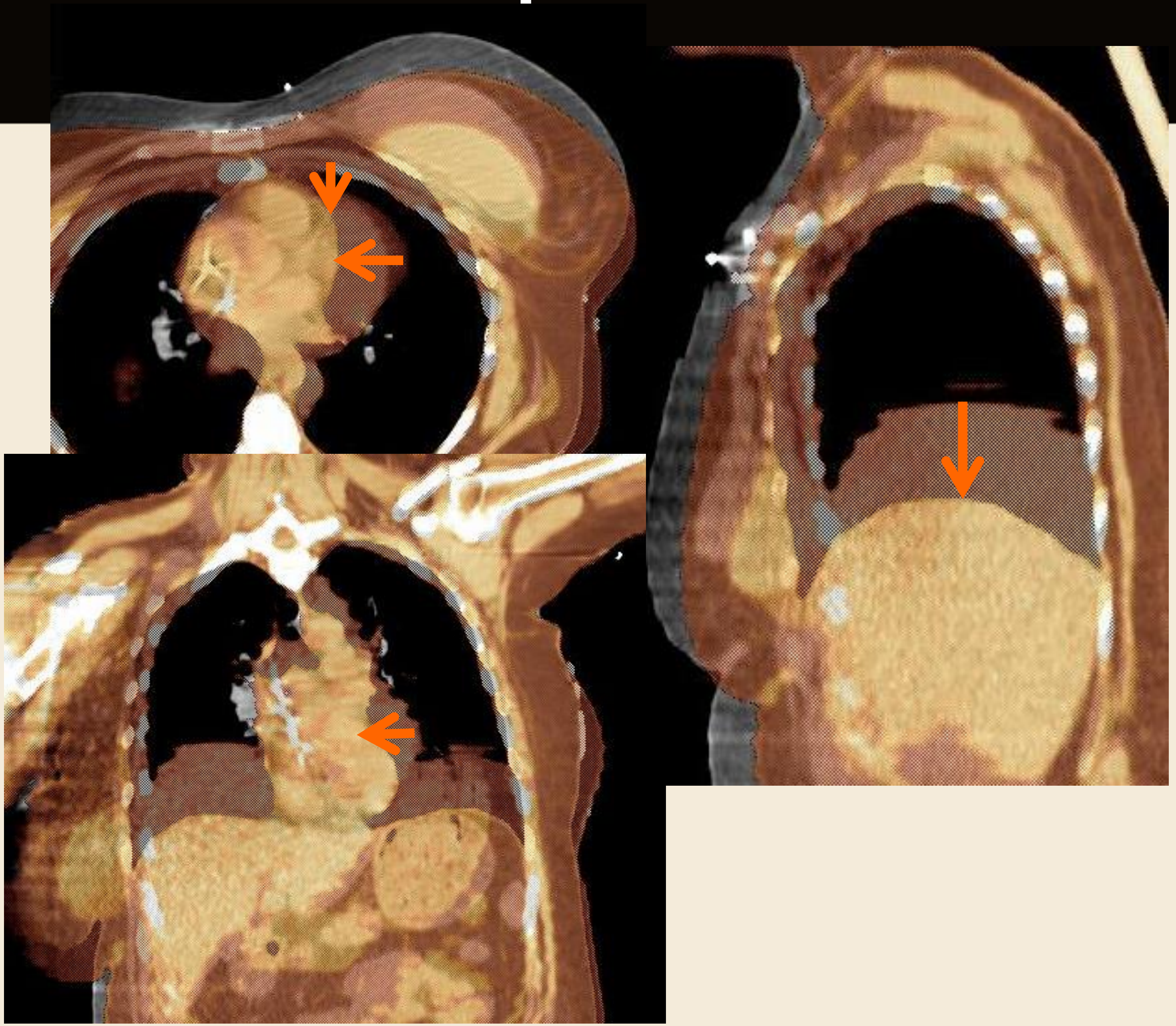
Reference: AAPM Task Group 76 - The Management of Respiratory Motion in Radiation Oncology. Section 6C Breath Hold Methods (2006)

DIBH Implementation

- Breast Service at MD Anderson treats ~ 1000 breast/CW cases every year.
- Implemented DIBH in 2004.
- Frequency of DIBH use:
  - ~ 90-95% of left sided breast/CW cases
  - 3-5% of right-sided cases when small lungs and/or barrel chested.
- DIBH technique: self-held breath control with respiratory monitoring and feedback guidance.

DIBH - Heart Displacement

- Registered images from CT scans in DIBH (grey scale) and FB (orange) modes.

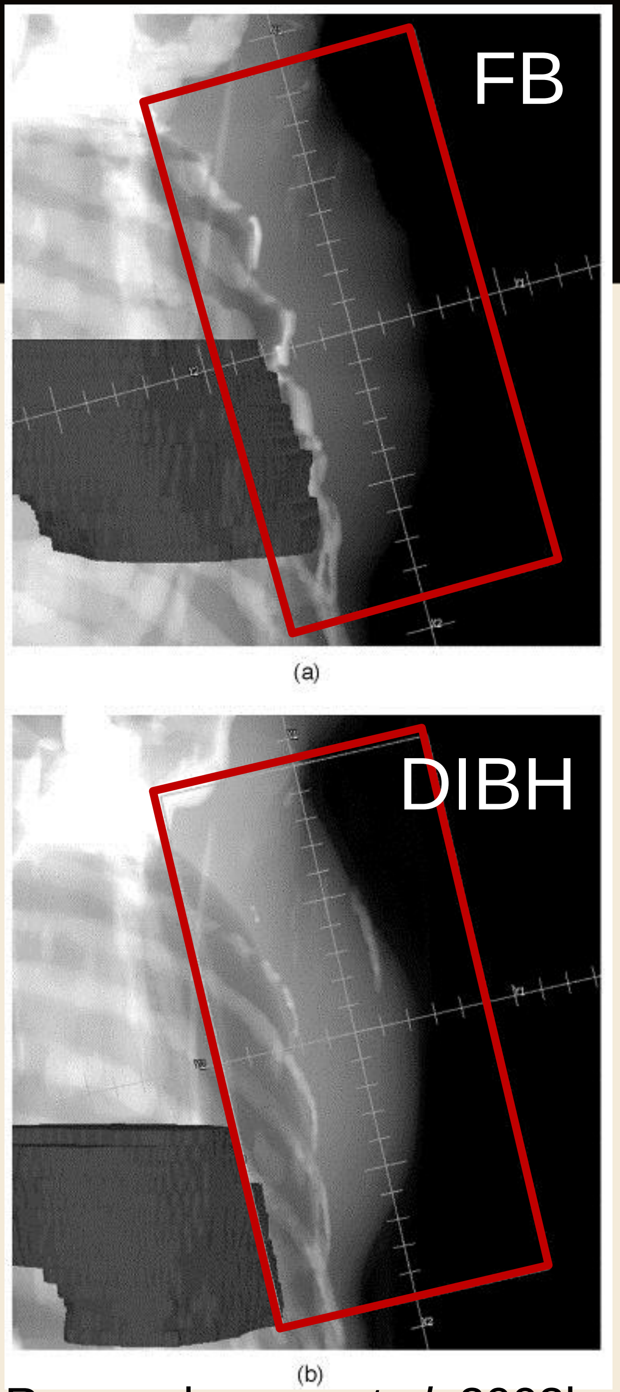


Heart displaced posteriorly, inferiorly, and to the right.

DIBH - Heart Displacement

- **Heart displacement during DIBH results in less heart volume included breast treatment fields, e.g.,** **Remouchamps *et al.* 2003b.**

- **The % heart volume receiving particular doses decreases for breast RT with DIBH as compared FB.**
  - ***Numerous references, see reference slide at end of presentation.***



Remouchamps *et al.* 2003b.

How much heart dose?

Left-sided Cases (95% DIBH)

Heart Metric	Tangents (N=119)		T + SC + IMC (N=158)	
	mean ± 1SD	> CI(95%)	mean ± 1SD	> CI(95%)
D_{mean} (Gy)	0.60±0.28	0.65	3.51±2.11	3.84
V_{4Gy} (%)	1.17±2.38	1.60	2.51±12.03	2.698
V_{20Gy} (%)	0.02±0.13	0.04	1.89±5.62	2.77
V_{25Gy} (%)	0.01±0.09	0.03	0.95±3.38	1.48
V_{30Gy} (%)	0.01±0.05	0.02	0.44±1.79	0.72

Data presented at ASTRO 2014 Annual Meeting
Abstract: IJROBP 90(1):S857-S858, 2014.

DIBH
Lung Volume Changes

- **During DIBH, air is drawn into the thoracic cavity, i.e., the lung volume increases.**
- **The % lung volume receiving particular doses will decrease for breast RT with DIBH as compared FB.**
  - **Remouchamps *et al. (2003a)* reported a significant decrease in the V_{20Gy}.**

Comparison of Lung Metrics for Breast Cases treated in DIBH and FB

Lung Metrics	Left Sided DIBH Cases	Right Sided FB Cases
n	131	101
Volume (cc)	4055.9 ± 784.4	2670.9 ± 687.0
Mean Dose (Gy)	4.75 ± 2.9	6.21 ± 3.49
V_{13Gy} (%)	11.95 ± 7.71	15.59 ± 9.37
V_{20Gy} (%)	8.93 ± 5.78	13.13 ± 7.40

Data Collected at our institution in 2013 (unpublished).

- **Treatment techniques for both left and right sided cases were CRT and included the following techniques tangents (T), T + SC, and T + SC+IMC.**

SAMS Questions

During deep inspiration, the heart position shifts (compared to free breathing)

0% 1. Posterior, inferior, and to the right

0% 2. Posterior, inferior, and to the left

0% 3. Anterior, superior, and to the right

0% 4. Anterior, inferior, and to the right

0% 5. Posterior, superior, and to the right

Correct Answer:
1. Posterior, inferior, and to the right

- Registered images from CT scans in DIBH (grey scale) and FB (orange) modes.

Heart displaced posteriorly, inferiorly, and to the right.

The expected change in the lung V_{20Gy} for a patient whose CT scan was acquired in DIBH mode is expected to be __________ (compared to a scan acquired during FB mode)?

0%

0%

0%

0%

0%

1. Higher dose
2. Lower dose
3. Negligible difference

Correct Answer:
2. lower dose

- During inhalation, air is drawn into the thoracic cavity, this anatomical change leads to an increased total lung volume (TG-76).
- This results in a lower percentage of lung volume with in the breast treatment fields.
- Consequently, the % volume receiving particular doses is lower, e.g., V_{20Gy}.

Remouchamps *et al.* (2003)

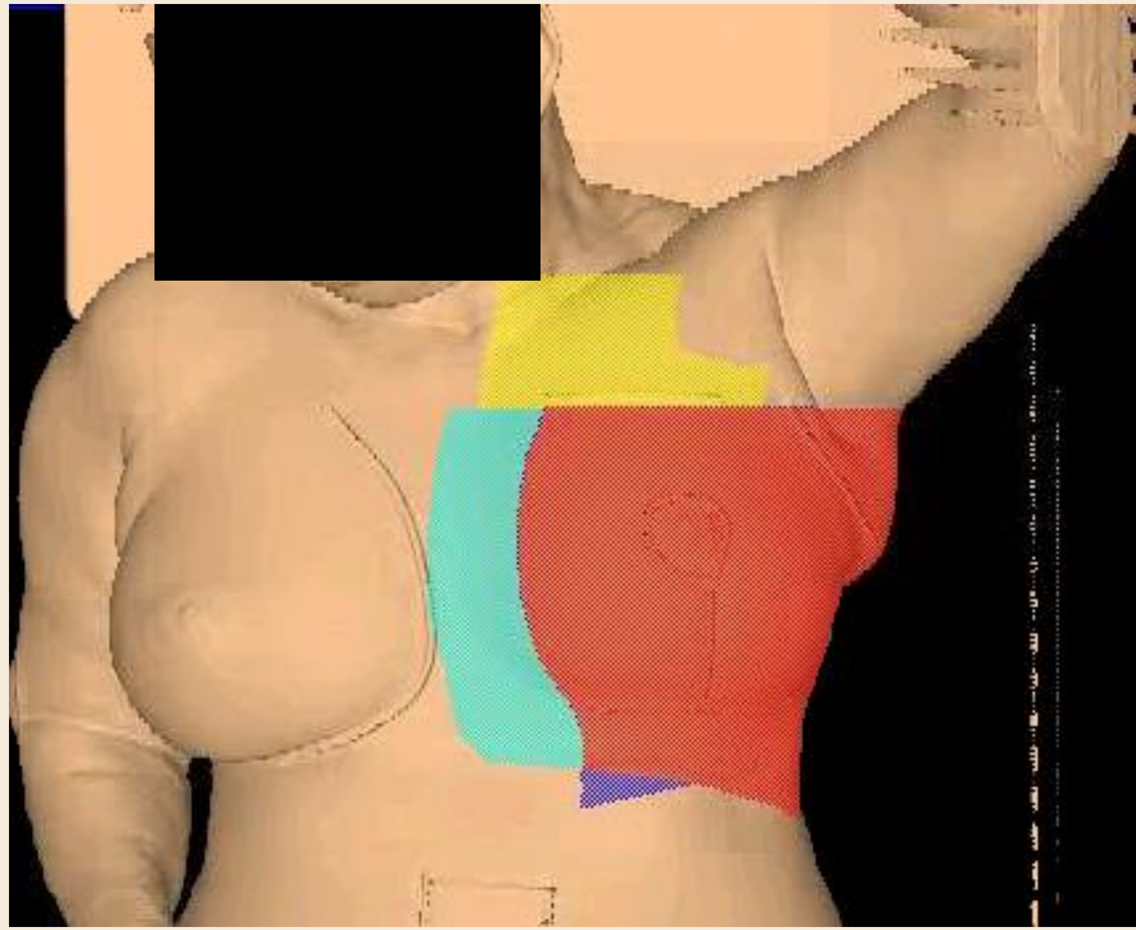
Field Design

Cases with Regional Node Irradiation

Field Design
Comprehensive Breast Treatment

- **Many different techniques, wide/deep tangents, IMRT, VMAT….**

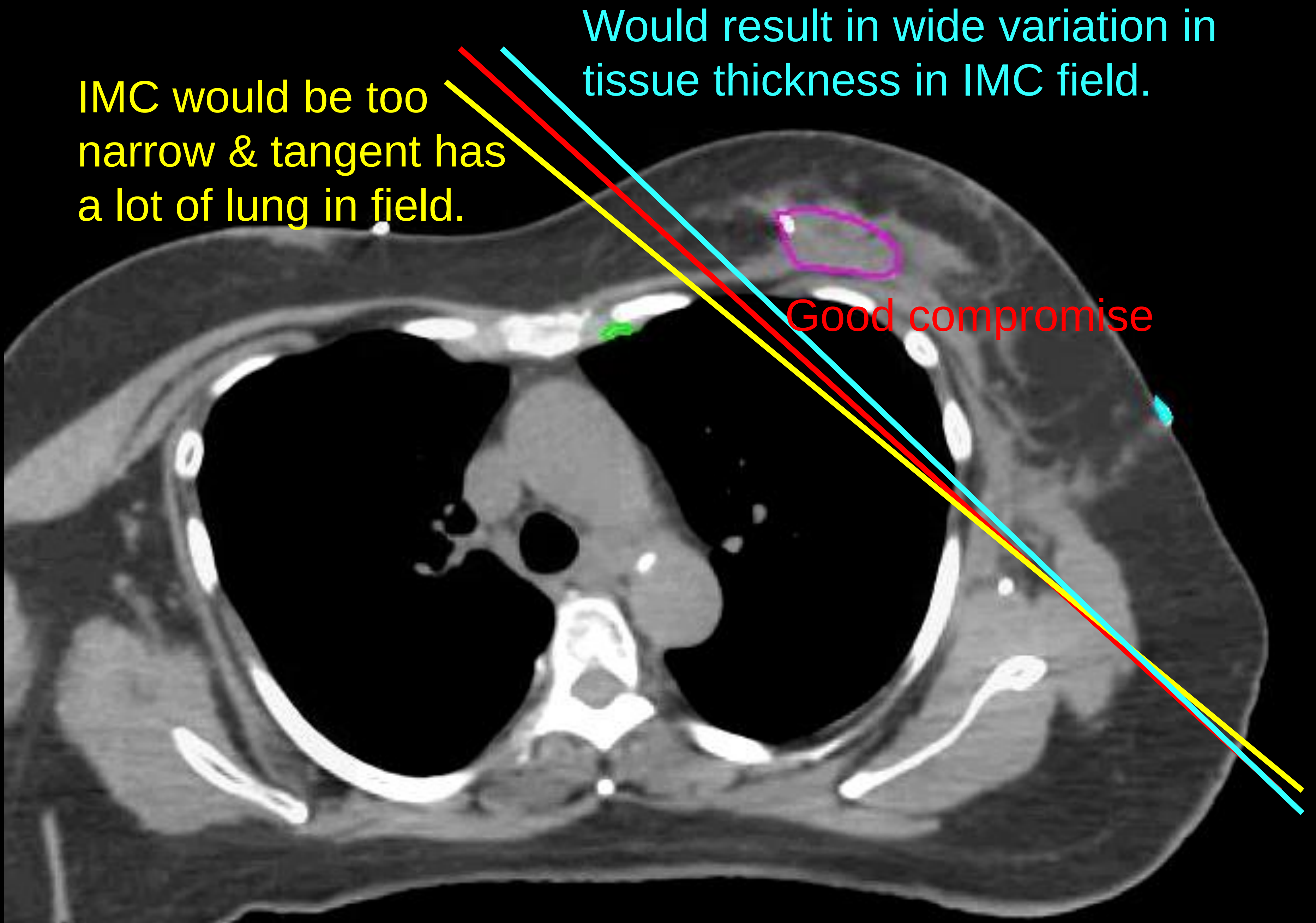
- **This presentation will focuses on comprehensive multi-isocenter 4-field CRT.**



Tangents (T) + SC+ IMC

General Guidelines for the Tangents

- Same basic principles as for tangents only, but…
  - Gantry angle is steeper to accommodate the IMC field.
- Select “break-point” such that thickest part of breast and tissue with variable thickness is included in tangent.
  - Don’t want highly variable thicknesses across IMC field.


Would result in wide variation in tissue thickness in IMC field.
IMC would be too narrow & tangent has a lot of lung in field.
Good compromise

Tangential Beams
Energy Selection/Modulation

- **If the separation is <23 cm:**
  - **6 MV for primary open field**
  - **18 MV for FIF.**
  - **Splitting energy on the primary beam can also be used to reduce hot spot while still maintaining adequate skin coverage.**

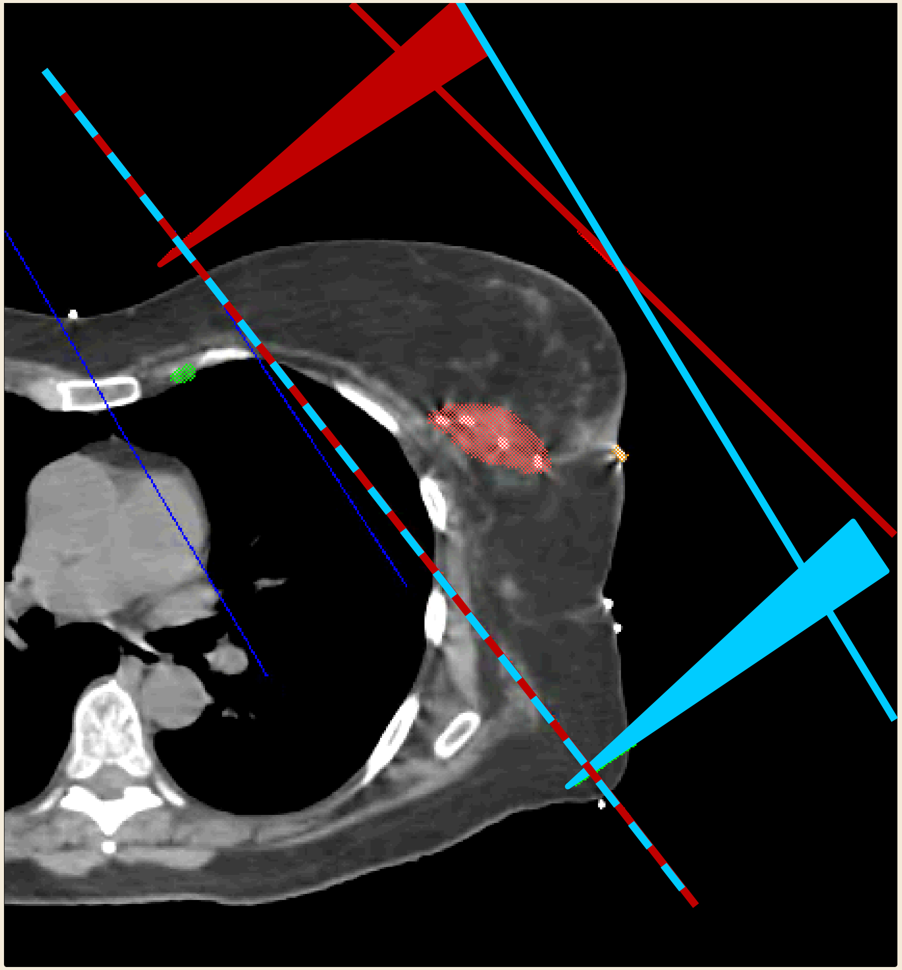
Most modulation with field-in-field.

- **If the separation is >23 cm:**
  - **18 MV photons for primary open filed**
  - **6 MV for FIF**

- ***Note: Energy is selected to achieve "best" plan***

When are wedges used over FIF?

- **For a very steeply peaked breast.**
- **If trying to push dose deeper, e.g., tumor bed close to muscle.**
- **Reduce number of sub-fields (applies if using “step-n-shoot” FIF technique.)**



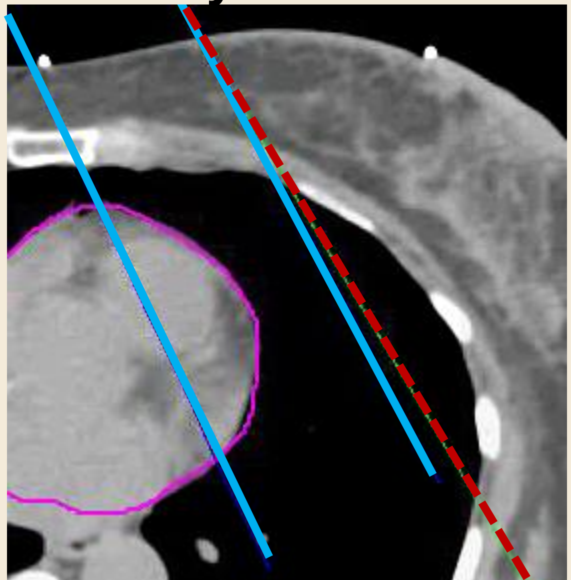
General Guidelines for IMC Fields

- IMC beam angle, compromise between en-face' and cold triangle at junction.
  - The IMC angle is generally 15^o to 25^o and rarely more that 30^o.
- The IMC field should be at least 4 cm wide and more ideally ≥ 5 cm wide.
  - Needed for electron equilibrium
  - If field too small d_{max} shifts to more shallow depth.
- Use lowest energy possible.
- Use lower energy for inferior portion of field when breast/CW tissue thinner.

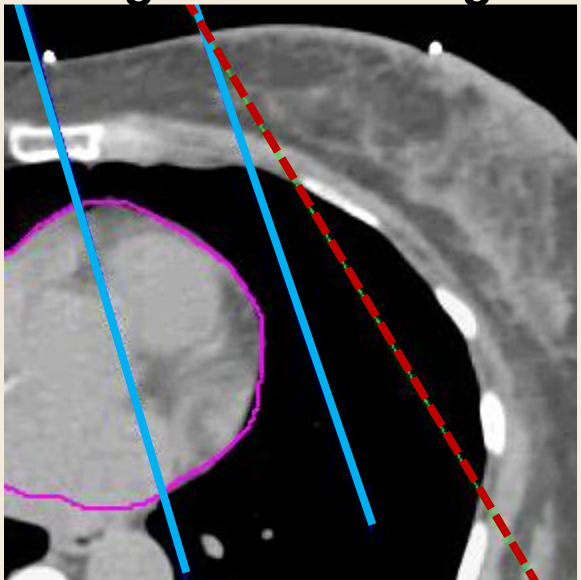
General Guidelines
Tangent-IMC Junctions

- **The hinge angle between the IMC and tangent field is usually 10^{o} to 15^{o}.**
  - **Too small = plan gets really hot**
  - **Too large = big cold triangle**

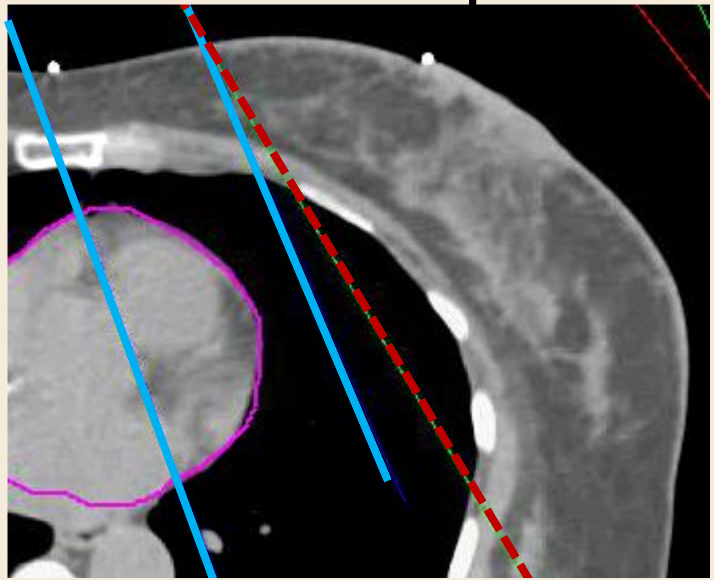
7^{o}
Nearly Parallel



17^{o}
Large Cold Triangle

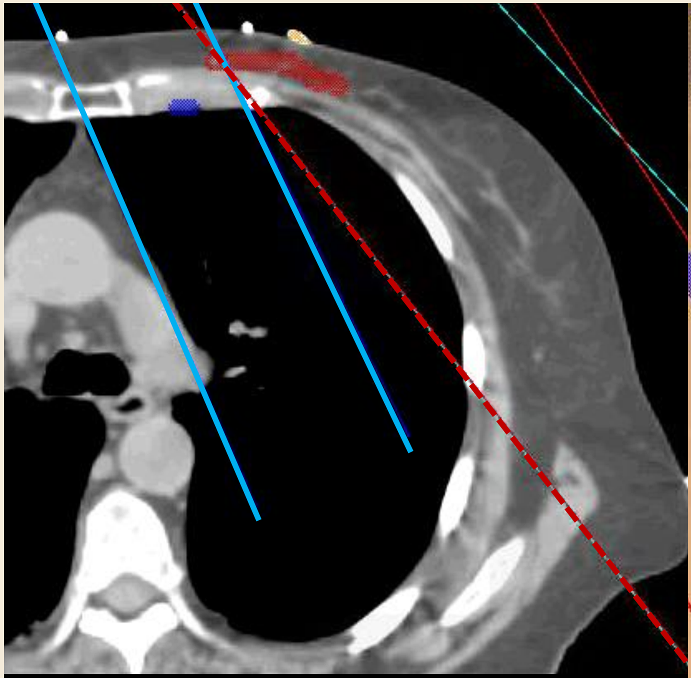


12^{o}
Reasonable compromise

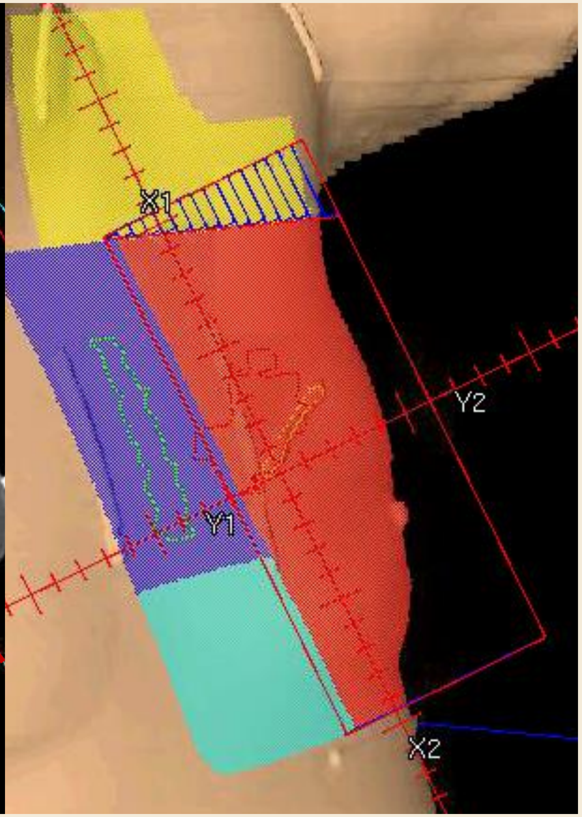


General Guidelines
Tangent-IMC Junctions

- **Should not junction IMC and tangent over tumor bed.**
- ***Primarily an issue when tumor bed very medial.***
  - **If junction near tumor bed cannot be avoided, may consider:**
  - **3 mm overlap, but plan will get "hot" at junction.**
  - **Wide tangents, but lung dose may be higher.**



D_{max}= 70.4Gy,
65Gy = 1.6 cc, 60Gy = 24.0 cc

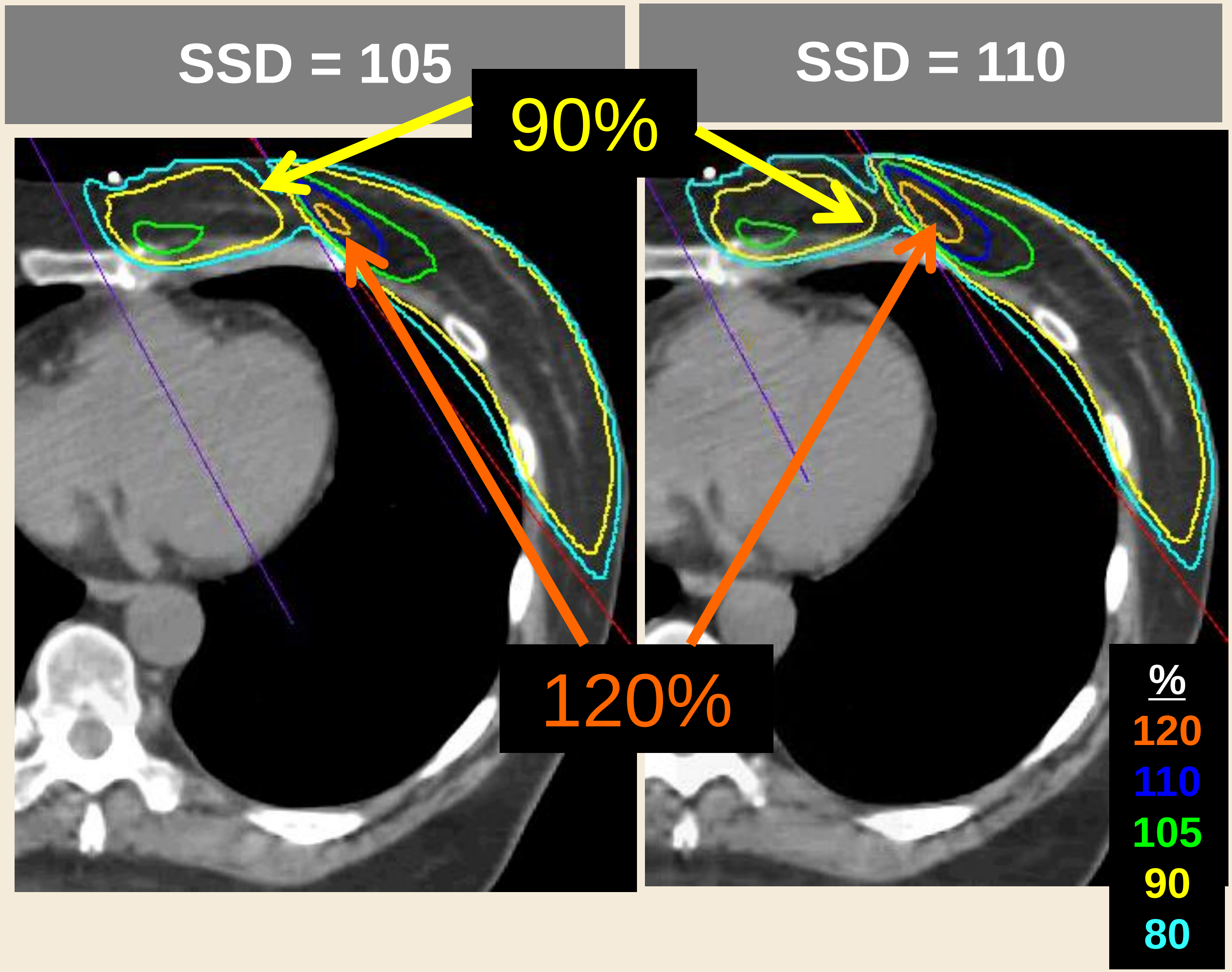


Tangent-IMC Junction
Junction Dosimetry and SSD Dependence

Junction Region

- Hot on photon side of junction.
- Cold on electron side of junction.
- Caused by out scattering of electrons.

- **Hot and cold spots increases with SSD.**



IMC Field(s)
Energy Selection

- The energy of this field is based on coverage of the nodal areas.
- The IMC vessels level I-III should be covered by the 90% isodose line.
  - Beyond level III, 90% isodose line should extend cover to the pectoralis muscle.
- This coverage generally achieved using electron energies between **6 MeV and 20 MeV.**

IMC Field
Energy Selection Considerations

- In many patients, the tissue thickness varies in the superior and inferior portions in IMC field.
- Split IMC into upper and lower portions:
  - Upper = Higher energy
  - Lower = Lower energy
    - Advantages = Decrease heart and lung dose

IMC Field
Energy Selection Considerations

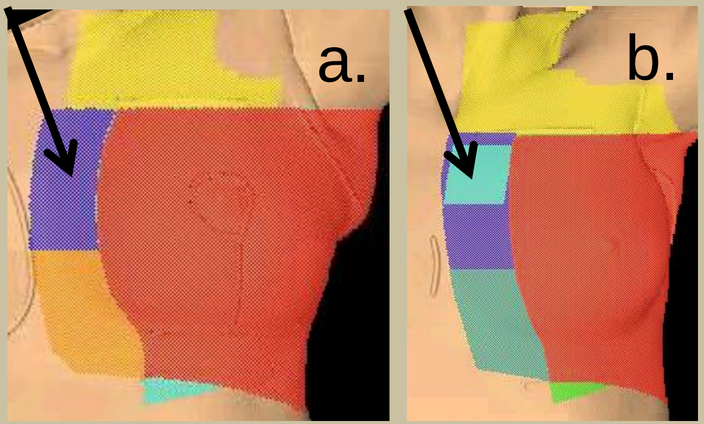
If 16 or 20 MeV needed to achieve coverage of deep IMC vessels, skin dose may be very high.

- **Coverage can be achieved by photon electron mixing, i.e., lower energy electrons + photon supplement.**

  a. 4:1 electron to photon when identical dimensions *or*

  b. Additional supplement over a portion of the field when only supplementing part of field, e.g., 4 - 8 Gy for 50 Gy course.

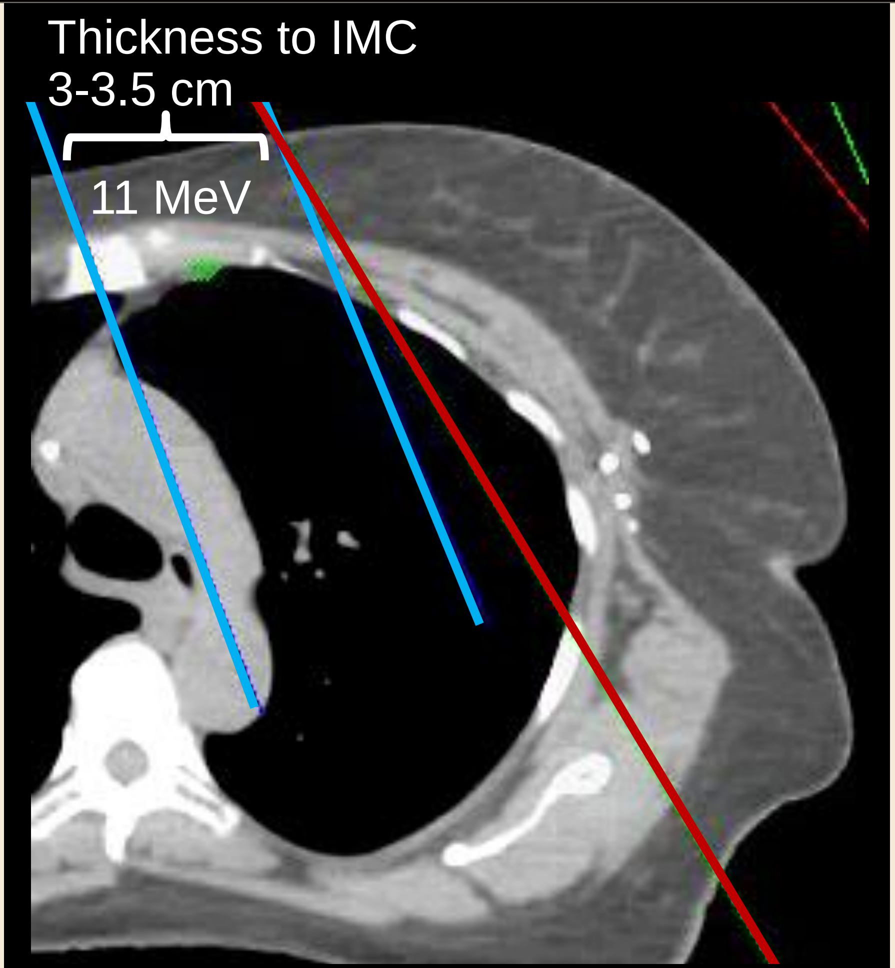
Photon Supplement



- **Adding photons may increase lung and heart dose; risk vs benefits must be assessed.**

“Good Anatomy” for T + IMC

- Breast tissue is more lateral, chest area reasonably “flat” and tumor bed not near IMC.
- Can easily cover anatomy with:
  - Steeper tangent
  - Matched with electron IMC.



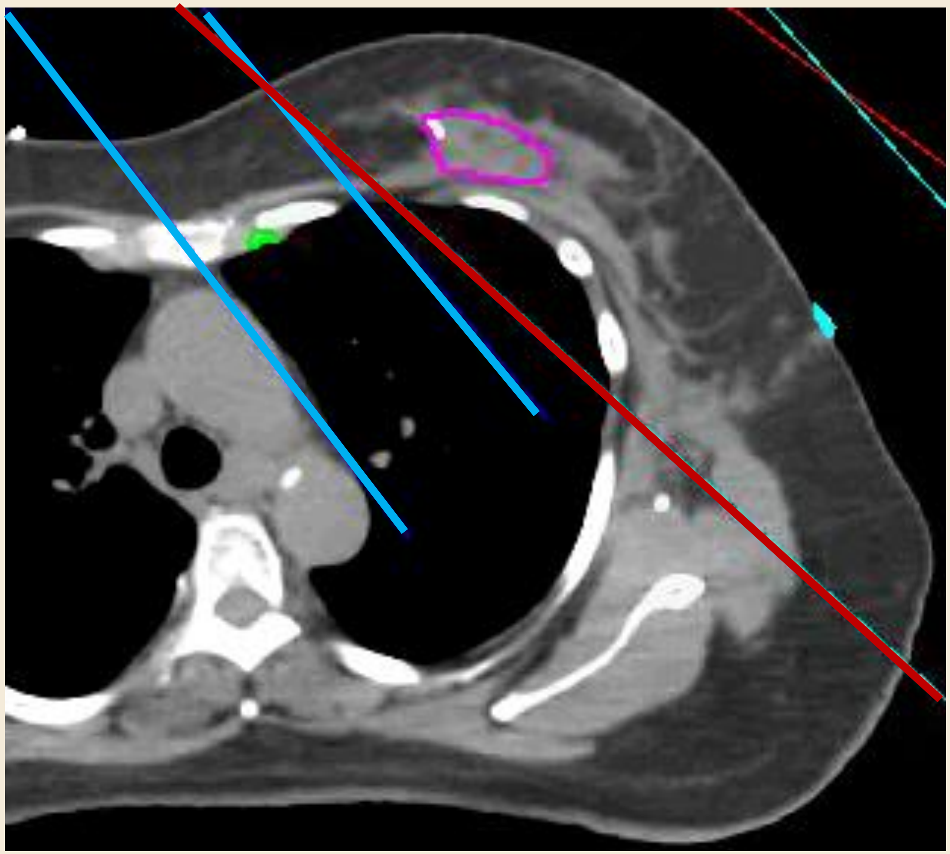
- Medial tangent gantry angle = 326°
- IMC gantry angle = 338°
- 12° hinge angle

“Good Anatomy” for T + IMC

- **Also, thinner in lower portion of Chest.**
- **Able to split IMC and use lower energy for lower portion.**
  - **Lower energy exiting heart.**

More Challenging Anatomy for T+IMC

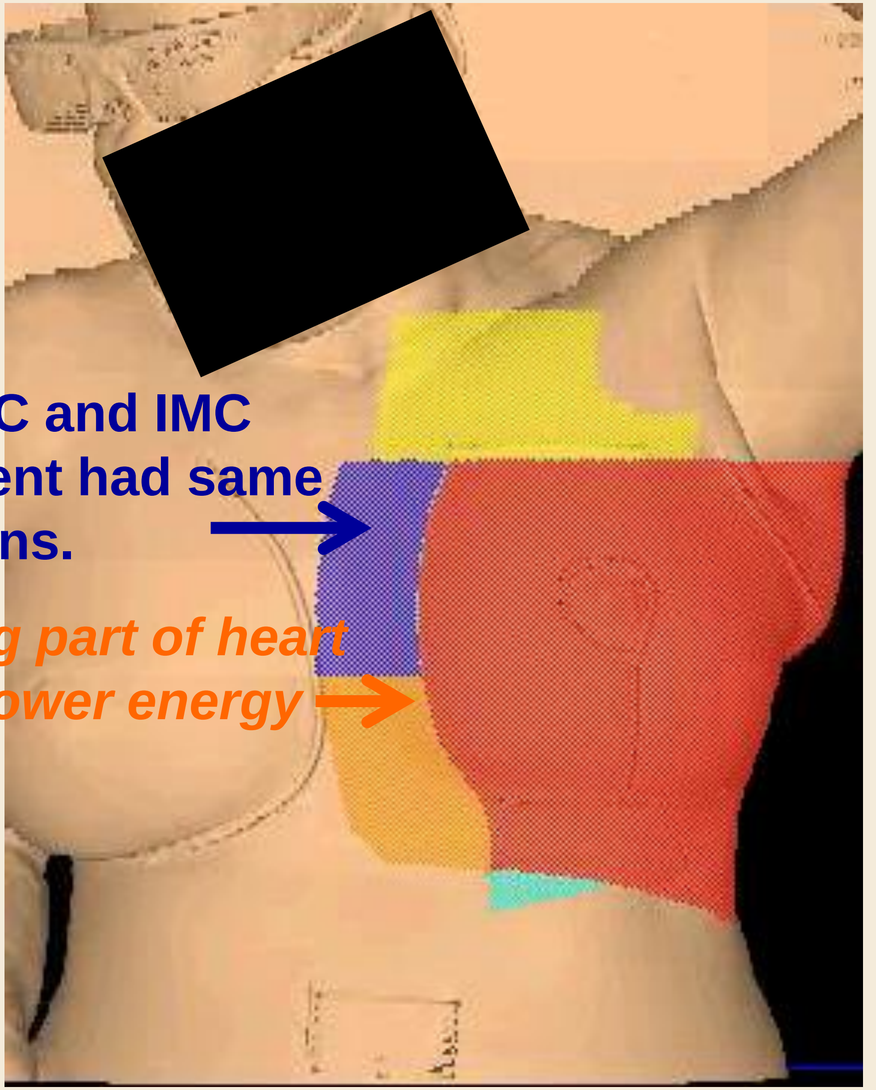
- **Breast tissue more medial, chest is not flat, and tumor bed somewhat medial.**
  - **Requires less angling of tangent and more angling of IMC (compared to previous example).**
- **Why not Partially wide tangents?**
  - **Barrel chested → too much lung in field**



- Medial tangent gantry angle = 338^{o}
- IMC gantry angle = 340^{o}
- 10^{o} hinge angle

Example Case
Comprehensive Breast Treatment

- **Med/Lat Tangents (50 Gy)**
  - –6 MV Open: 17%
  - –18MV Open :27%
  - –18 MV FIF(2): 4% & 3%
- **SC (50 Gy)**
  - –18 MV: 50%
  - –6 MV: 50%
- **12 MeV Upper IMC (50 Gy)**
- **18 MV Upper IMC Supp (7.5 Gy)**
- **9 MeV Lower IMC (50 Gy)**

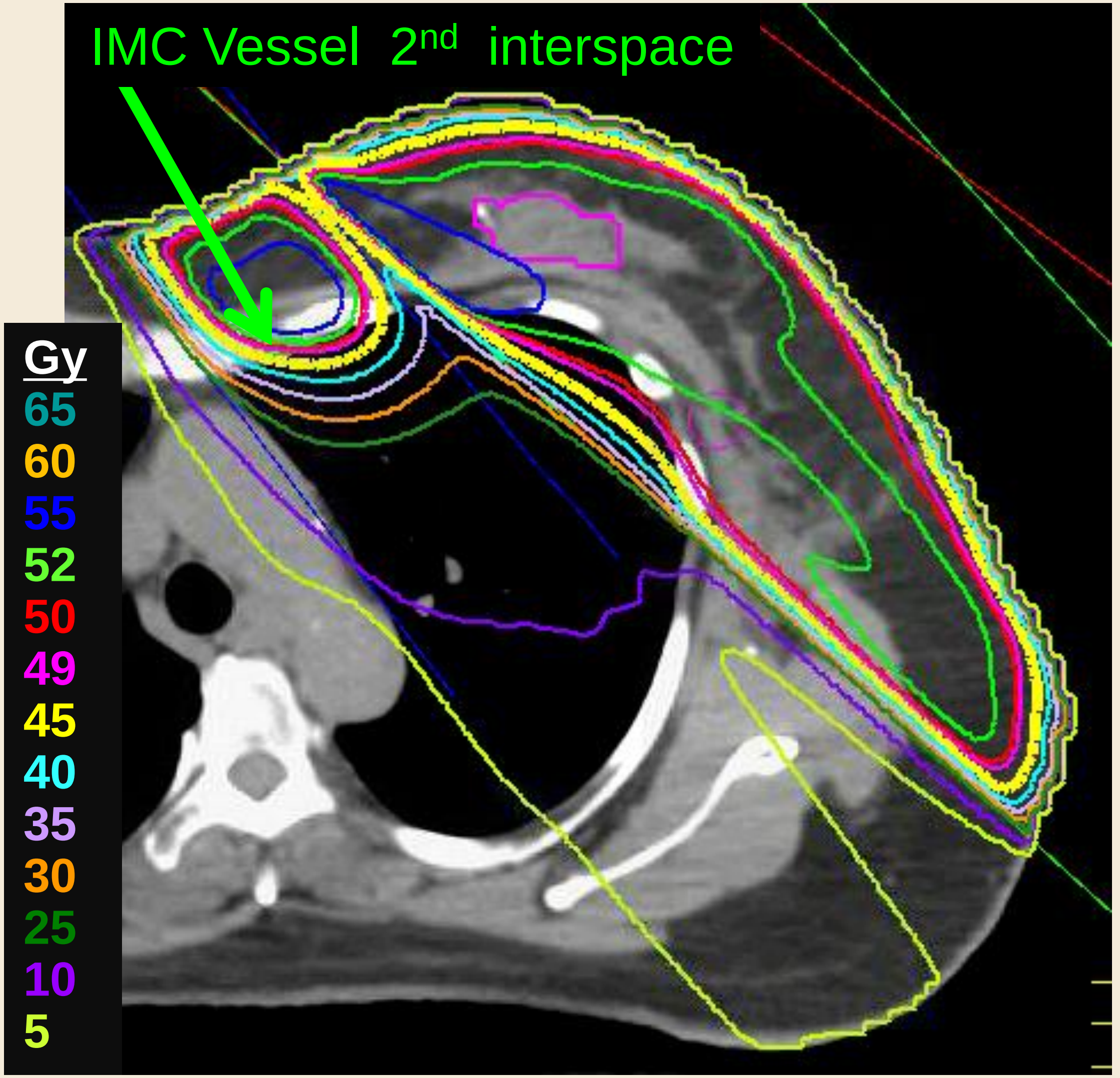


Upper IMC and IMC supplement had same dimensions.

Exiting part of heart With lower energy

Example Case
Comprehensive Breast Treatment

- **Deepest extent of IMC Vessels was 5 cm.**
- **12 MeV Electrons with 18 MV supplement selected for coverage 90% isodose .**
- **Without photon supplement, 20 MeV needed (↑ skin dose).**



Some Plan Statistics

- Hotspot on photon side of IMC and tangent junction.
  - Max dose = 72.3 Gy
  - 65 Gy = 3.1 cc
  - 60 Gy = 15.7 cc
  - 55 Gy = 120 cc

Note: SSD for IMC was 107 due to clearance

- Normal Tissue Dose
  - Heart
    - V_{4Gy} = 20 %
    - V_{20Gy} < 1 %
    - Mean dose = 2.8 Gy
  - Lungs
    - V_{5Gy} = 32 %
    - V_{13Gy} = 20 %
    - V_{20Gy} = 16 %
    - Mean = 7.8 Gy

SAMS Question

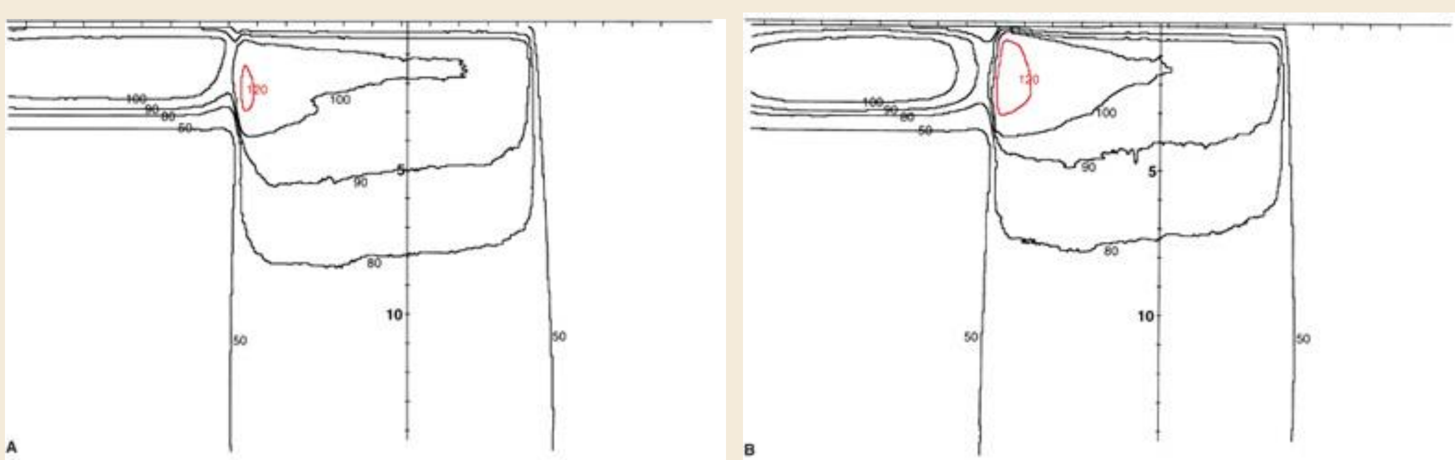
At the junction of a photon tangent beam and an electron IMC beam, the hot spot will be on the __________ side of the junction and will __________ with increasing electron beam SSD.

0%	1. Photon, decrease
0%	2. Photon, Increase
0%	3. Electron, decrease
0%	4. Electron, increase
0%	5. Photon, no change

Correct Answer

- **Correct answer: B the hot spot will be on the photon side of the junction and will increase with increasing electron beam SSD.**
- **Caused by out scattering of electrons.**

Reference : Khan. Physics of Radiation Therapy. Chapter 14. Fig14.31



Isodose curves in a plane perpendicular to the junction line between abutting photon and electron fields. 9-MeV electron beam; field size = 10 × 10 cm; 6-MV photon beam; SSD = 100 cm.
A: Electron beam at standard source to surface distance (SSD) of 100 cm. B: Electron beam at extended SSD of 120 cm.

Partially Wide Tangents

Alternative to T + IMC

Partially Wide Tangents (PWT) As Alternative to T + IMC

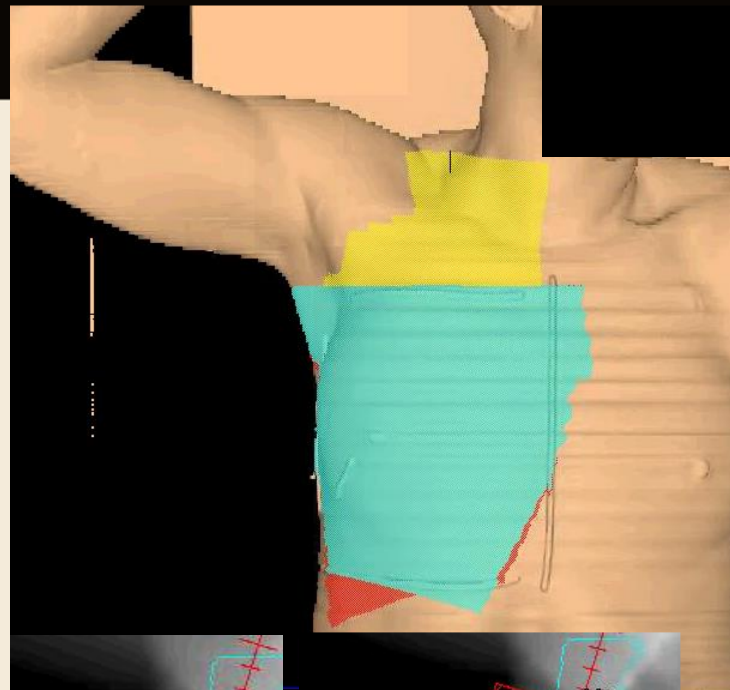
- **Anatomically, PWTs are better option in patients where breast is more medial, *but …..***

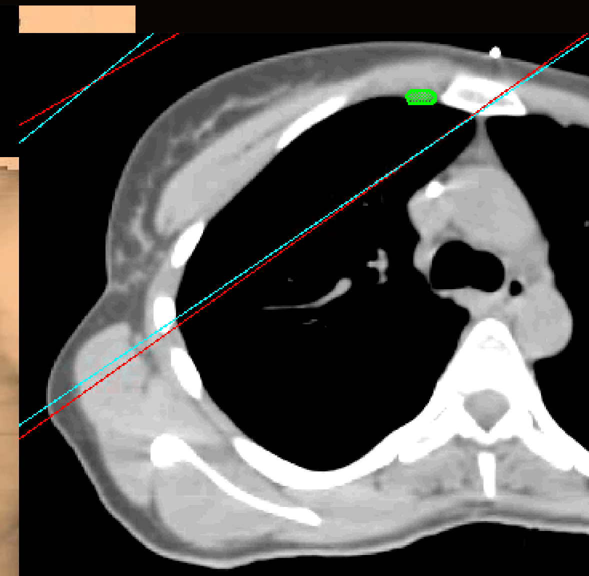
there are some scenarios where lung and/or contalateral breast dose is higher than for T+IMC:

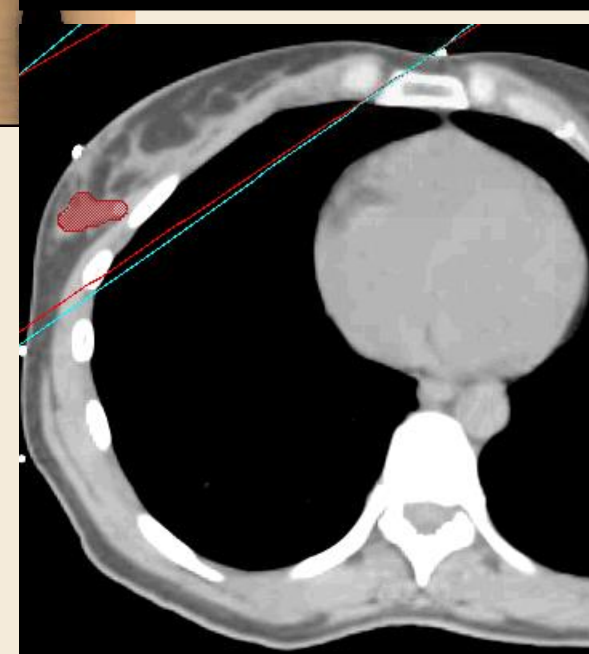
- **Contralateral breast is very medial (and large) → contralateral breast partially within PWTs.**
- **Not barrel chested → loo much lung within PWTs.**

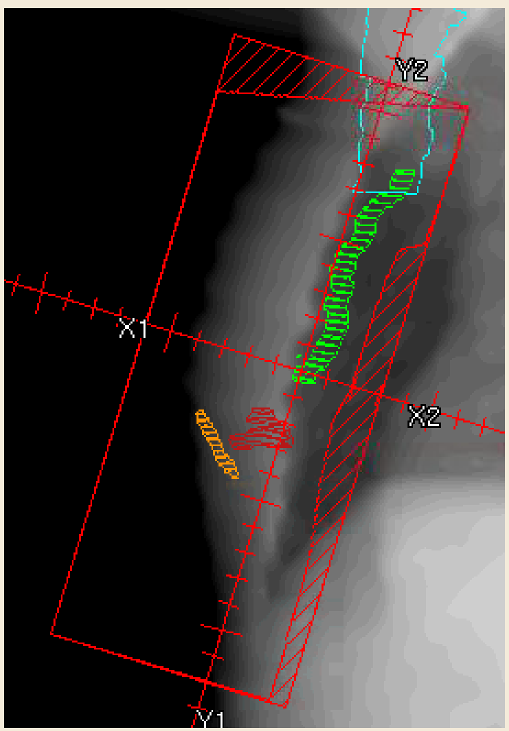
Partially Wide Tangents Example Case

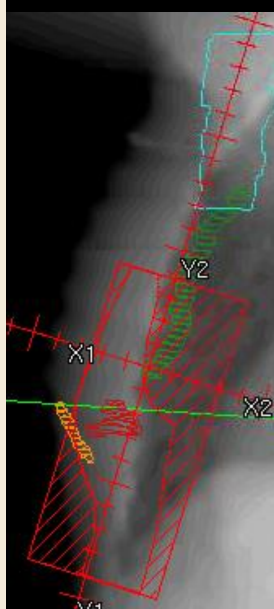
- **Med/lat tangents**
  - **–Open 6X: 30%**
  - **–Open 18X:14%**
  - **–2 18X FIFs: 3%**
- **SC: 6:18; 1:1**











Partially Wide Tangents Example Case Plan Details/ Isodose Distribution

<u>Tumor bed and IMC vessels</u>

- **V_{50Gy} = 98%**

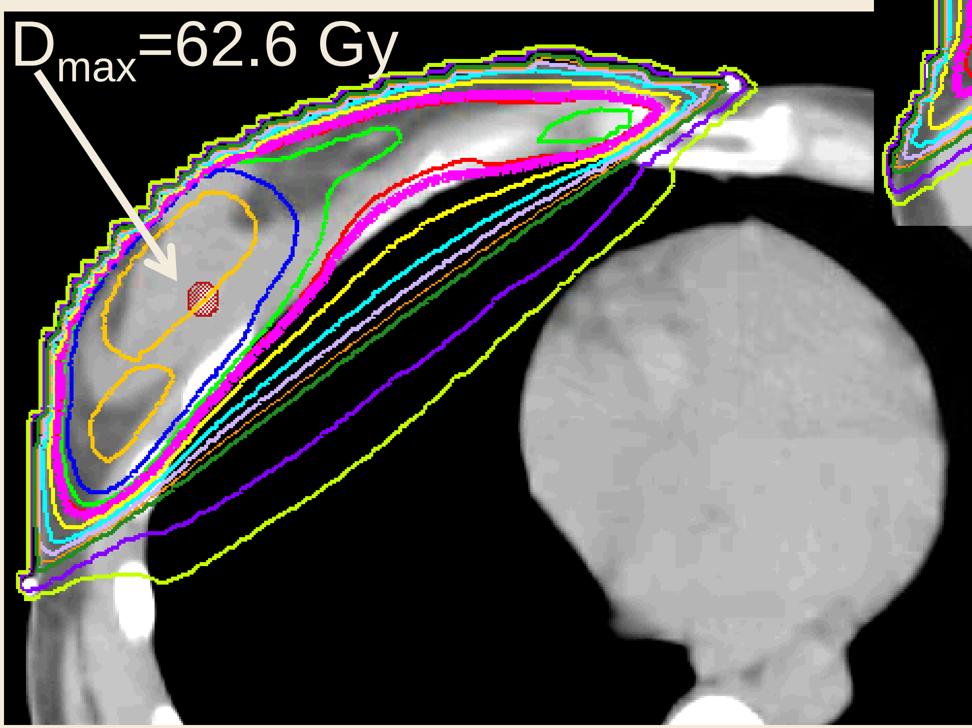
<u>Lungs</u>

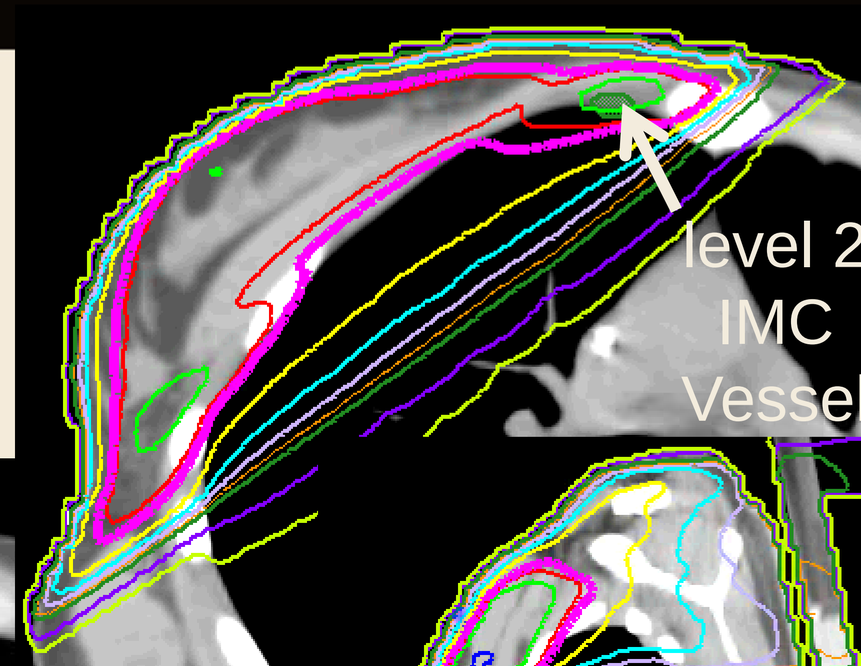
- **$V13_{Gy}$=18.5%, $V20_{Gy}$=17%, Mean=7.7 Gy**

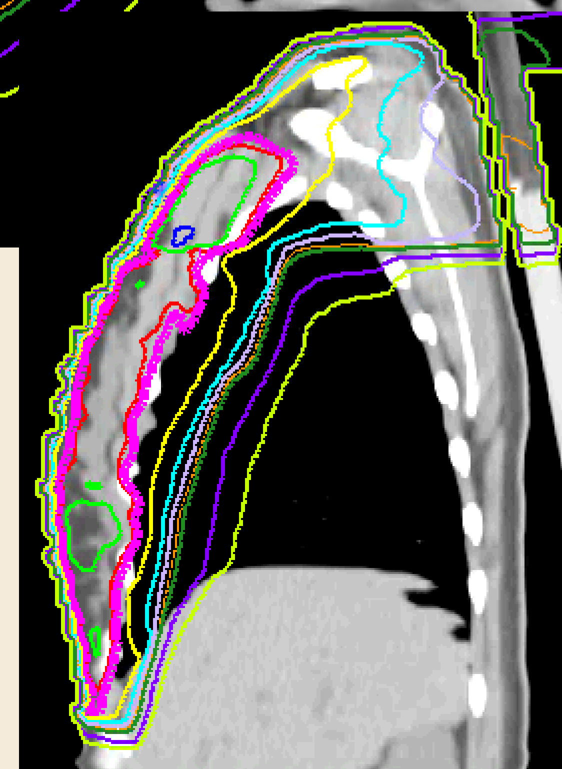
<u>Heart</u>

- **$V4_{Gy}$~0%, $V20_{Gy}$=0%, Mean=0.6 Gy**

<u>Gy</u>
60
55
52
50
49
45
40
35
30
25
10
5







Chest Wall and RNI

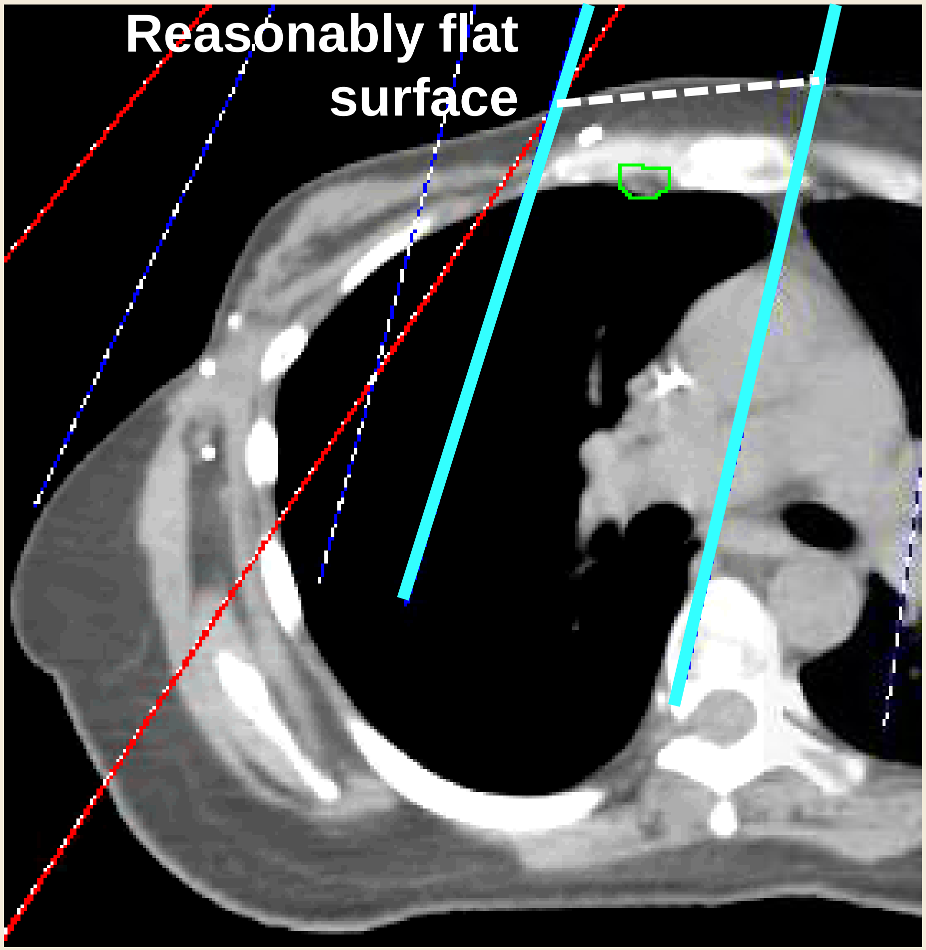
What are key differences in the field design for patients undergoing CW and RNI compared to breast and RNI?

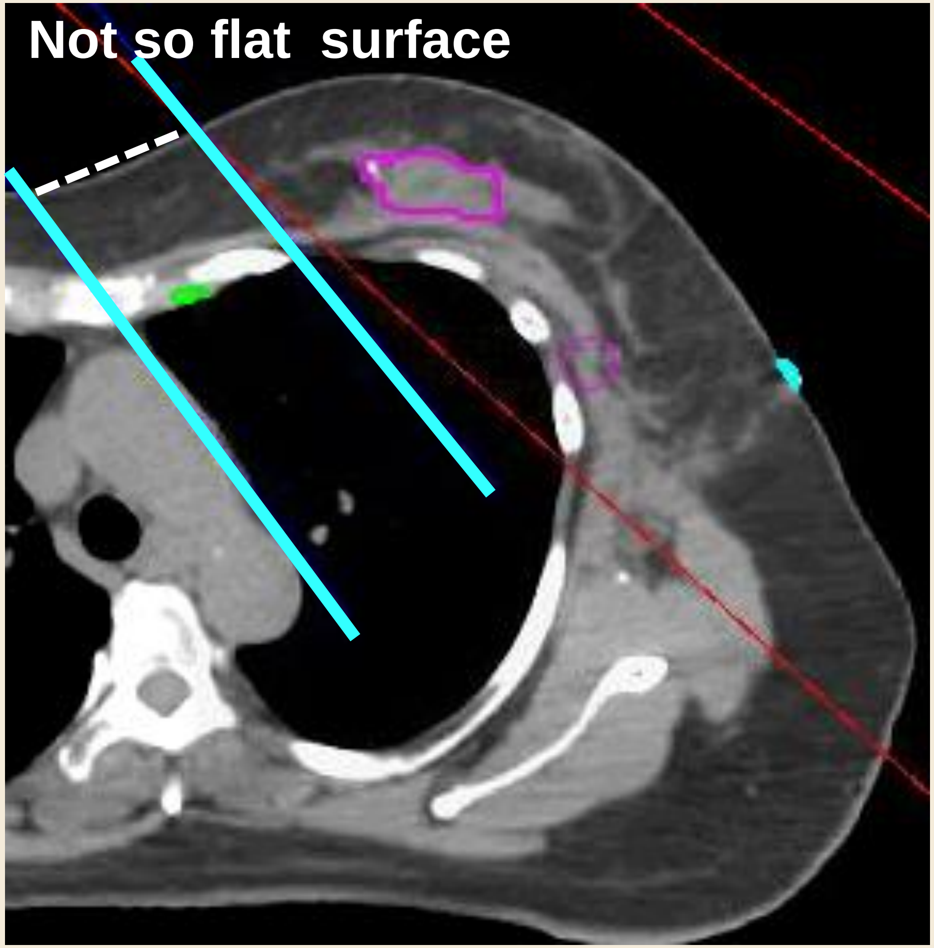
Comprehensive CW Treatment Field Design

- Field design is similar to comprehensive breast treatments, i.e., 4 field CRT: T+SC+IMC
- For CW cases, angle of IMC field is often smaller than for breast patient because surface is flat (or at least more flat than in breast patient).
- The entire volume of the mastectomy flaps is included in the field.
- Special T4 Considerations:
  - Drain sites are routinely covered
  - junctions routinely overlapped 3-5 mm

Comprehensive CW Treatment Gantry Angles

IMC Beam CW Shallow IMC Gantry Angle	IMC Beam Breast Steeper IMC Gantry Angle



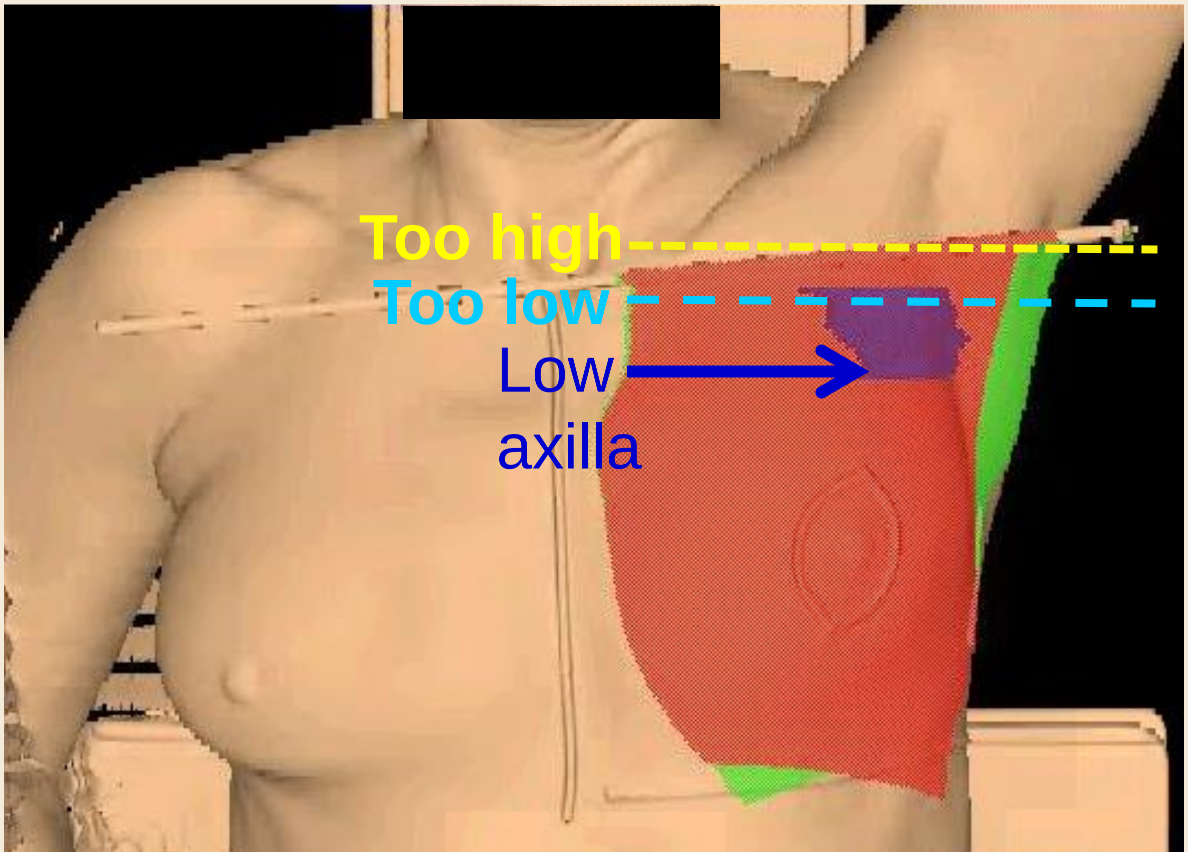


Clinical Scenarios where non-divergent *angled* superior border may be advantageous?

Rod and Chain and

Virtual Rod and Chain Techniques

Rod and Chain when Treating High Tangents



If used axial slice, i.e., straight border) border would be…..

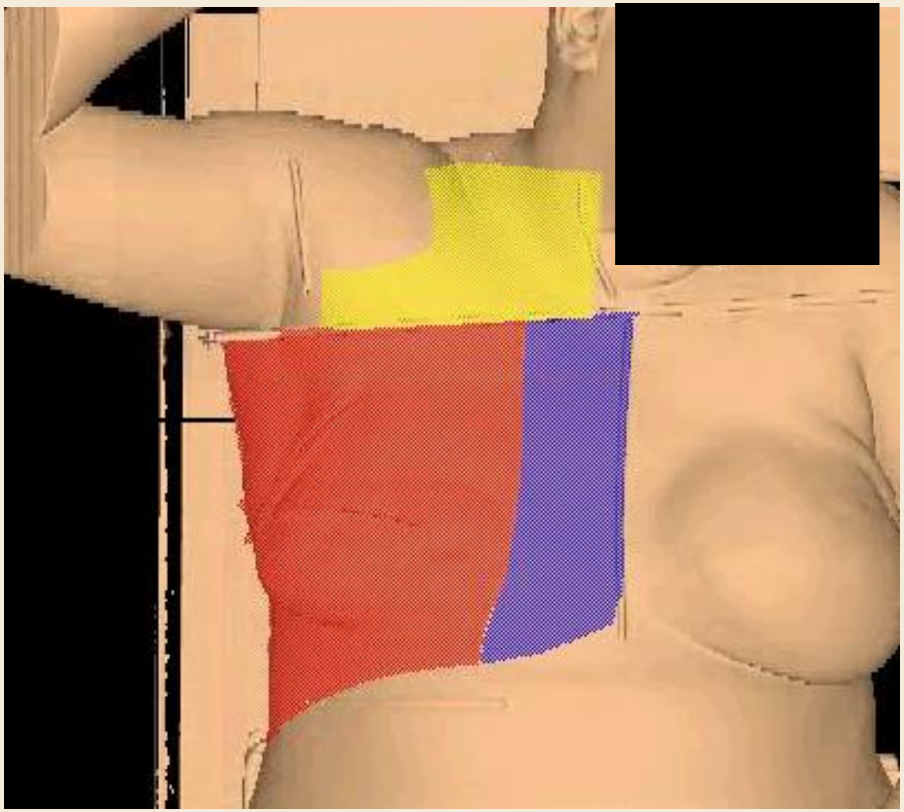
- **High tangents that include low axilla.**
- **Rod and chain technique achieves angled superior border that includes axilla and minimize amount normal tissue in the field.**

Rod and Chain when Arm Position Sub-optimal

- **Not be able to fully elevate arm, due to limited range of motion or pain (figure).**

  or

- **Sagging arm tissue that hangs down (even when raised to appropriate position).**



- **In these cases, the tangential beams would exit through the arm, potentially resulting in increased skin reactions.**

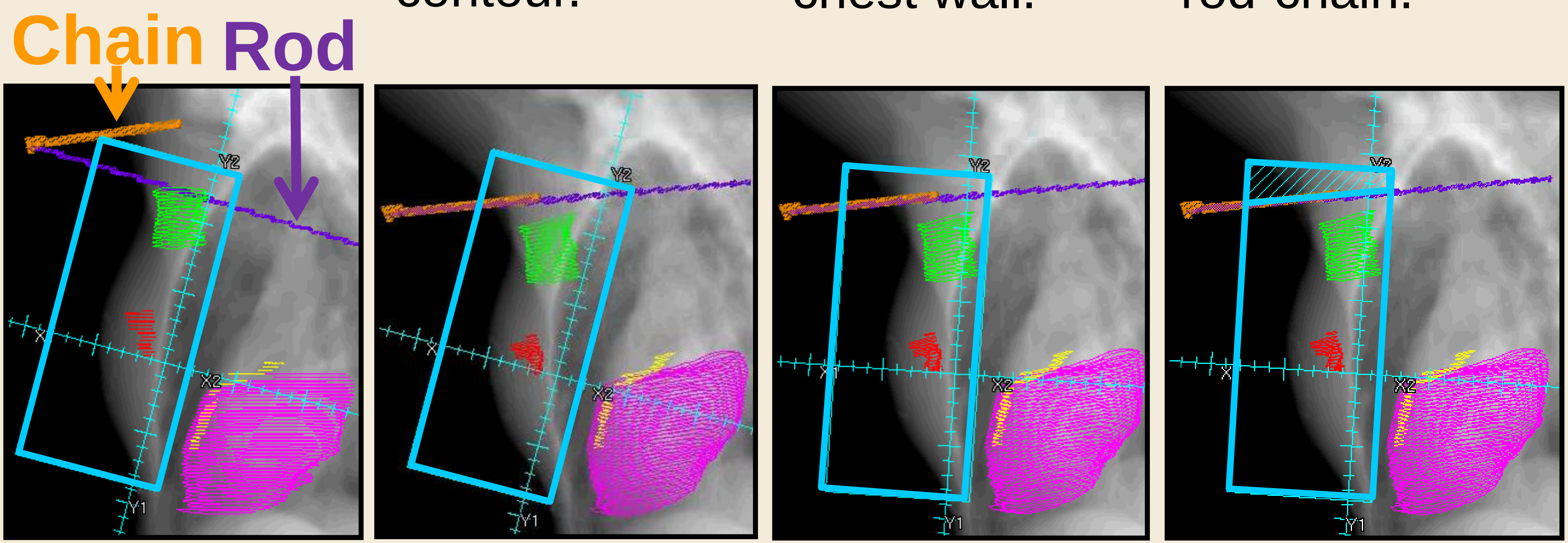
Beam Design for Rod and Chain

Rotate gantry and collimator as usual.

Rotate couch until the rod contour aligns with the chain contour.

Collimator will require adjusting to be realigned with chest wall.

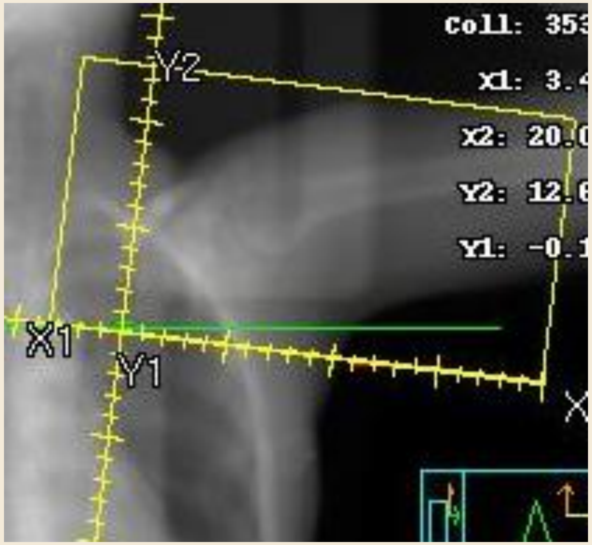
Add block (MLC) to follow along superimposed rod-chain.



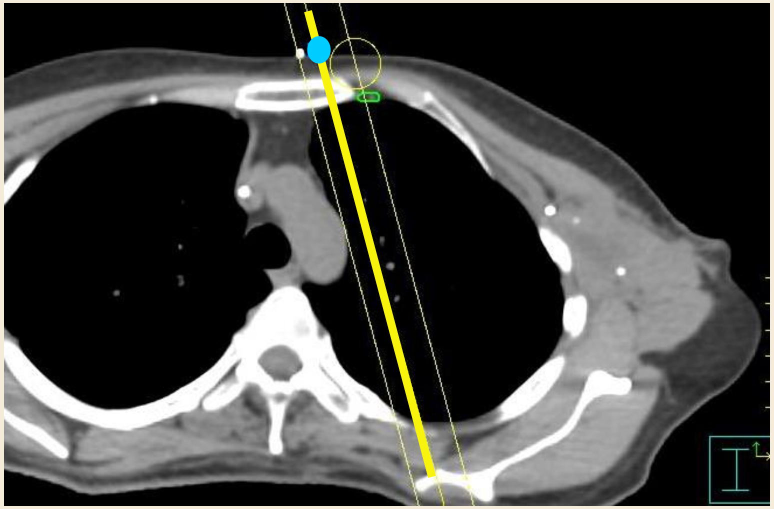
Virtual Rod and Chain

- Virtual rod and chain can be used as alternate to "real" R&C.
- Create "fake" contours to mimic a rod and chain.

1. Create "desired" SC field: rotate gantry (15º-20º) and collimator (5º-15º).

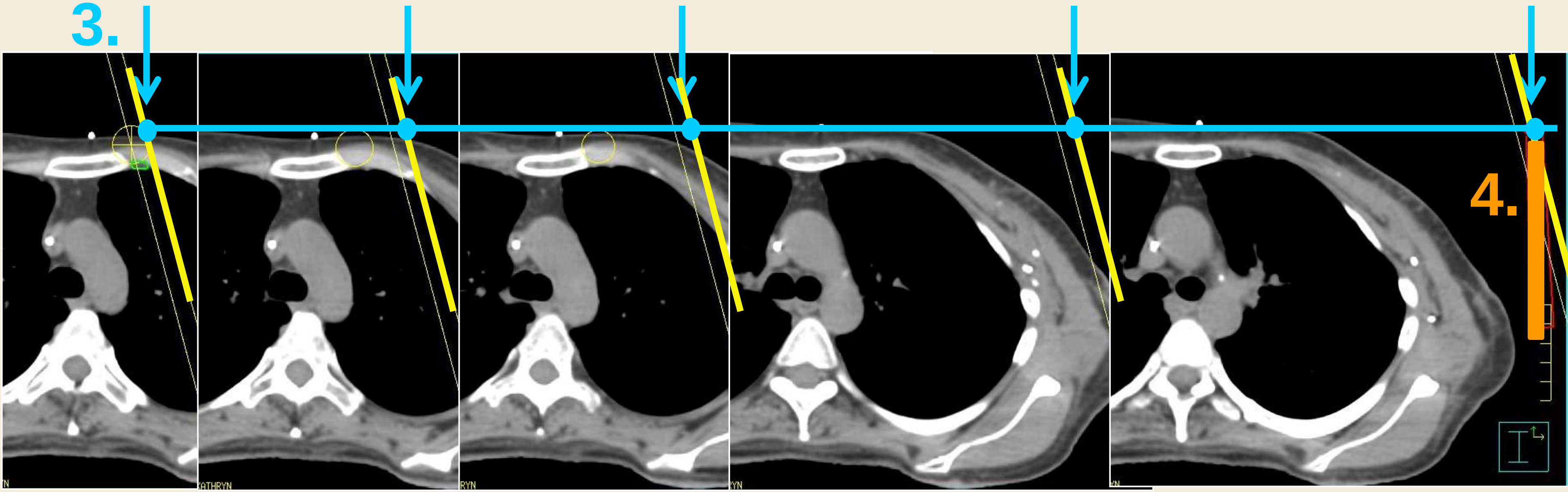


2. Draw small circle for rod contour at skin surface at edge of SC field on first axial slice with SC field.

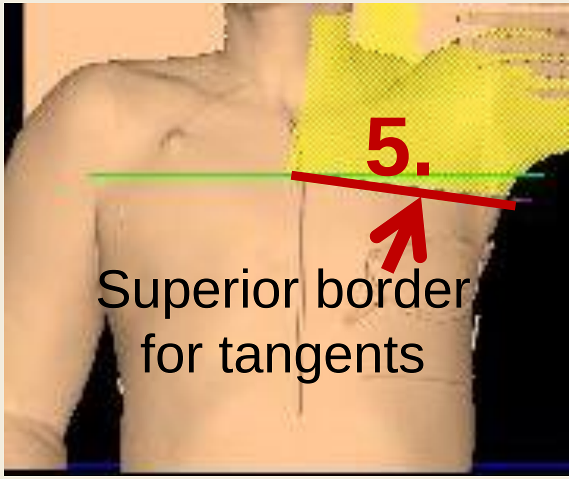


3. Hold curser at about same height and go slice by slice (inferiorly) and contour rod along SC.

4. When get to slice where completely outside body, draw chain contour.



5. Use virtual rod and chain contours and design tangents with angled superior border to match the "angled" inferior border of the SC.



Concluding Remarks
Every Breast/CW Case is Unique

- **Every breast/CW case presents with unique anatomy challenges and specific staging.**
- **So, while basic planning principles can be generally applied, there are many exceptions…..**

each patient's plan is unique.

Acknowledgements
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End

Thank You

Additional Slides
Placement of Isocenter and Set-up Points

Simulation
Patient Positioning and Immobilization

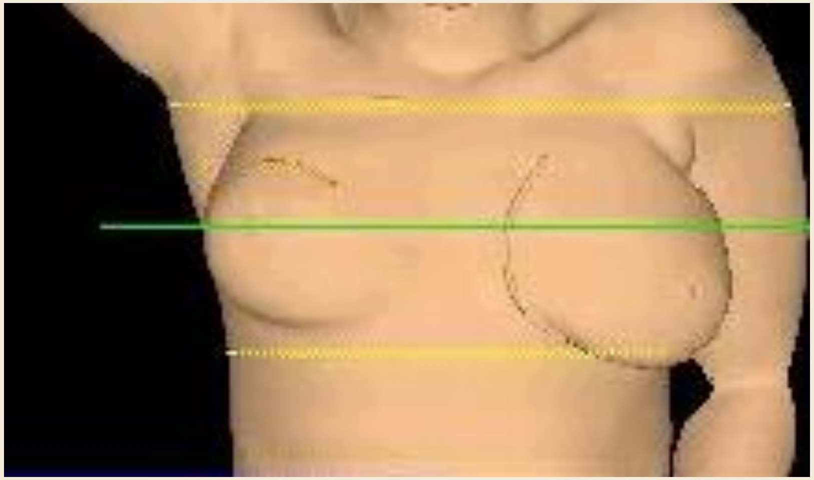
- Supine (and “straight”)
- Exact bar
- Vac-lock with breast board on incline
  - Incline: 5^{o}-20^{o} depending on patients’ chest slope, 10^{o} most common.
- Ipsilateral arm raised
- Contralateral arm by side with thumb tucked in waistband (for comfort and reproducibility)
- Wedge under knees

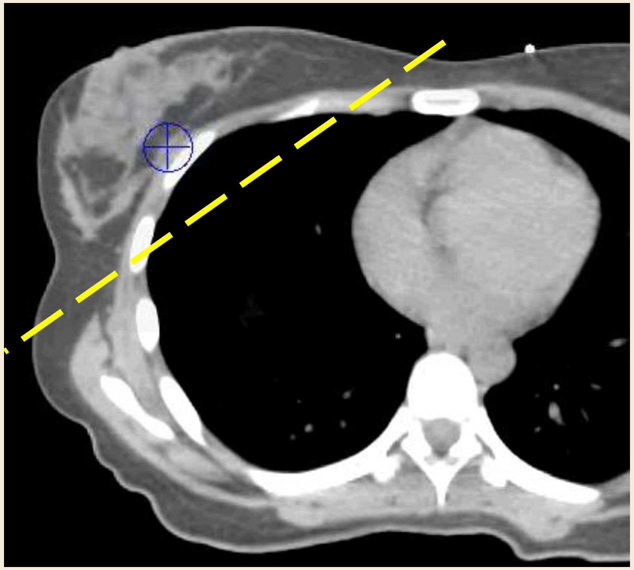
Face/head is usually turned away from involved side. *Can be straight when treating tangents only. But beneficial to have consistent set-up for all cases.*

Simulation
Isocenter Placement

Breast Case (Tangents Only)

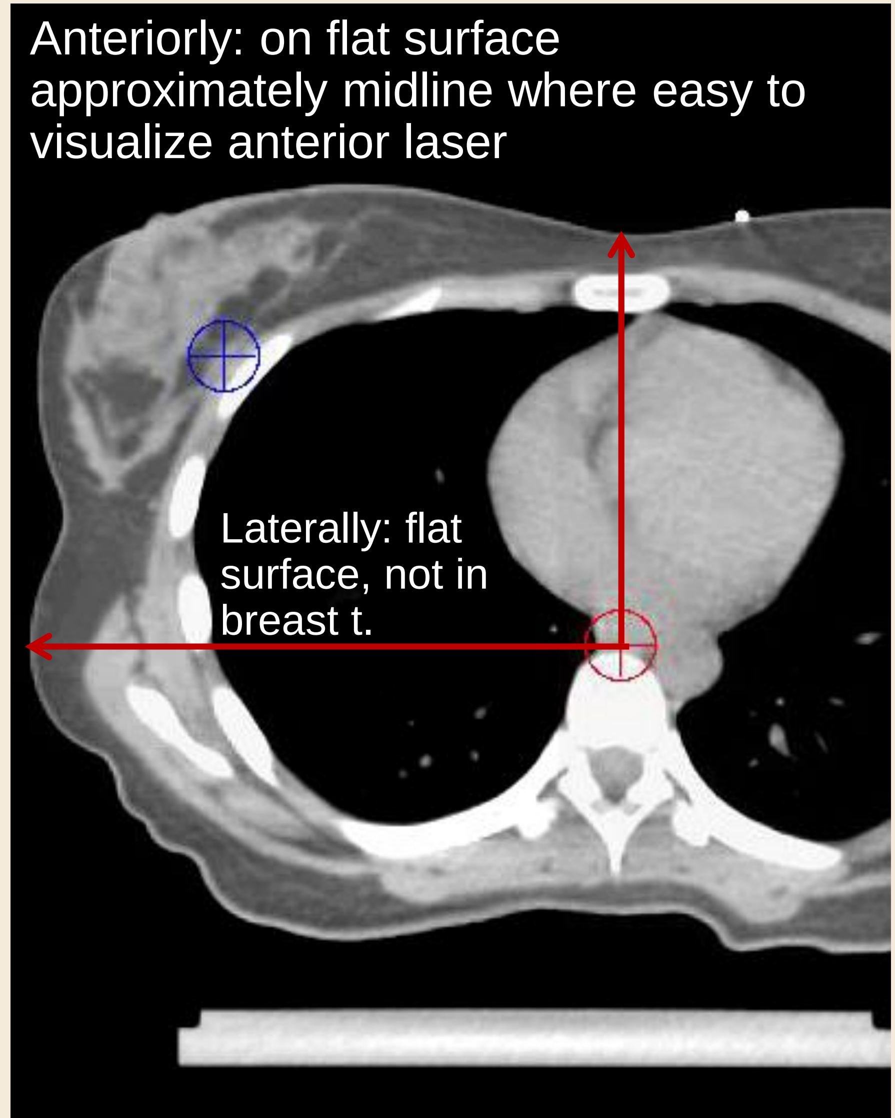
- Select axial slice midway between upper and lower border
- Isocenter approximately midway between anterior and lateral borders for the “approximated tangent field” (yellow dashed line) between muscle and breast tissue.





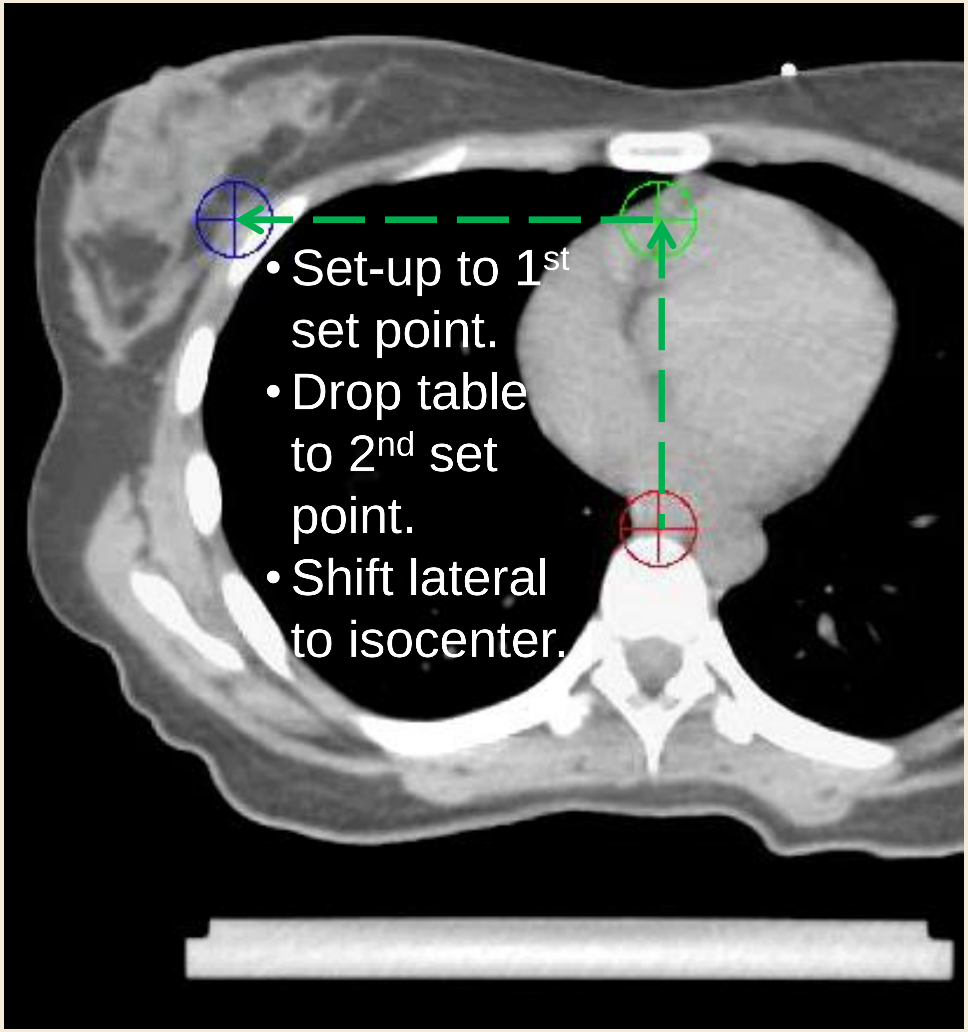
Simulation
Set-up Point Placement

- **1st set point (red):** primary localization point used improve reproducibility of daily set-up:
  - Located on same axial slice as tangents' isocenter.
  - Not in breast tissue which is prone to daily movement.
  - Location selected for easy visualization with anterior and lateral lasers.



Simulation
Set-up Point Placement

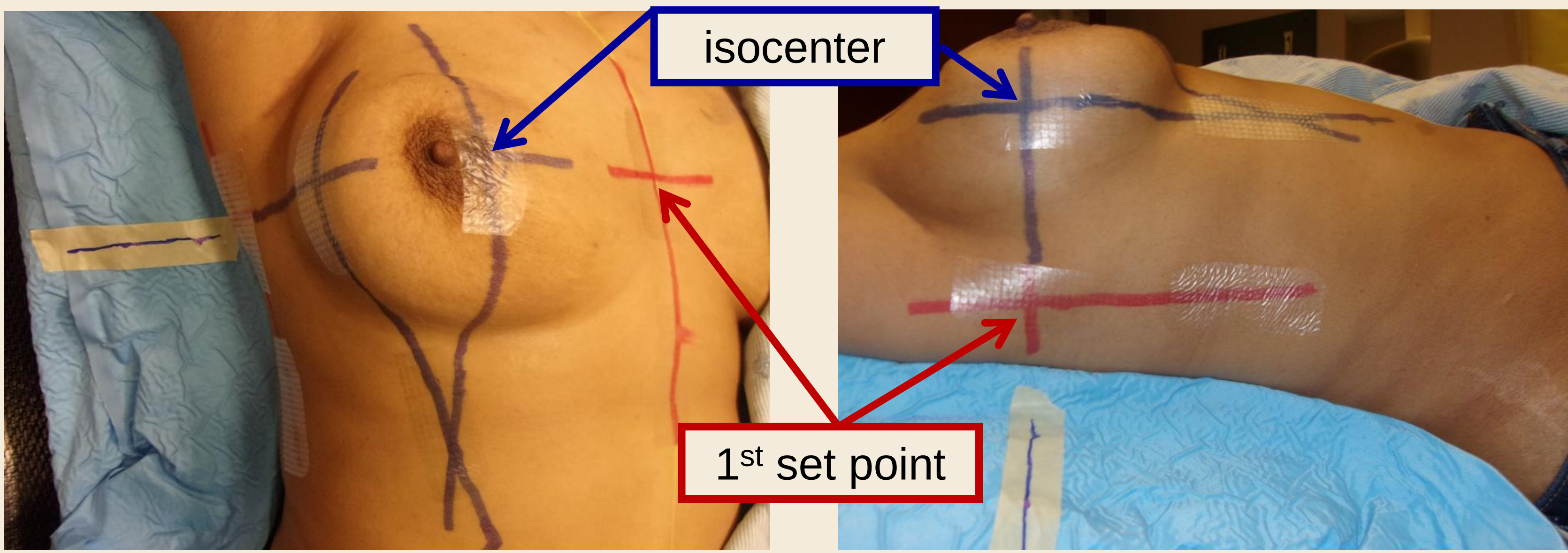
- **2nd set point (green): provides shift coordinates between isocenter and 1st set point:**
  - **Same lateral coordinate as 1st set point**
  - **Same anterior/poster coordinate as isocenter.**



Simulation
Patient Marking Isocenter and Set Point

Anterior Patient Marks

Lateral Patient Marks



Note: 2nd set point is not "marked" on patient skin, only used to determine couch shift coordinates between 1st set point and isocenter.

Simulation for Comprehensive Breast/CW
Breast Board Angle Considerations

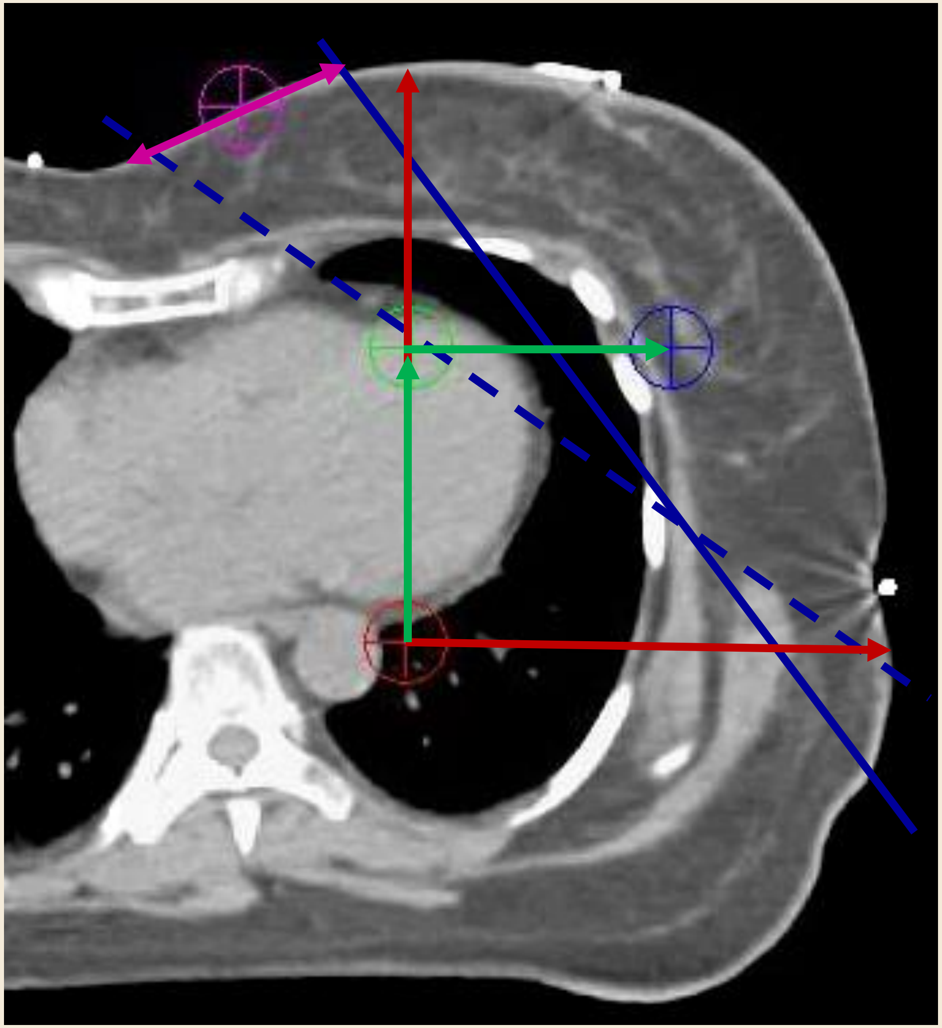
Similar to patients receiving tangents only, with few additional considerations.

- **Head is ALWAYS turned away to opposite side.**
- **May use increased breast board angles to make the IMC field more appositional which will decrease skin dose.**

  However…..

  - **Higher angles may lead to increased lung dose in supraclavicular field).**
  - **May be less reproducible day to day easier for patient to “slide” downward.**

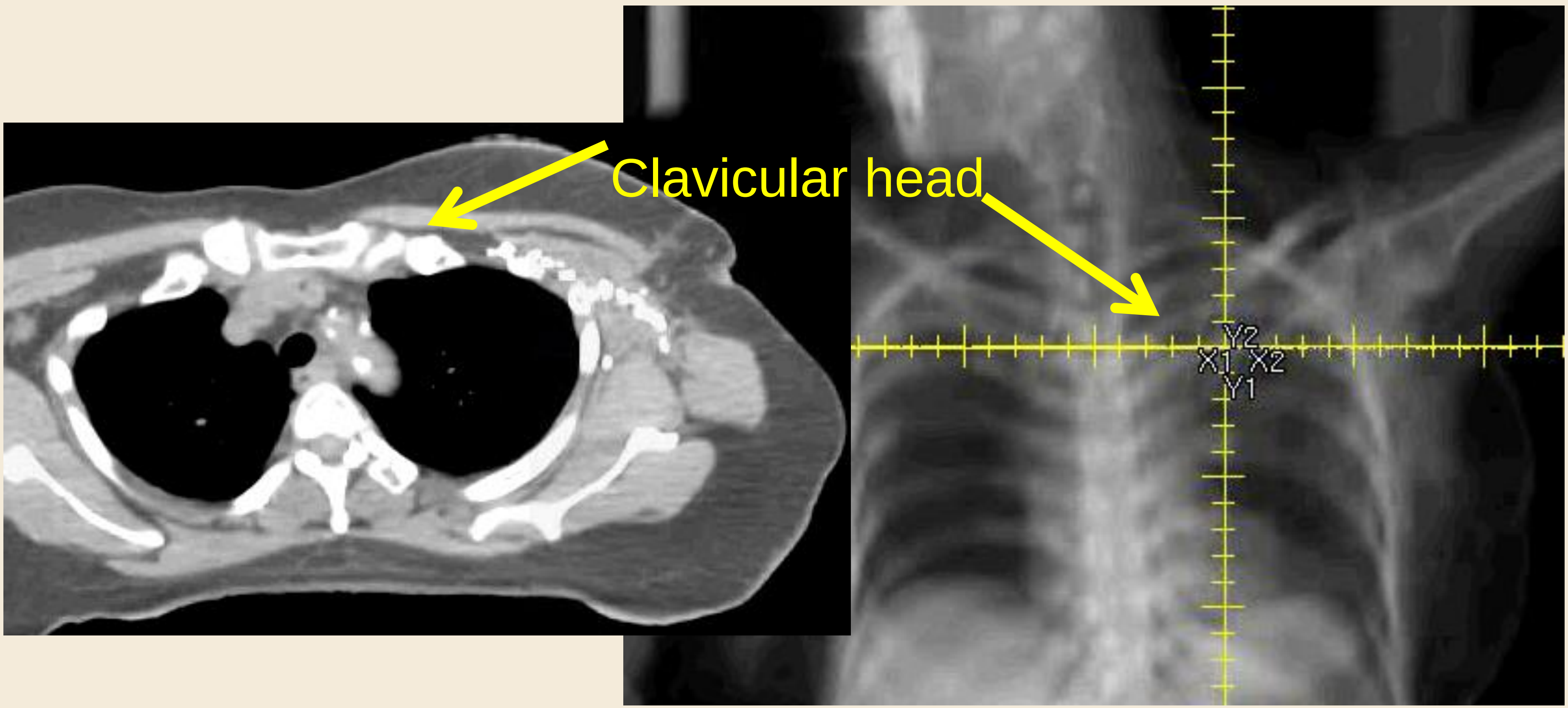
Tangent and IMC
Isocenter/Set-up Points Placement Breast Cases



- Tangents' isocenter (blue), more lateral than if tangents only → beam angle will be steeper.
- 1st (red) and 2nd (green) set points → Same positioning relative to tangent beam isocenter
- IMC isocenter placed at SSD = 100 approximately between medial edge of tangent and midline.

SC Isocenter Placement

- **Match plane between inferior border of SC and superior border of tangents is chosen on a CT axial slice at the level just below the inferior border of the clavicular head.**



SC Isocenter Placement

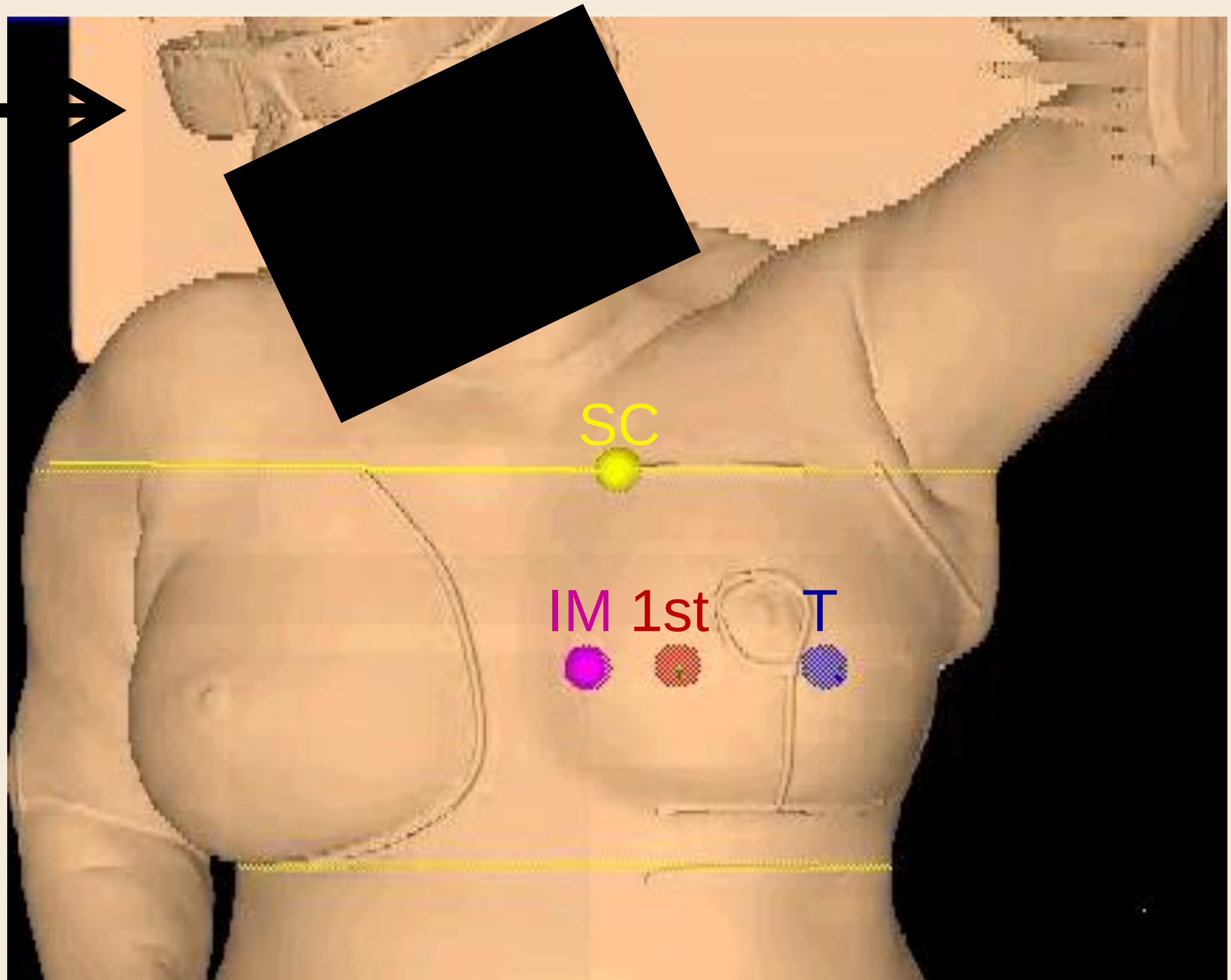
- **Match plane between inferior border of SC and superior border of tangents is chosen on a CT axial slice at the level just below the inferior border of the clavicular head.**

Placed on "selected" axial slice

- **At skin surface (100 cm SSD).**
- **Typically about ⅓ to ½ of field width medial to the point.**

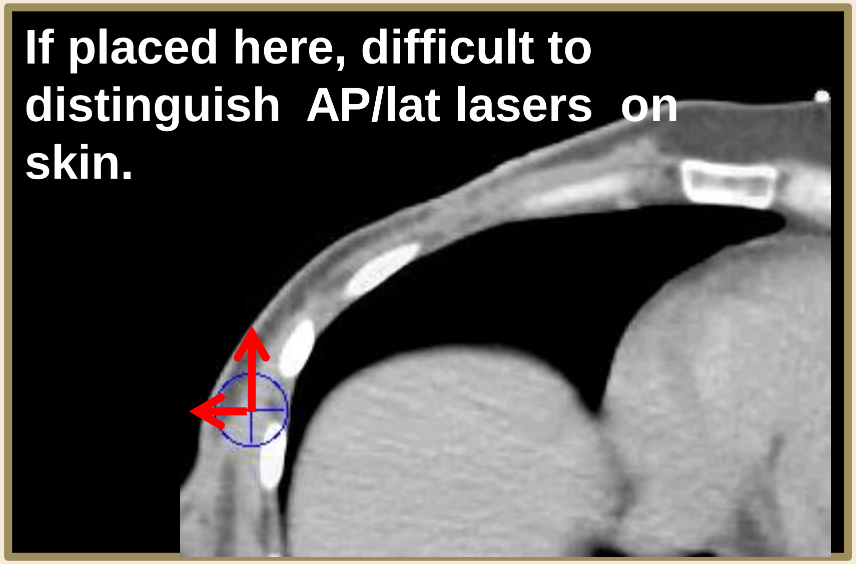
Isocenter(s) and Marking Points

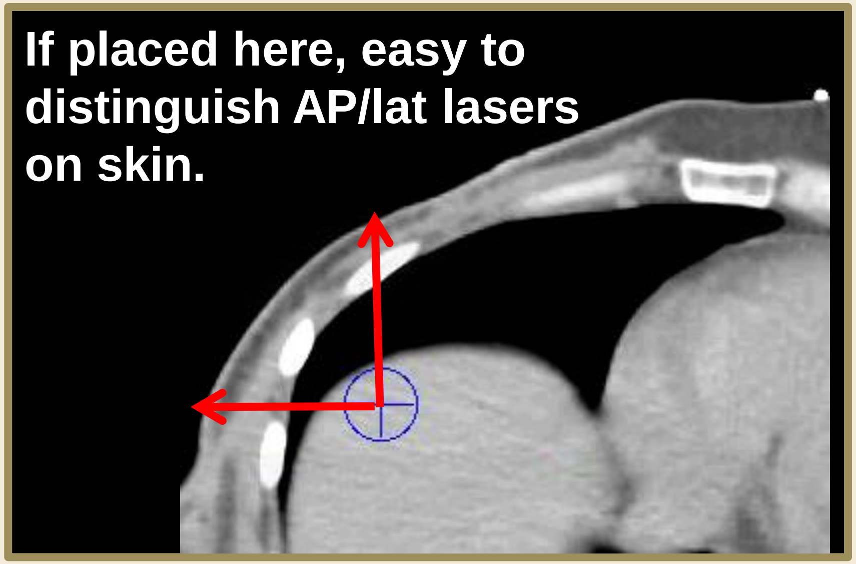
Feedback goggles



Tangent Isocenter Placement Comprehensive CW Treatment

- Isocenter placement is similar for comprehensive breast and CW treatments.
- If CW really thin, minor difference for tangents' isocenter:
  - may place more medial to keep lateral and AP setup lasers from being too close to distinguish on skin.





Additional Slides
Medial and Lateral Tangents
Field Design

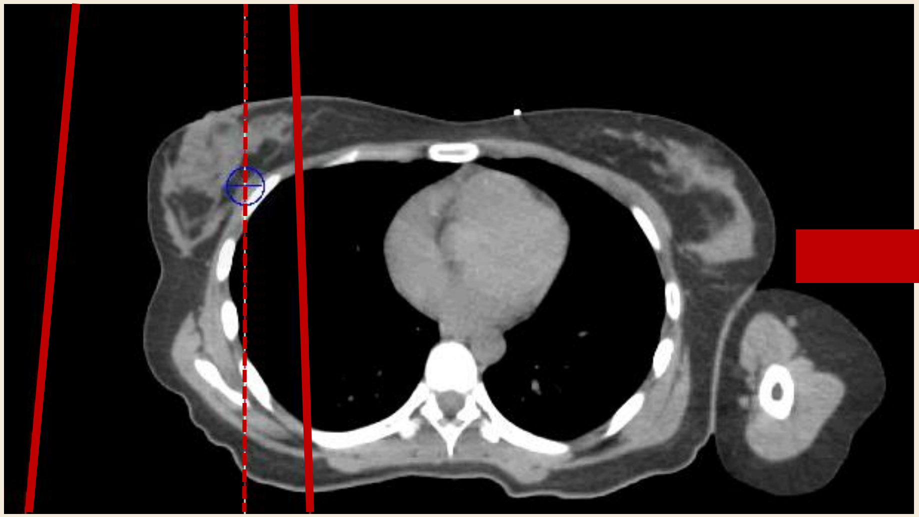
Summary
Field Design Tangents

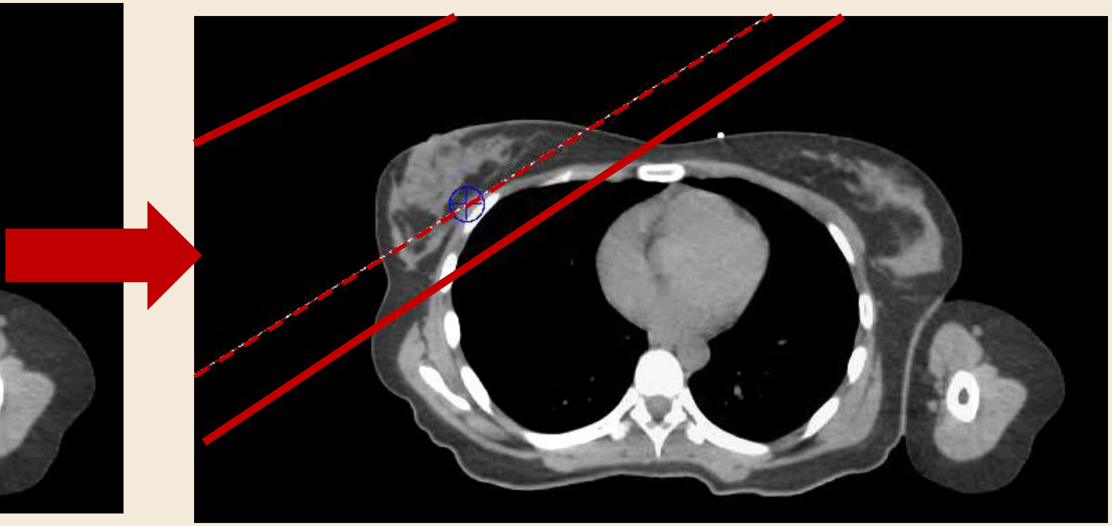
- Start with medial tangent (then match lateral)
- Set “reasonable” initial field size.
  - Length: Upper border to ~ 1.5 to 2 cm below breast mound.
  - Width: 1- 3 cm (depending on isocenter) on “deep” margin (lung side) and wide enough to give ~2 cm flash.
- Gantry, couch, collimator rotation
  1. Rotate gantry to reasonable angle cover breast tissue
  2. Rotate couch to achieve non-divergent superior border (contour of axial image will collapse on itself).
  3. Rotate collimator so deep field edge is parallel with the slope of the chest wall.

  Then iterate collimator, couch, gantry of the above until covering the “breast”. *Helpful if you can have tumor bed contour and axilla apex (if that will be included).*

Beam Set-up Starting Point

Rotate Gantry

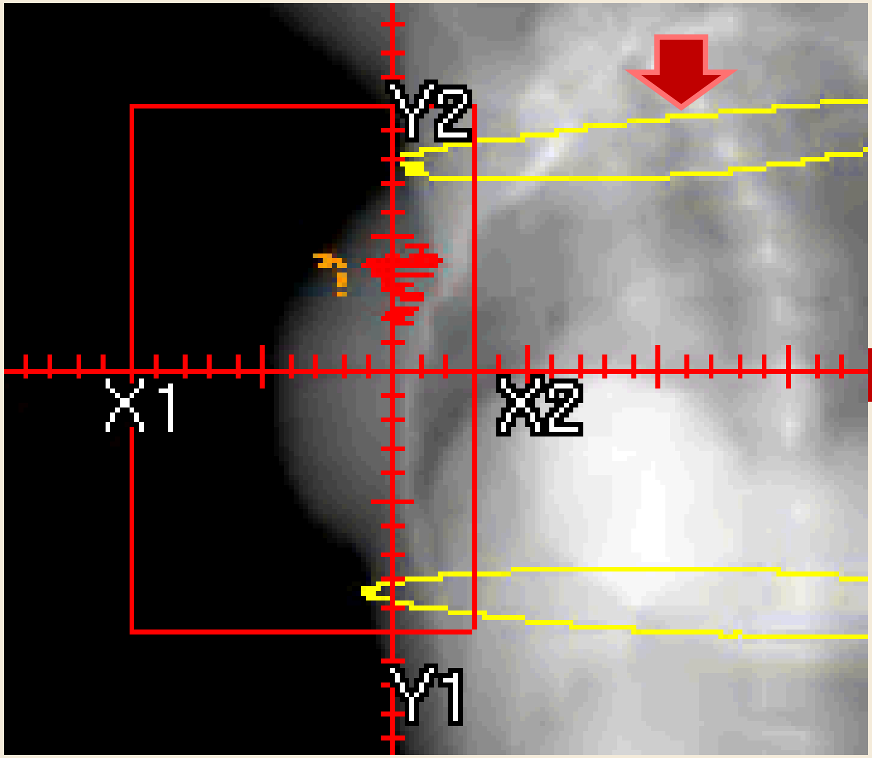


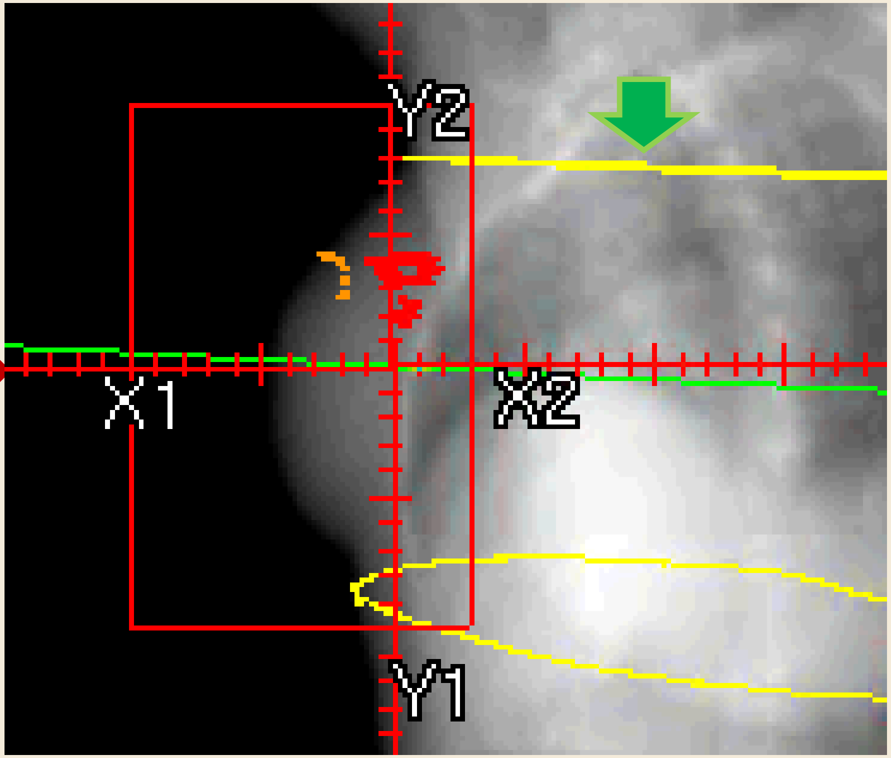


- *Rotate gantry to reasonable angle cover breast tissue.*
- *Usually between 50^o-60^o*
- *58^o in this example*

Rotate Couch

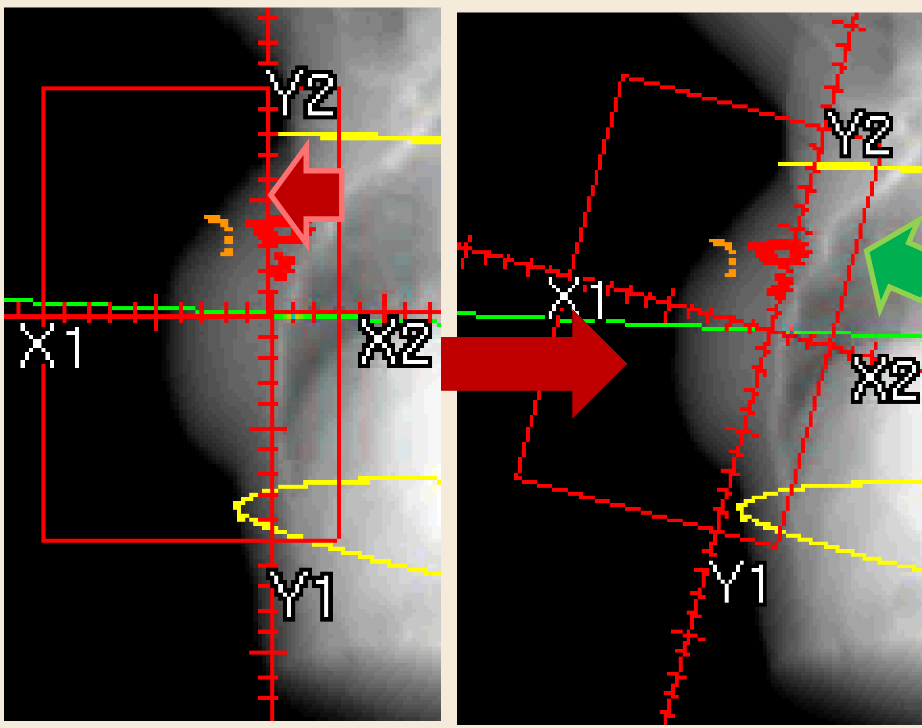
- Rotate couch to achieve non-divergent superior border.
- Contour of axial image (at superior border) will collapse on itself.
- Couch rotation: usually 2^{o} - 9^{o}, 5^{o} in this example.



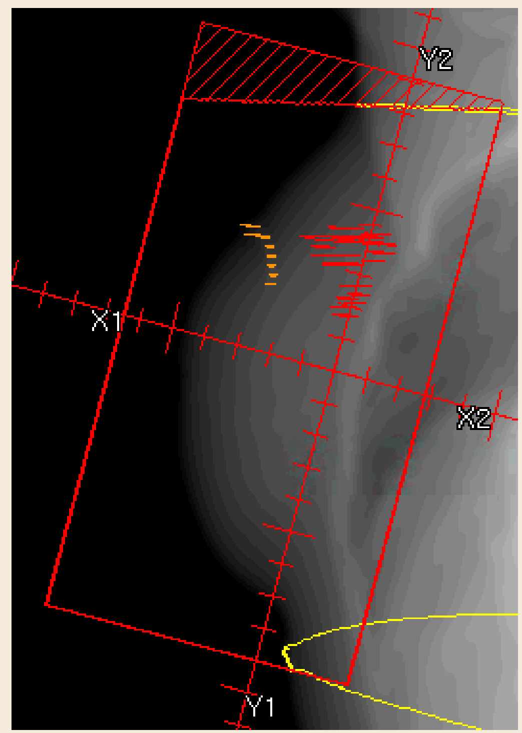


Rotate Collimator and Finishing Touches….

- Rotate collimator so deep field edge is parallel with CW slope.
- Collimator rotation ~ 8^{o}-20^{o}, 15^{o} this example.



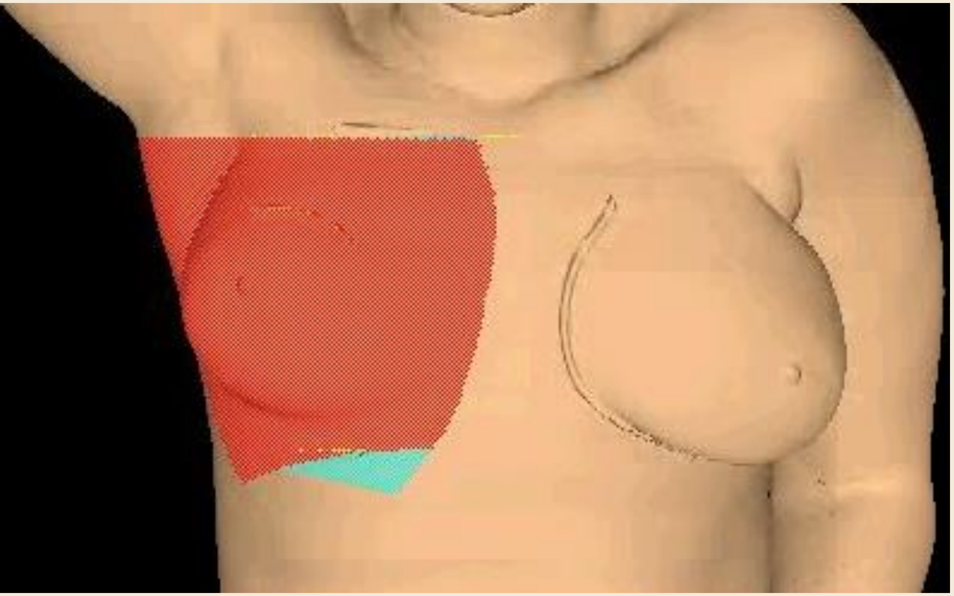
- Add superior block along “collapsed” superior border contour.
- Adjust field sizes



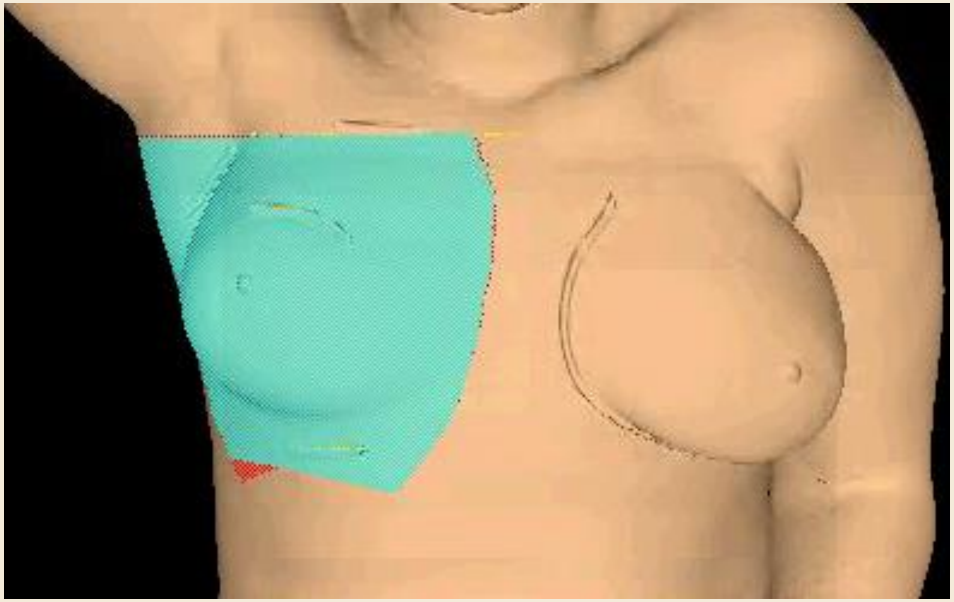
- Deep border to minimize lung ≤ 2 cm.
- Shallow border to achieve 1.5 - 2 cm flash.

Tangential Beams
Non-divergent Superior Border

Medial Tangent

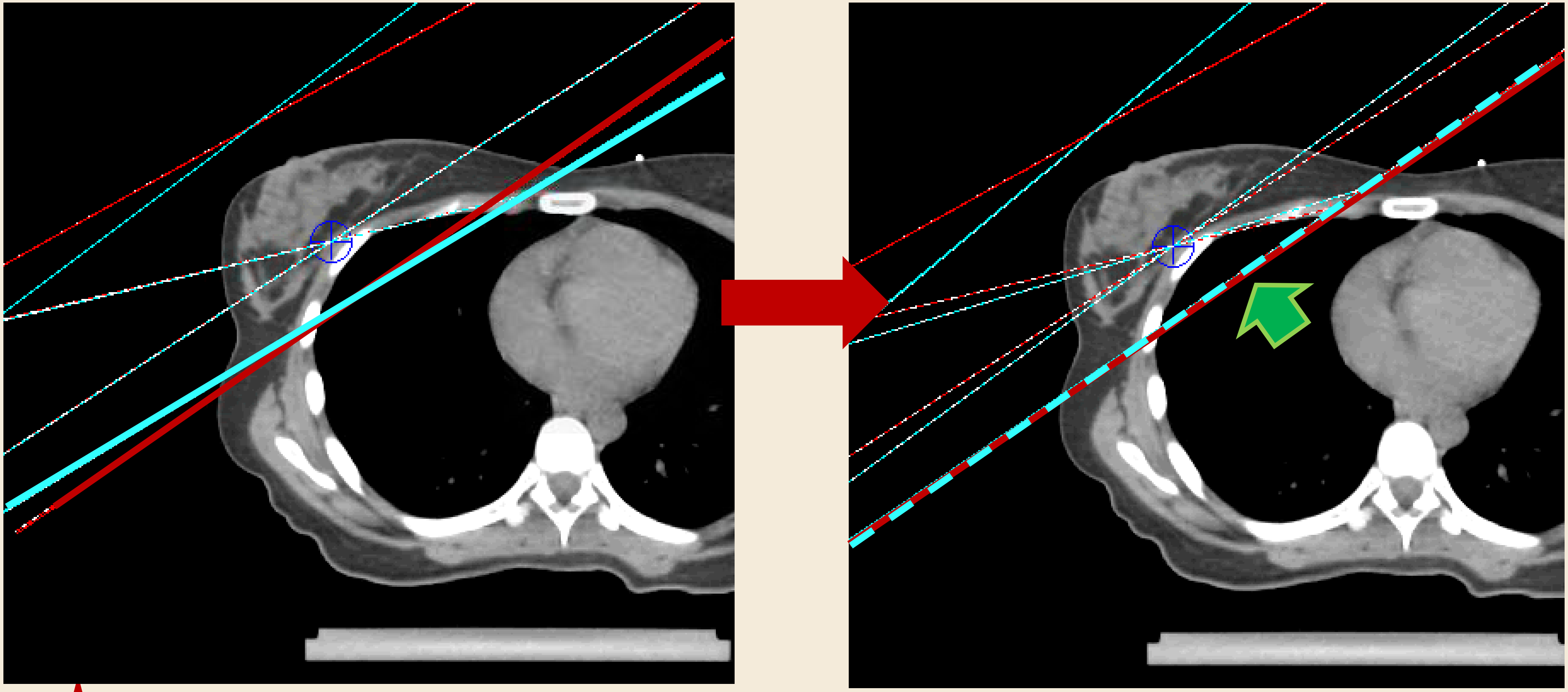


Lateral Tangent



Create "Matching" Lateral Tangent
Rotate Gantry

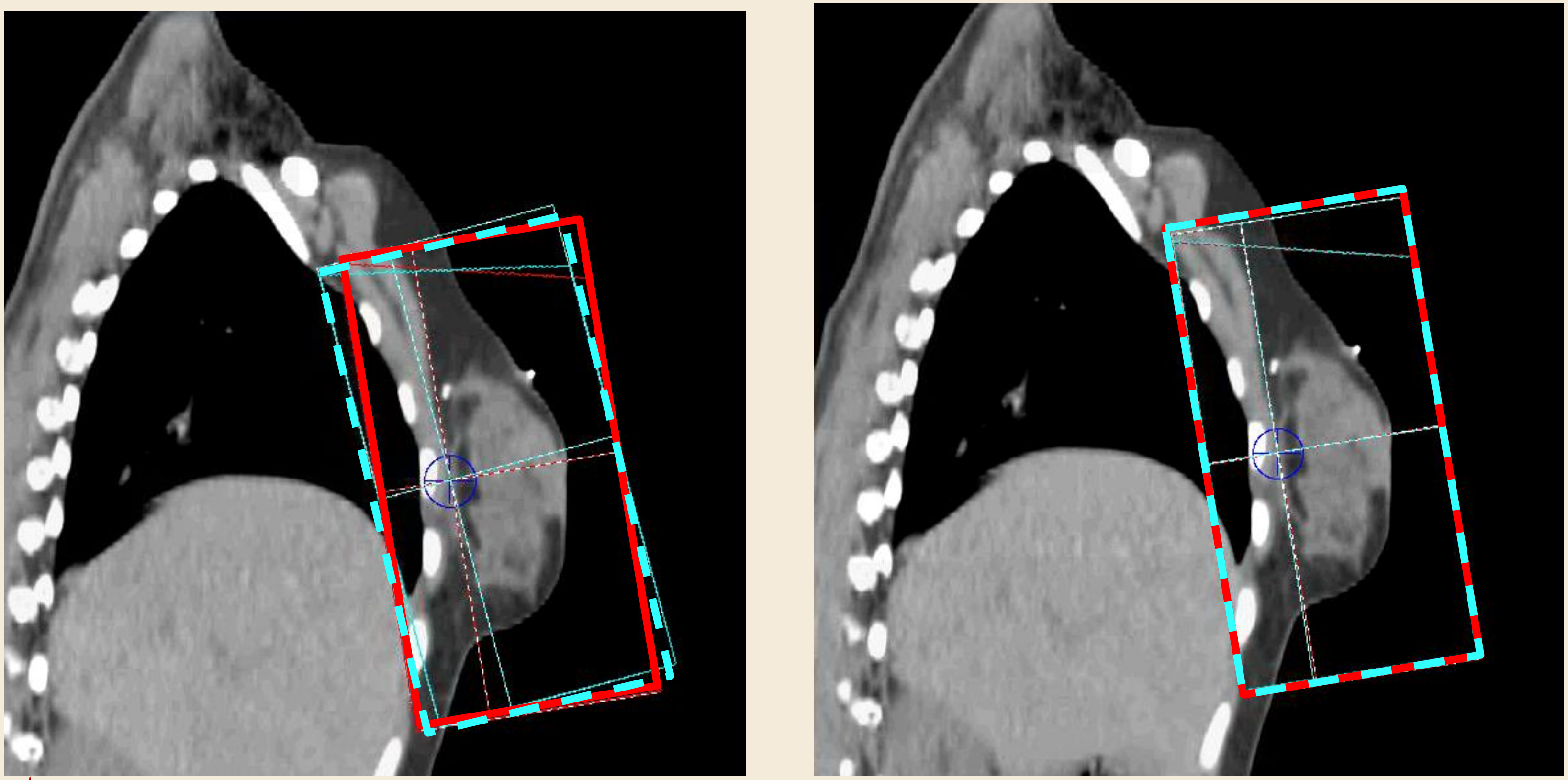
Rotate lateral tangent gantry to match medial. Do NOT rotate medial tangent.



★Best view to visualize gantry matching is axial.

Create "Matching" Lateral Tangent Rotate Collimator

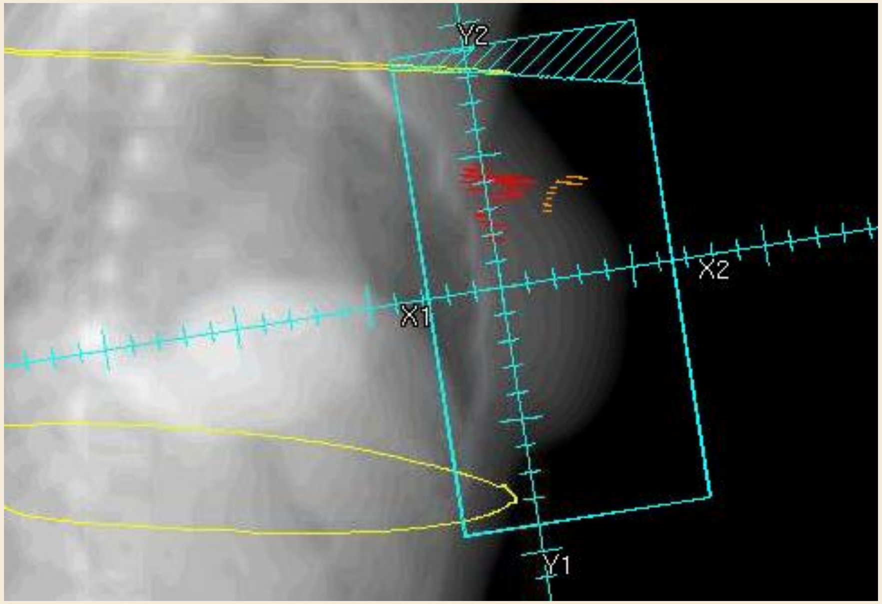
Rotate lateral tangent collimator to match medial. Do NOT rotate medial tangent.

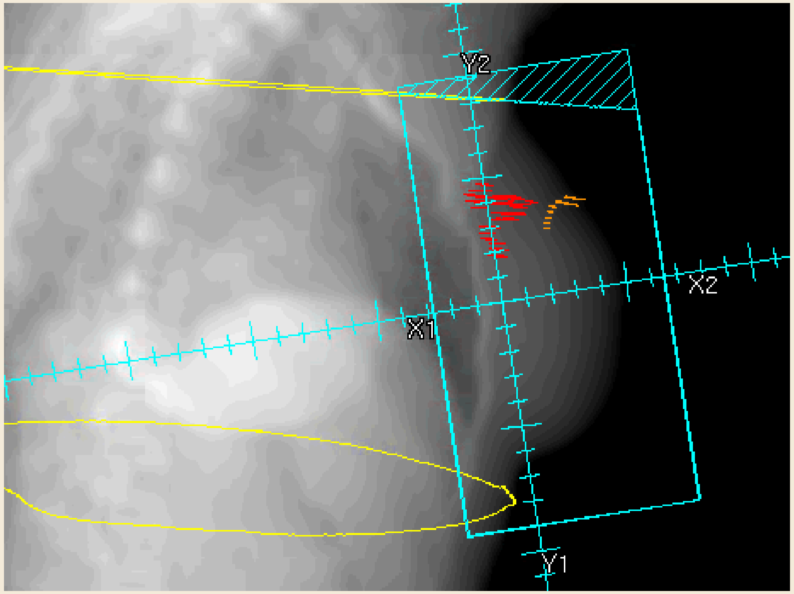


★Best view to visualize collimator matching is sagittal.

Create “Matching” Lateral Tangent Rotate Couch

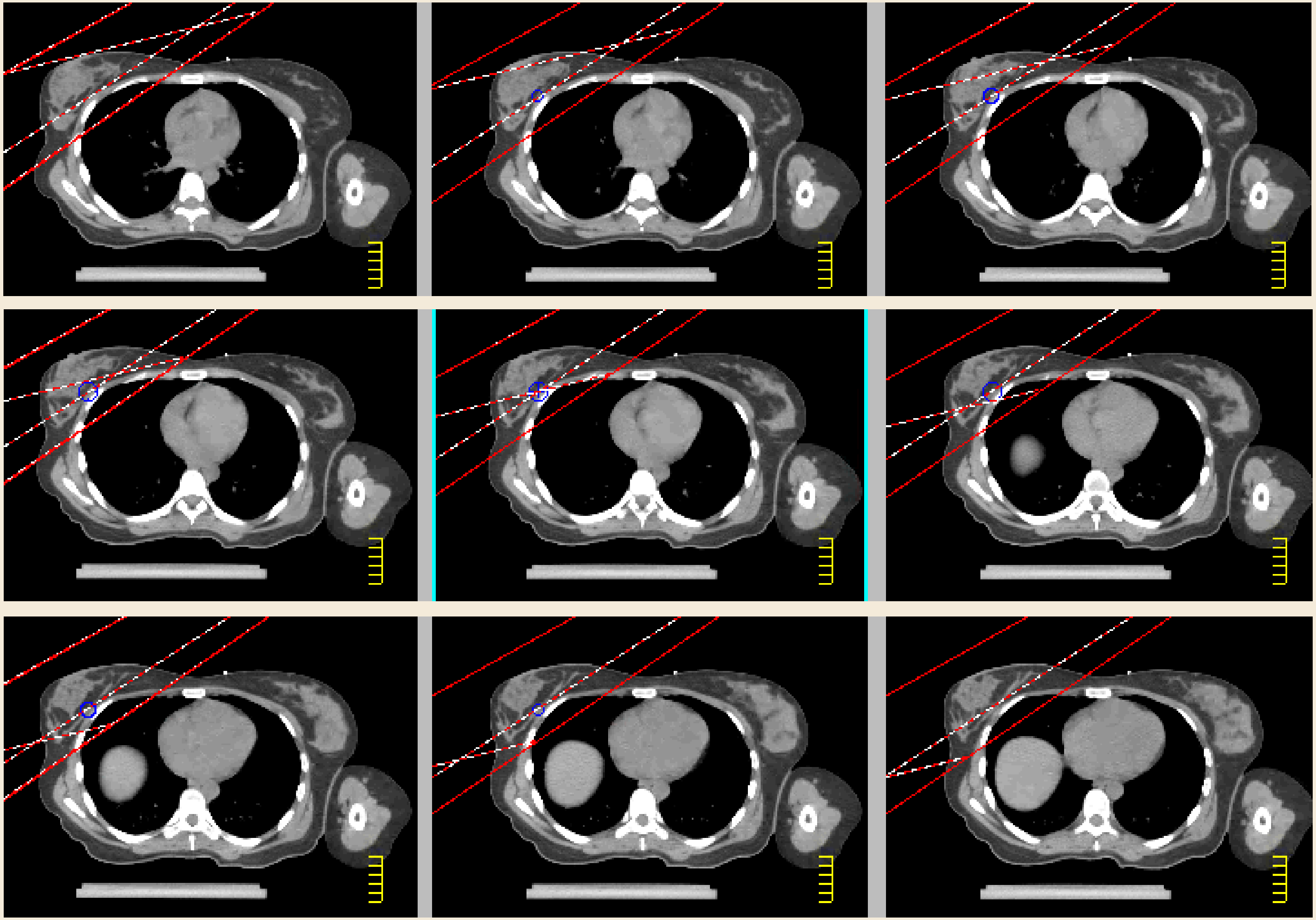
- Rotate lateral tangent couch to be non-divergent, then confirm matching on axial and sagittal planes (usually 1º-2º from the “opposed angle”.
- “Tweak” gantry and collimator if needed.
- Re-verify non-divergence





★Best view to visualize non-divergent border is field DRR.

And…
Review ALL Axial Slices

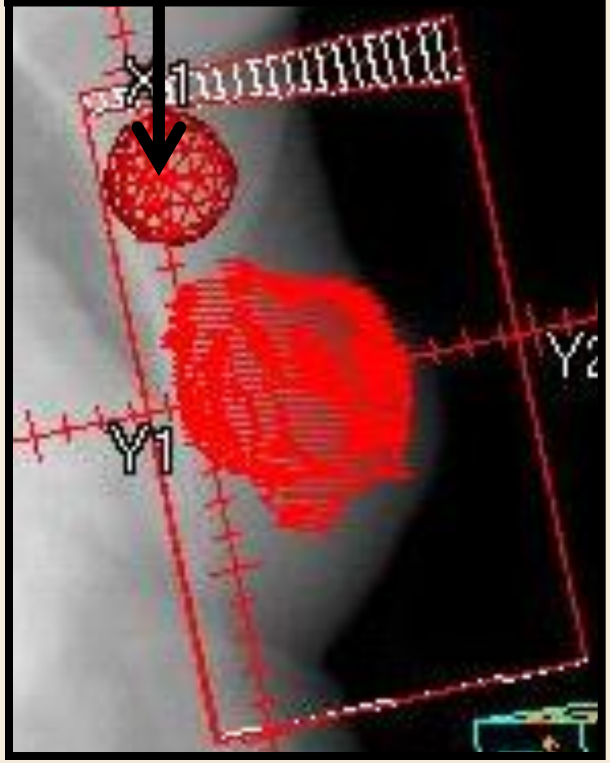


Tangential Beams
Calculation Point Placement

Why Necessary?

Isocenter usually near lung, bone or field edge.

Tip: To help evaluate placement - Make point 4 cm diameter



Point Placement/Location Details

- **Not in bone or lung.**
- **Should be within 4 cm of tissue**
- **Should ≥ 2 cm from block edge**
- **Do not place in build-up region**

Good starting location for placement: thickest portion of the breast, usually at most superior & posterior portion of field.

SC Field
Borders and Angles

Borders

- Inferior: Inferior aspect of clavicular head.
- Superior: Choicoid
  - If + SC node, border extended to mastoid tip (w/ mandible block).
- Medial: Pedicles of vertebrae
- Lateral: To cover the lateral edge of the pectoralis muscle (to achieve coverage of interpectoral nodes).

Angles

- <u>Gantry:</u> 15º - 20º
  - To avoid trachea and spinal cord.
- <u>Collimator:</u> 0º
  - Unless using rod & chain (~4º - 12º).
- <u>Couch:</u> 0º

SC Field
Energy Selection

- **The energy on this field is based on coverage of the nodal areas.**
  - **The axillary apex, i.e., level III axilla should be covered by the 90% isodose line.**
- **This can be achieved by mix of 6 MV and 18 MV photons prescribed to their respective d_{max}.**

Additional Slides
DIBH Imaging and Treatment

Varian Real-time Position Management (RPM) System + “In-house” Modifications.

DIBH Imaging

- Acquire a free breathing scan.
- Breath hold "practice"
- Acquire DIBH scan
  - Physicist marks isocenter(s) on scan while during breath hold practice and acquisition of DIBH scan.
  - Upon completion of DIBH scan, isocenter coordinates transferred to CT for patient marking.
- Fusion of FB and DIBH scan.
- FB isocenter coordinates transferred to DIBH data set.

DIBH Imaging

- Respiration/imaging are coordinated using:
  - Abdominal IR transponder positioned at diaphragm.
  - RPM camera positioned at the end of the CT couch.

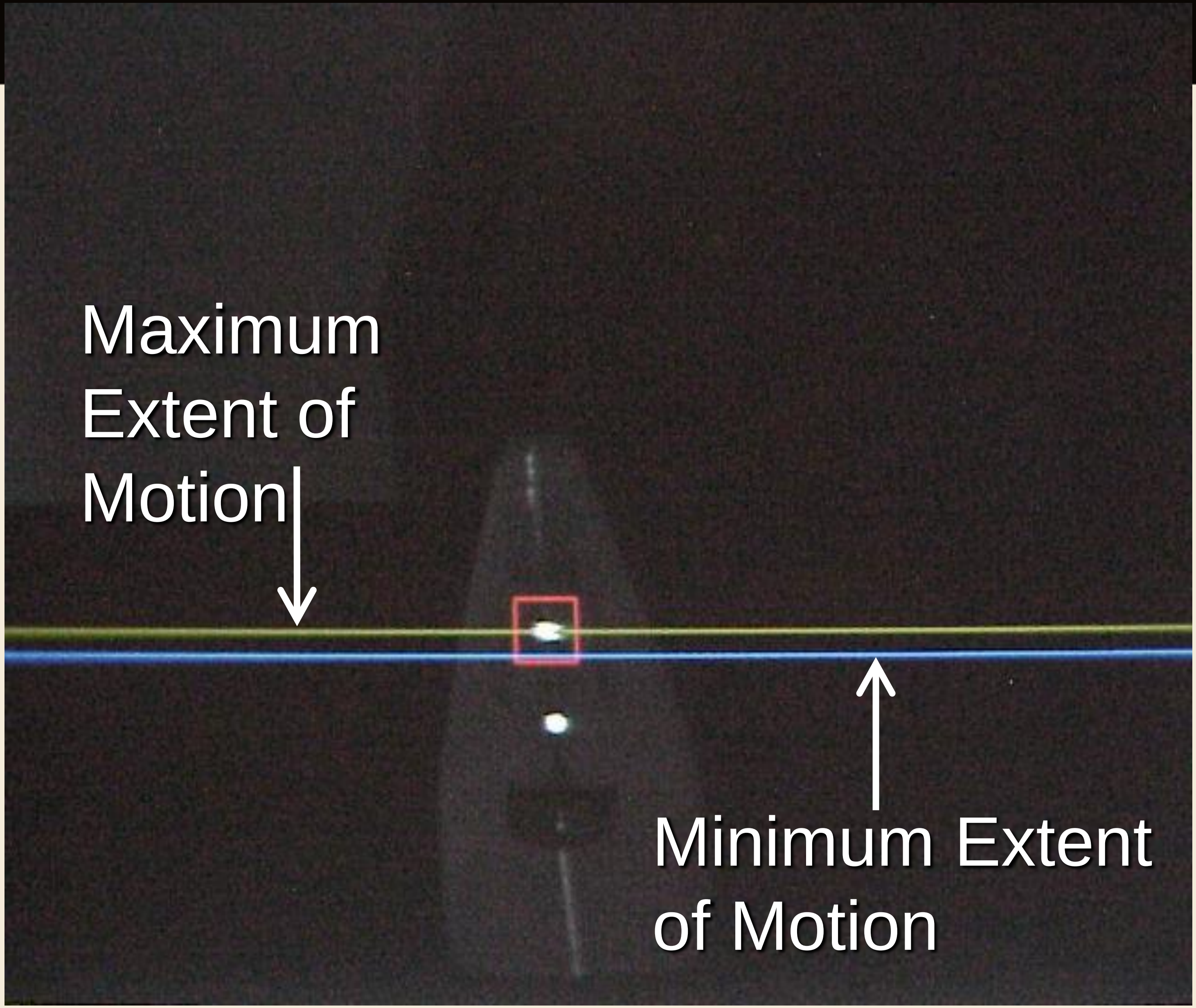
DIBH Imaging

- Real-time digital image processing is used to track chest motion by analyzing the time-dependent marker location
  - Motion data is displayed and recorded in the form of a moving strip chart
  - Video images from the fluoroscope or CCD camera are synchronized to the recorded motion data
- Playback of the video images and strip chart are used to determine the gating thresholds

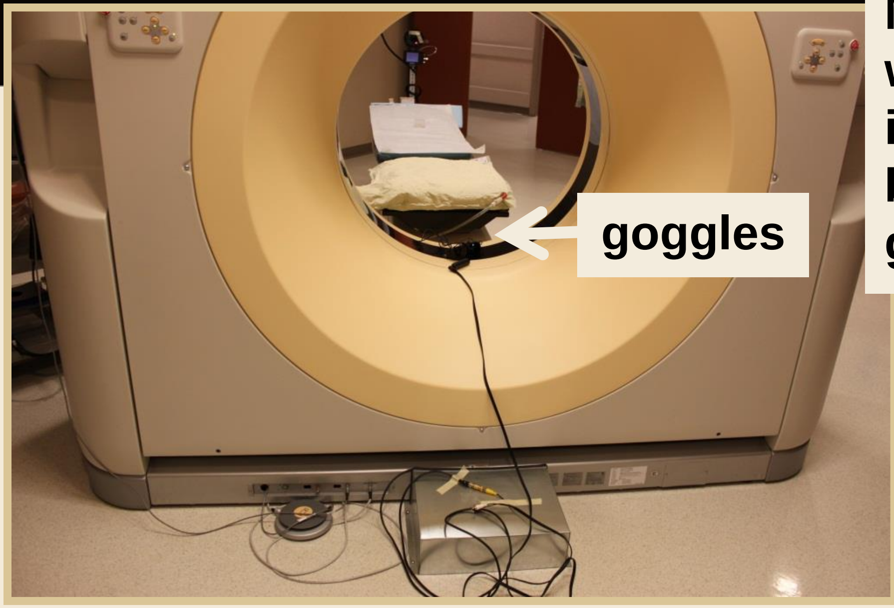
Gating Software

- The gating thresholds are saved as percentages of the maximum and minimum extent of motion
  - The range of marker motion is learned in the "Track" mode.
  - The maximum and minimum values are displayed as horizontal lines and are continuously updated.
  - If the motion is repetitive, the lines stay in approximately the same position.

Tracking Mode

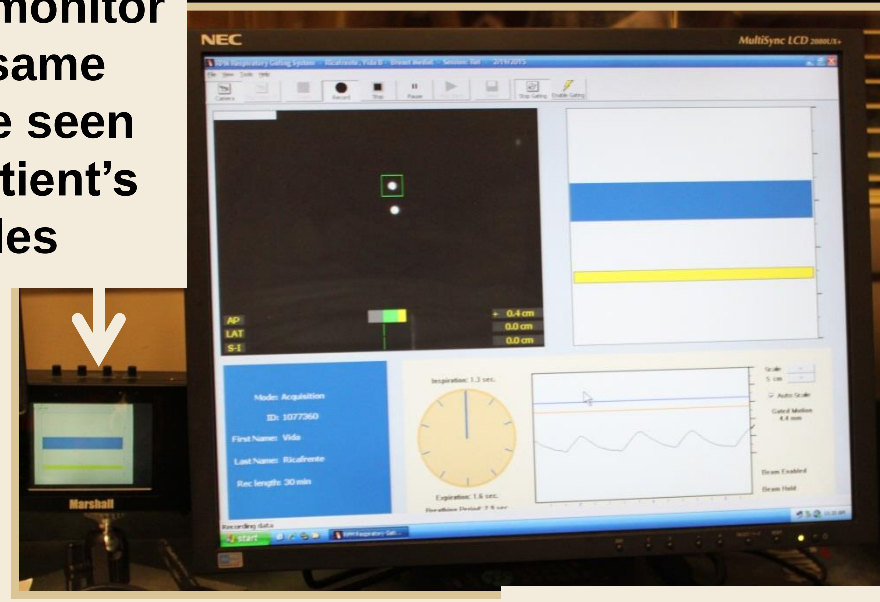


Feedback Guidance Hardware

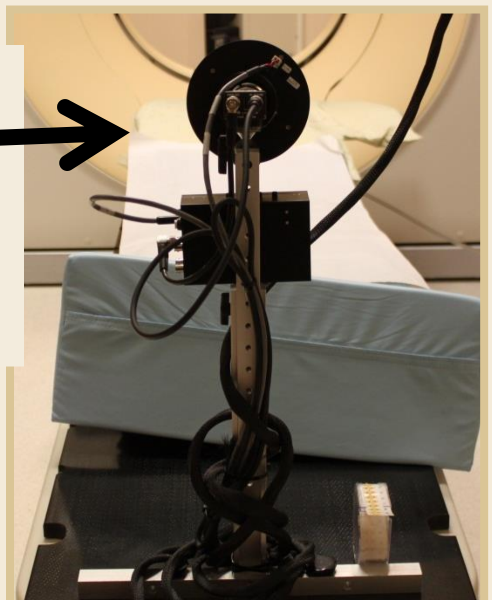


goggles

Mini-monitor with same image seen by patient's goggles



In-house aluminum camera mount (identical mount in treatment room).



Scan converter

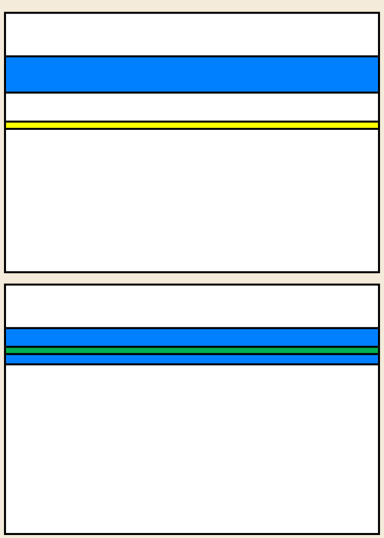
Feedback Guidance Software/Hardware

- **DIBH CT scan acquired using feedback guidance.**
- **Patient watches the respiratory pattern via feedback goggles and is asked to voluntarily hold breath w/in gate.**
- ***We use "generic" gaming goggles (~$700 on Amazon.com).***

Vuzix Wrap 310XL Widescreen Video Iwear

Feedback Guidance Software/Hardware

- **Split the signal from duel feedback video card from RPM PC to the:**
  - **Monitor in CT simulation workroom**
  - **Scan converter**
    - **Scan converter “grabs” the portion of screen that shows the gate window bar plot.**



Signal is split again and images from scan converter sent to:

- Goggles (minimizes data visualized by patient → less confusing).
- Monitor in CT workroom (so therapist and patient “see” same images.

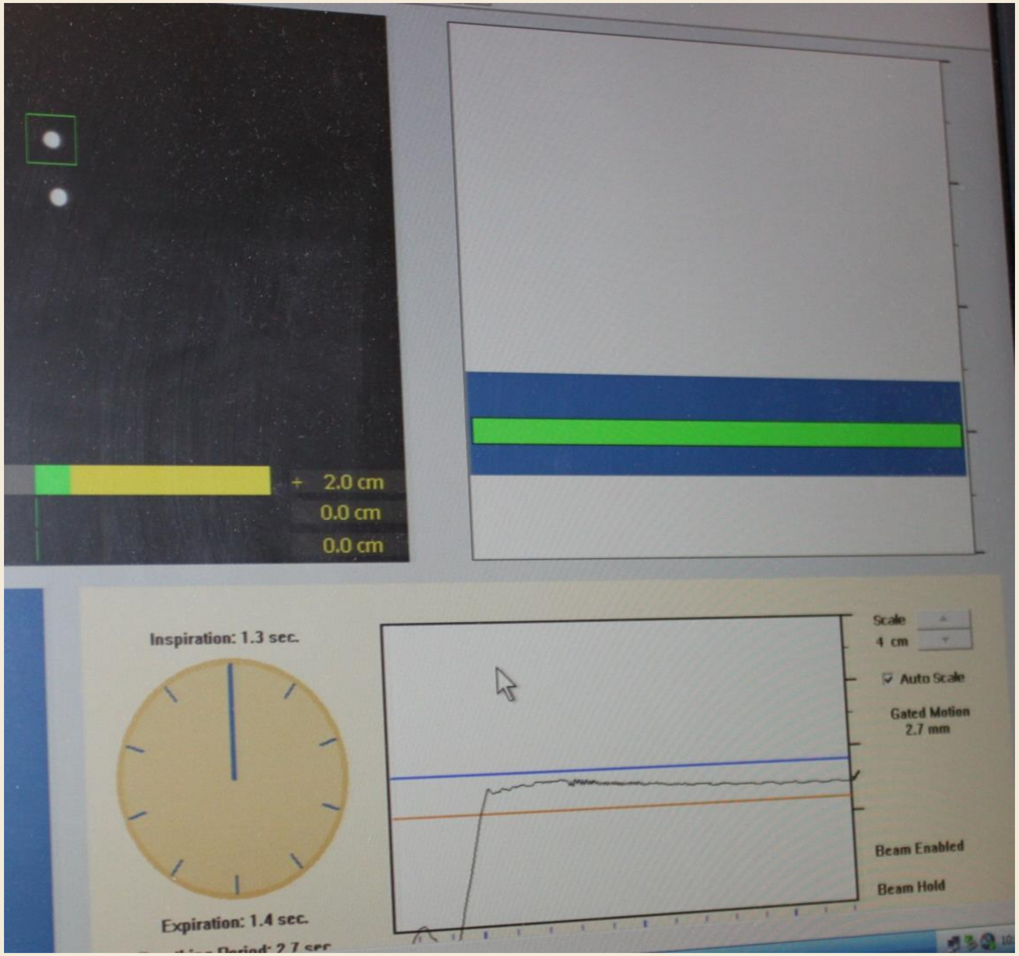
DIBH Imaging

- CT images acquired during maximal inspiration.

- Most patients can hold breath ~15 seconds.

- Sufficient time to complete scan in single breath hold.

- Typical scan → head to abdomen in 2.5 mm slices.



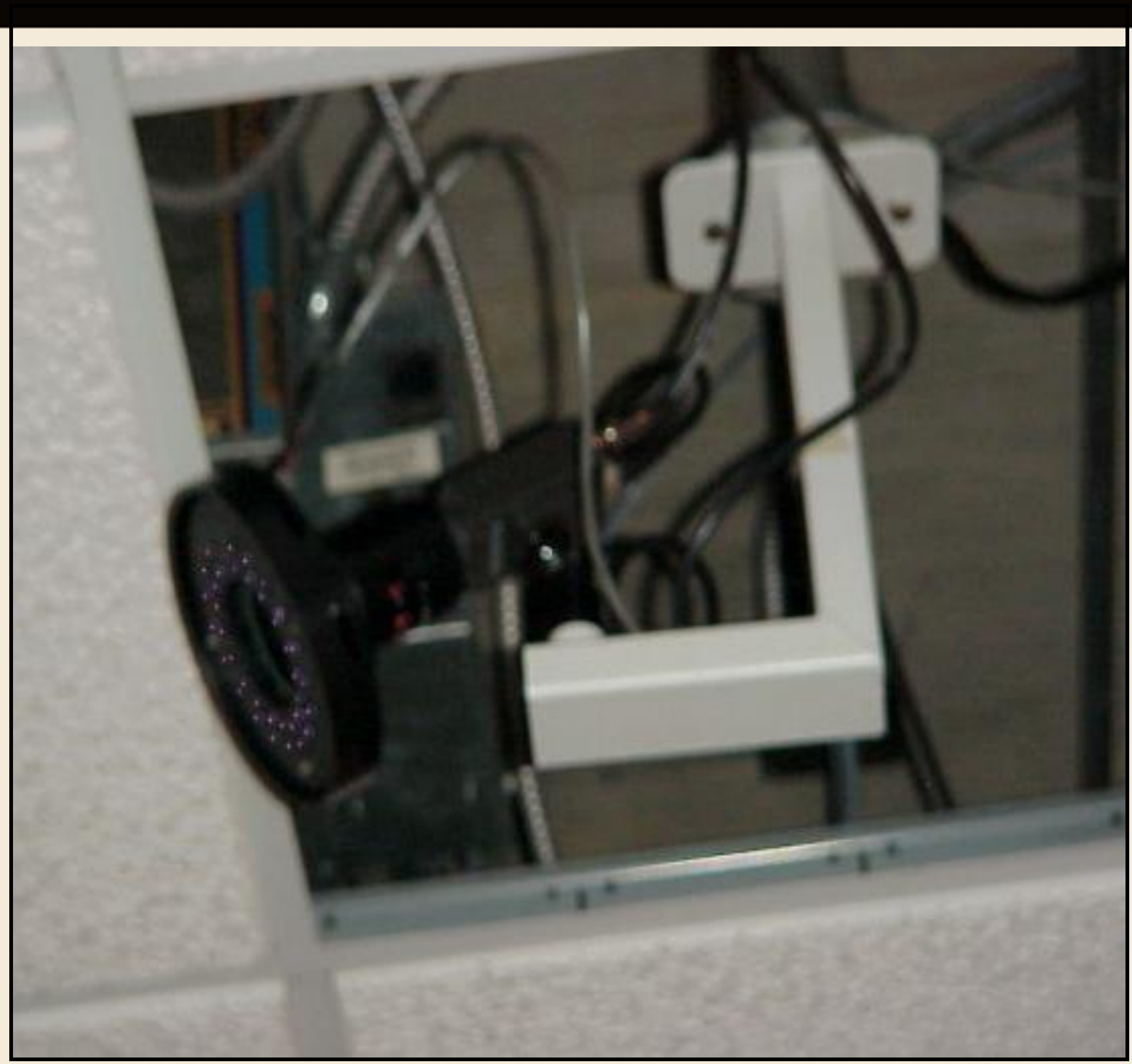
DIBH Treatment

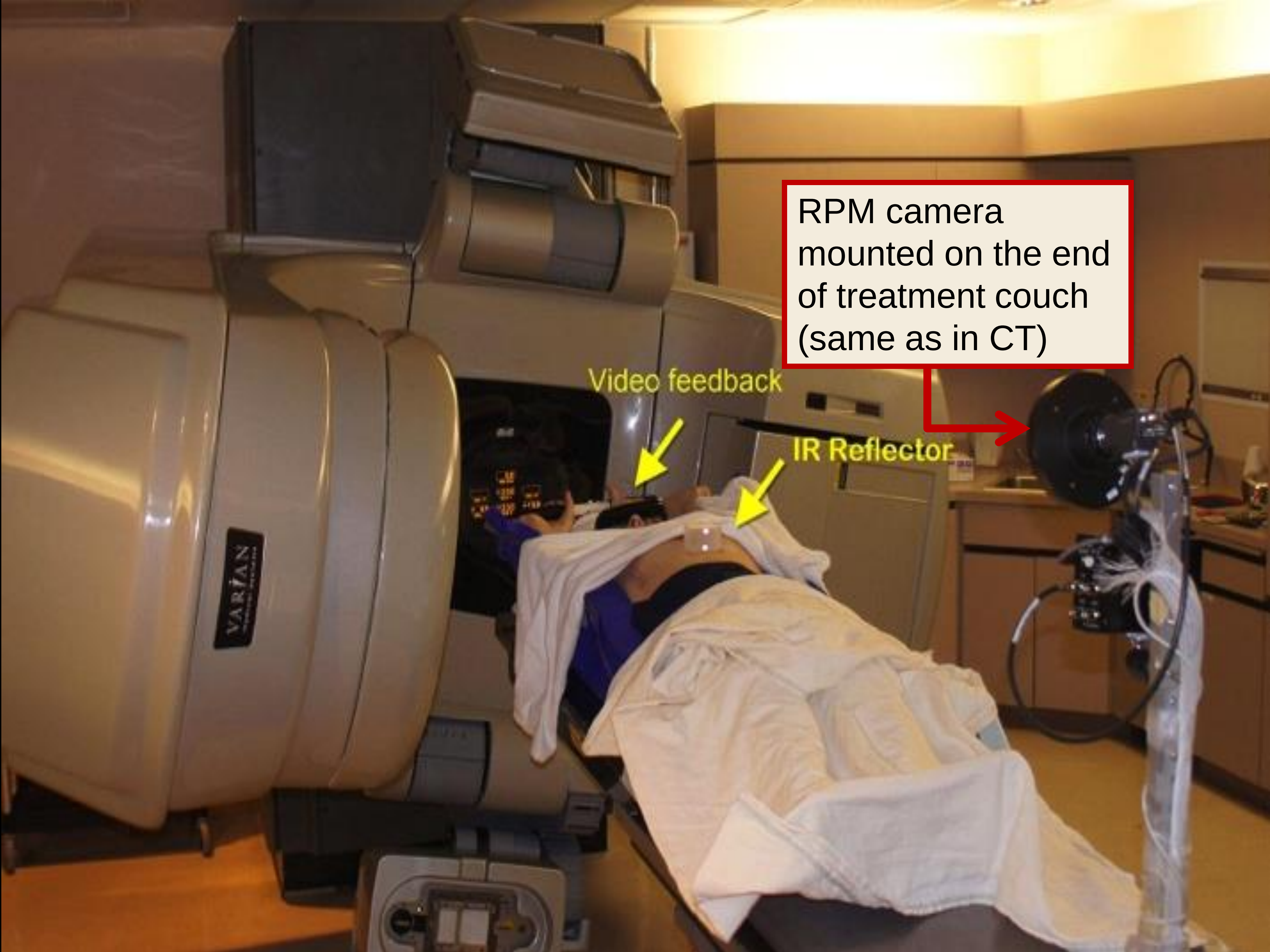
- During feedback-guided DIBH treatments, the beam is on during the maximal inspiration gate.
- The breathing trace file acquired during CT simulation is used for treatment (<u>do not reacquire new file</u>).
  - Breathing trace file database is shared between CTs and linacs → file pulled from a server by the RPM at treatment.

Why/how does this work?

Where's the RPM camera?

- **Standard ceiling mounting of RPM camera.**




RPM camera mounted on the end of treatment couch (same as in CT)
Video feedback
IR Reflector
VARIAN