Clinical Use of Bolus Electron Conformal Therapy (BECT) in the Treatment of Shallow and Irregularly Shaped Tumors

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Outline

- Bolus ECT Background
- Clinical Workflow
  - Simulations
  - Treatment Planning/Ordering
  - First Fraction
- Special Cases
  - Nose
  - Back
  - Foot

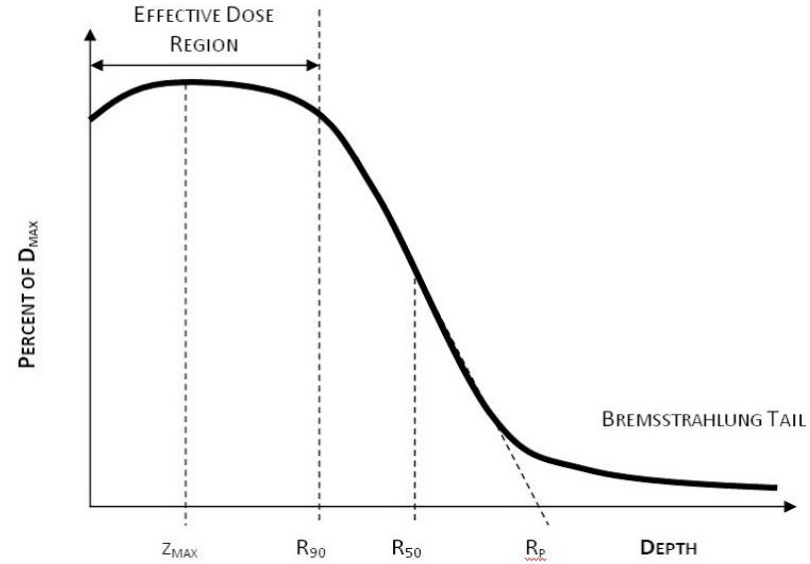
BECT Statistics at Barnes Jewish Hospital

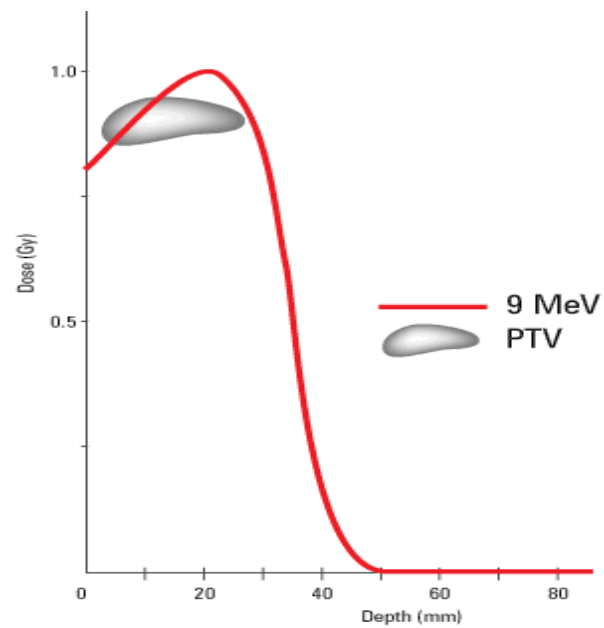
- 10 Linear Accelerators
- 6 Radiation Oncologists who have used .decimal
- 3 physicists and 2 dosimetrists who have worked extensively with .decimal
  - Omar Wooten
  - Lindsey Olsen
  - Merilee Spengler
  - Anthony Maglairi
- First patient treated with .decimal in 2010
- Treated 35+ patients
  - Head/face/neck
  - Feet/lower leg
  - Back
  - Shoulder
  - Breast/Chest Wall

Standard Electron Therapy

Why use electrons?

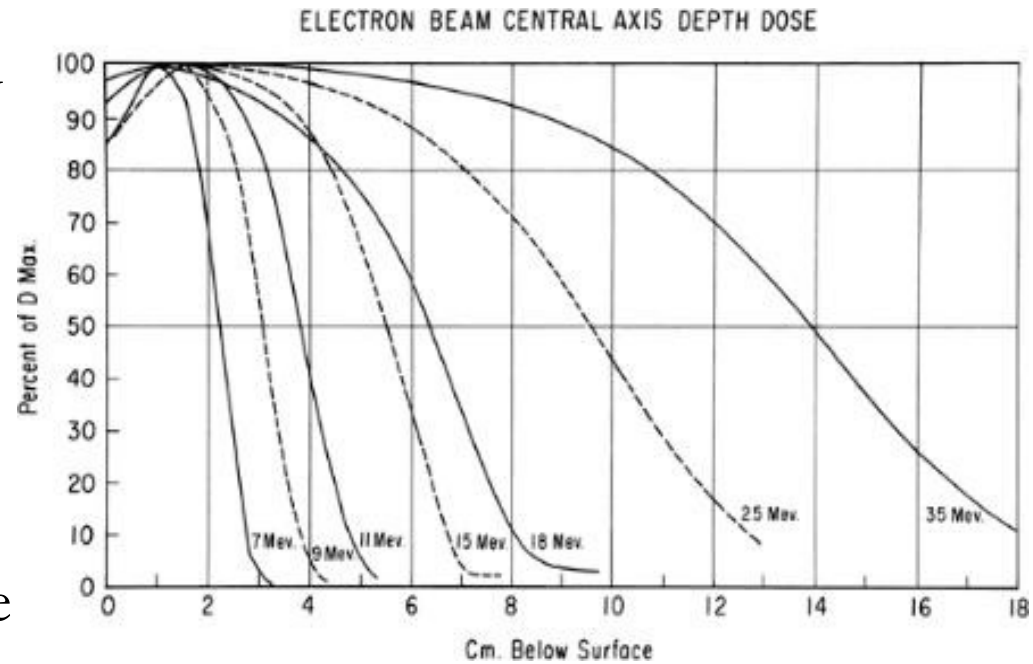
- Optimal for treating superficial tumors (d ≤ 6cm)
- Characteristics of electron dose distribution
  1. 90% - 100% dose spread (d <R_{90})
     - Uniform dose to Planning Target Volume (PTV)
  2. Sharp distal fall off (R_{90}-R_{10})
  3. Finite penetration depth (R_p)
     - Limited dose to critical structures distal to PTV





Standard Electron Therapy

- Clinical Electron Therapy
  - Modern linacs have discrete electron energies
    - 6 MeV to 20 MeV+
  - Dose typically Rx to the 90% isodose surface
  - Energy selected so that the 90% isodose surface is distal to the deepest part of the target
  - Rule of Thumb
    - Lowest Energy ≥ Depth * 3.3



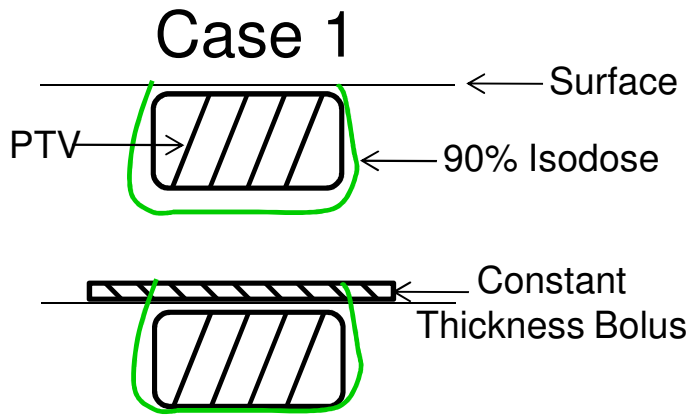
Example

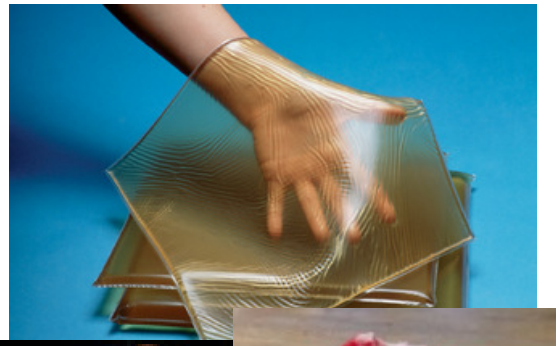
Maximum target depth is 4.5cm and the provided electron energies are 6 MeV, 9 MeV, 12 MeV, 16 Mev, and 20 MeV. What energy should be used?

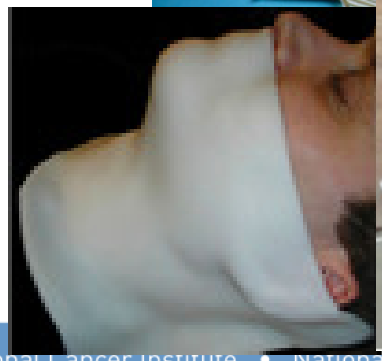
4.5 x 3.3 = 14.85; Answer: 16 MeV

Standard Electron Therapy

- Objective:
  - Conform 90% isodose surface to distal PTV surface.
- Case 1:
  - Issue: $R_{90} > d_{PTV}$
  - Solution: Constant thickness bolus
  - Decreases depth of R90
  - Increases skin dose
  - SuperFlab, Aquaplast, red wax, wet gauze



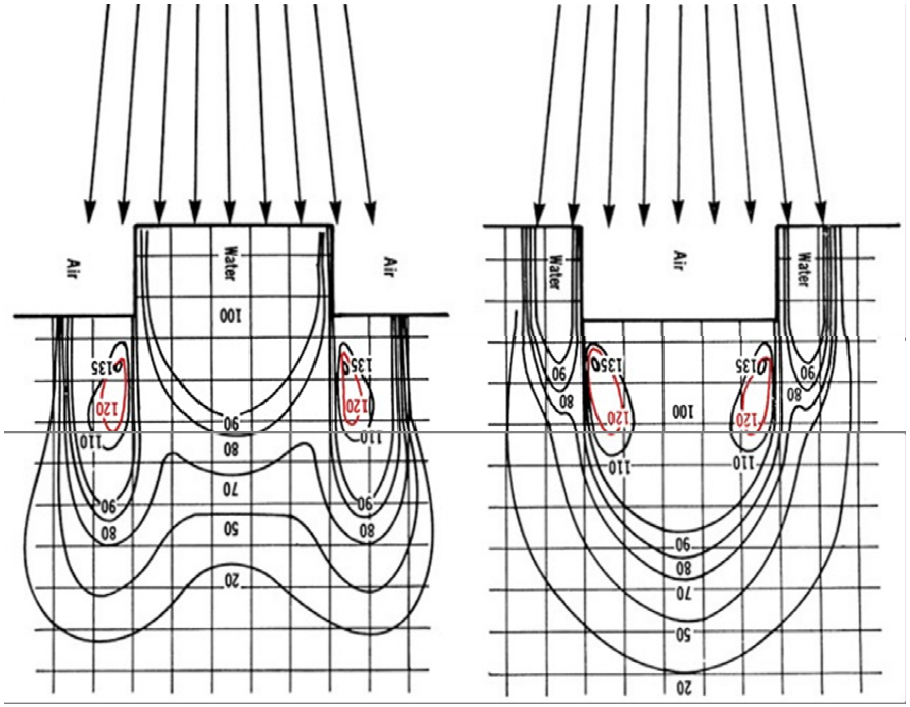


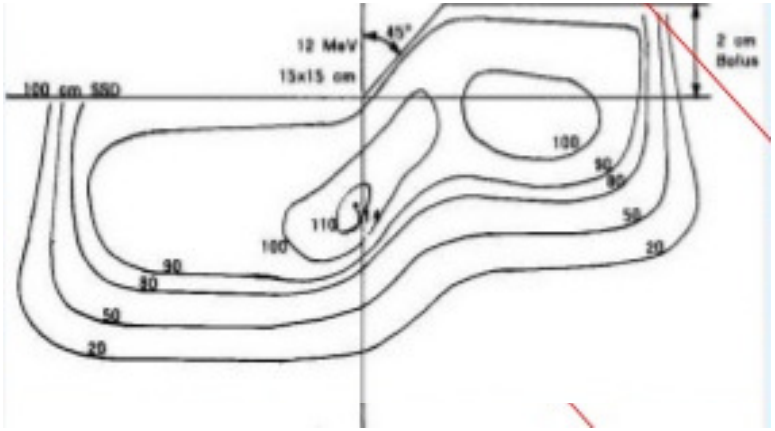


Standard Electron Therapy

Common Challenges

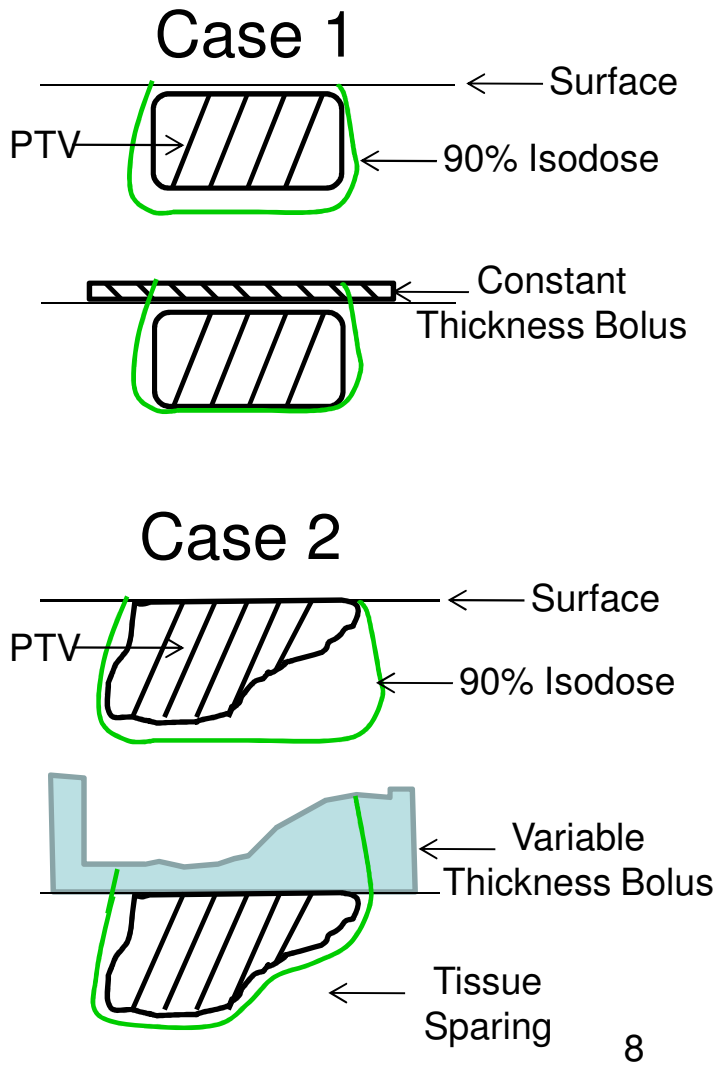
- Surface Irregularities
  - Create hot/cold spots
- Variable depth target volumes
  - Healthy tissue/OARs distal to shallow PTV treated to prescription dose
- Sloping surface creates oblique angle of incidence





Standard Electron Therapy

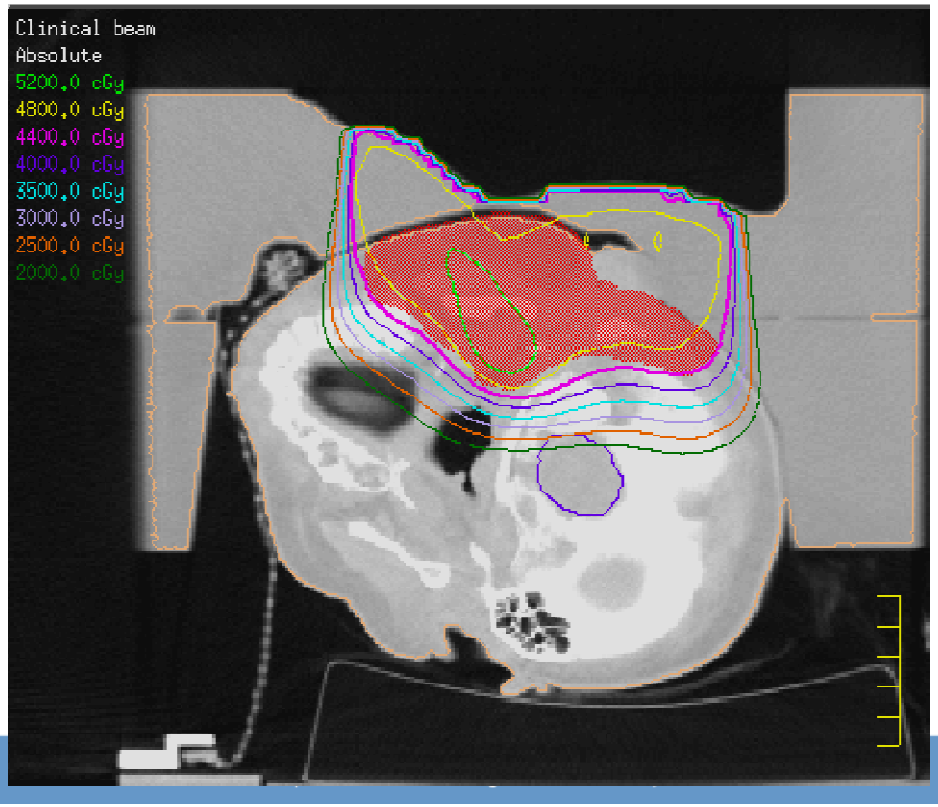
- Objective:
  - Conform 90% isodose surface to distal PTV surface.
- Case 1:
  - Issue: $R_{90} > d_{PTV}$
  - Solution: Constant thickness bolus
- Case 2:
  - Issue: Variable d_{PTV}
  - Solution: Variable thickness bolus



Bolus Electron Conformal Therapy

- Bolus ECT is the use of a single electron beam with a variable thickness bolus that is designed to shape the distal 90% dose surface to conform and contain the PTV.

Kudchadker et al. 2003

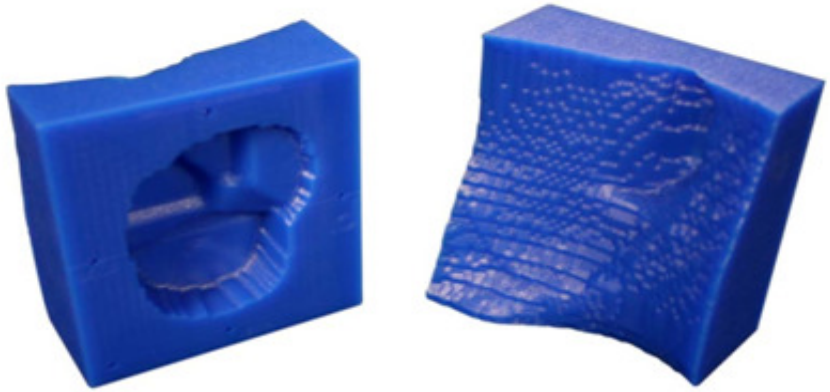


Bolus Electron Conformal Therapy

.decimal

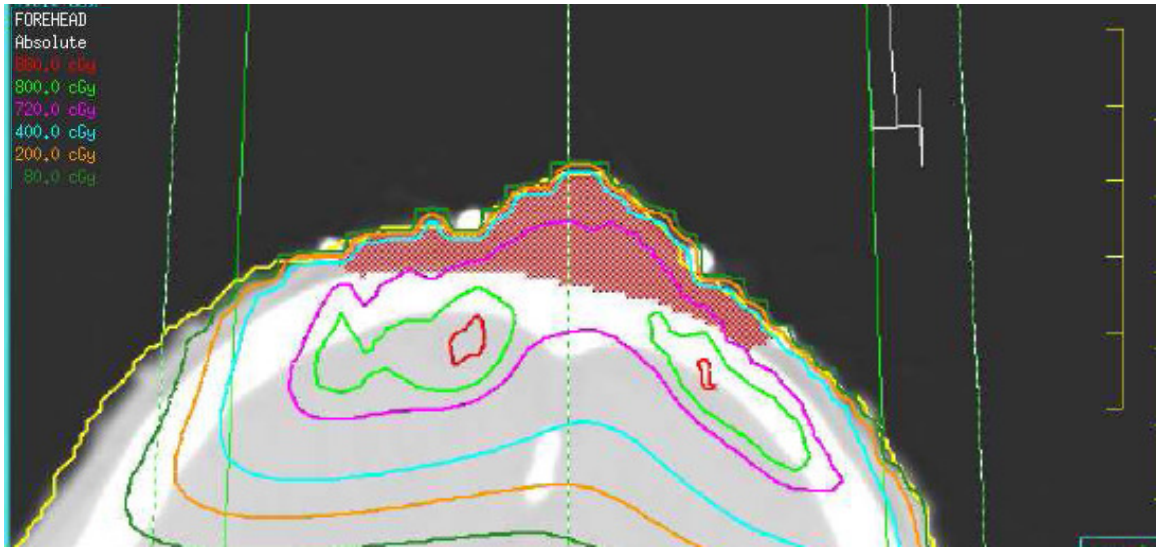
- Established commercial BECT product
- Design process utilizes work by Low et. al from MD Anderson developed in 1992
- Blue machinable wax milled to create custom bolus
  - Density = 0.92 g/cc
  - Conforms to patient surface

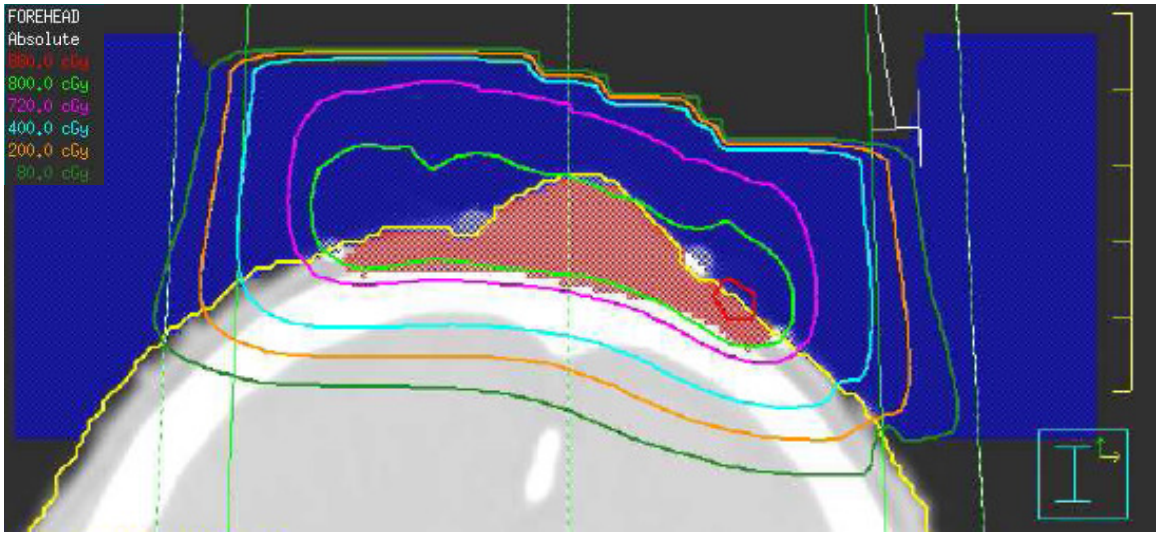
Custom Conformal Thickness



Bolus Electron Conformal Therapy

- 9 MeV electron beam
- Rx = 800 cGy
- Distal bolus surface conforms to patient surface
- Proximal surface shapes dose distribution.

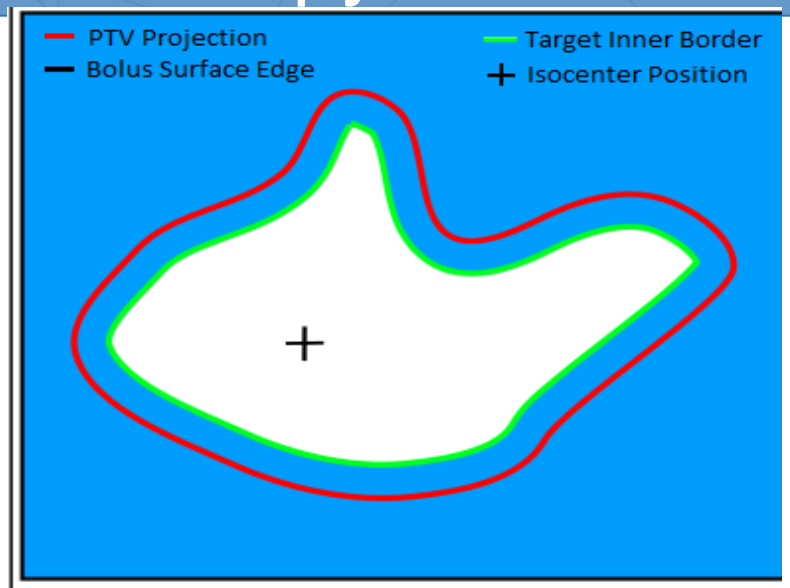




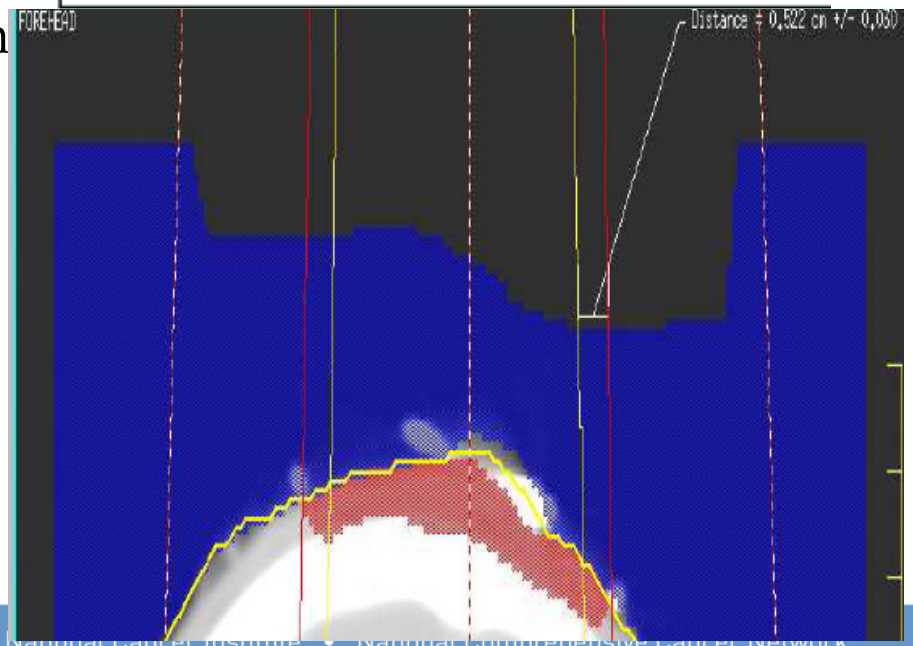
Bolus Electron Conformal Therapy

Bolus Regions/Margins

- Modulated region
  - Bolus thickness milled to shape isodose to target
- Inner Bolus Margin
  - User specified distance in from target edge towards CAX.
  - Flat extension of modulated surface
  - Minimizes effect of rapid reduction of target thickness
  - Typically ~ 5mm



(a) BEV



Bolus Electron Conformal Therapy

Bolus Regions/Margins

- Outer Bolus Margin
  - User specified extension of milled surface out from block edge
  - Allows for minor modifications of block after verification simulation
  - Typically ~1cm
- Unmilled Margin
  - Flat outer border
  - Provides structure and aids in daily setup

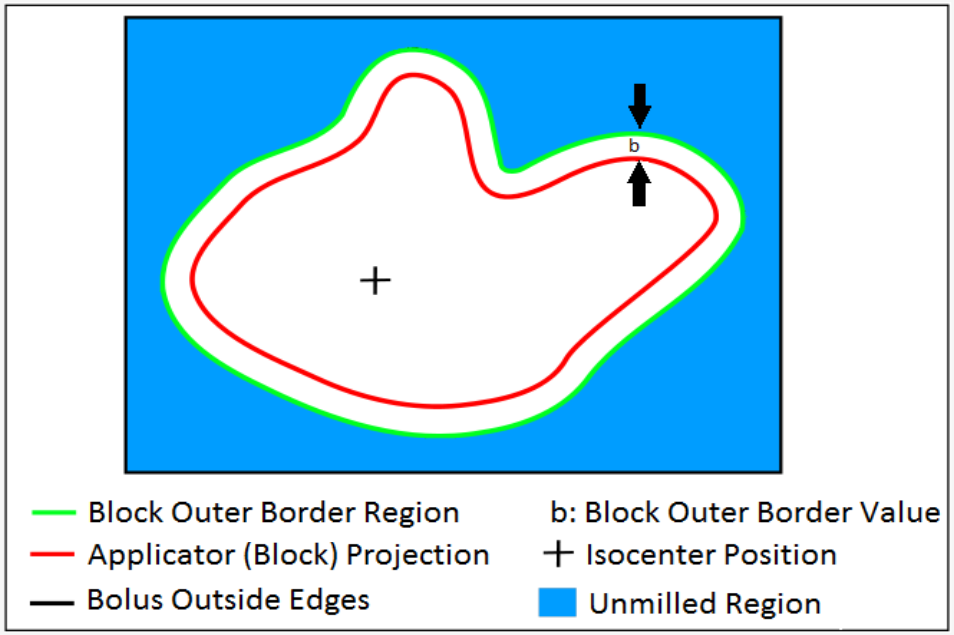
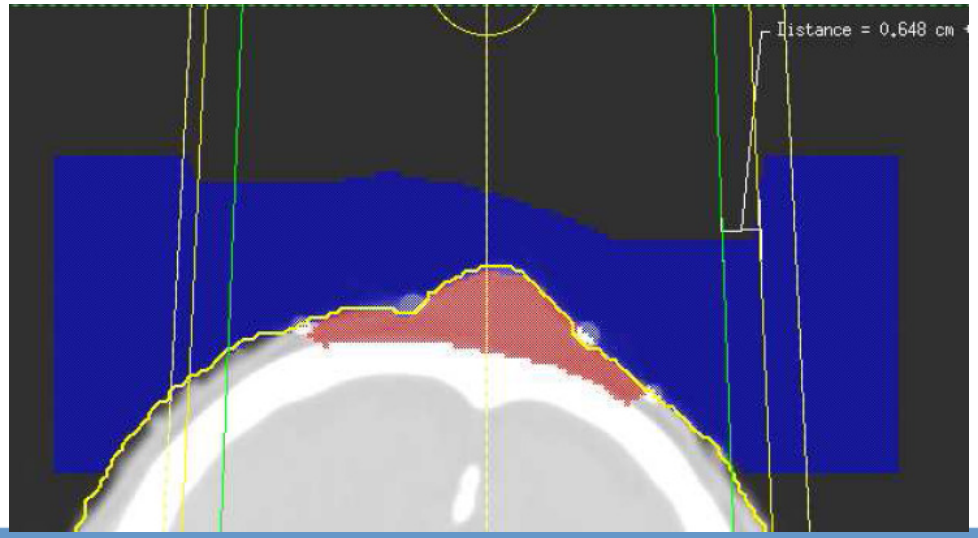


Figure 2: Block Outer Border (BEV)



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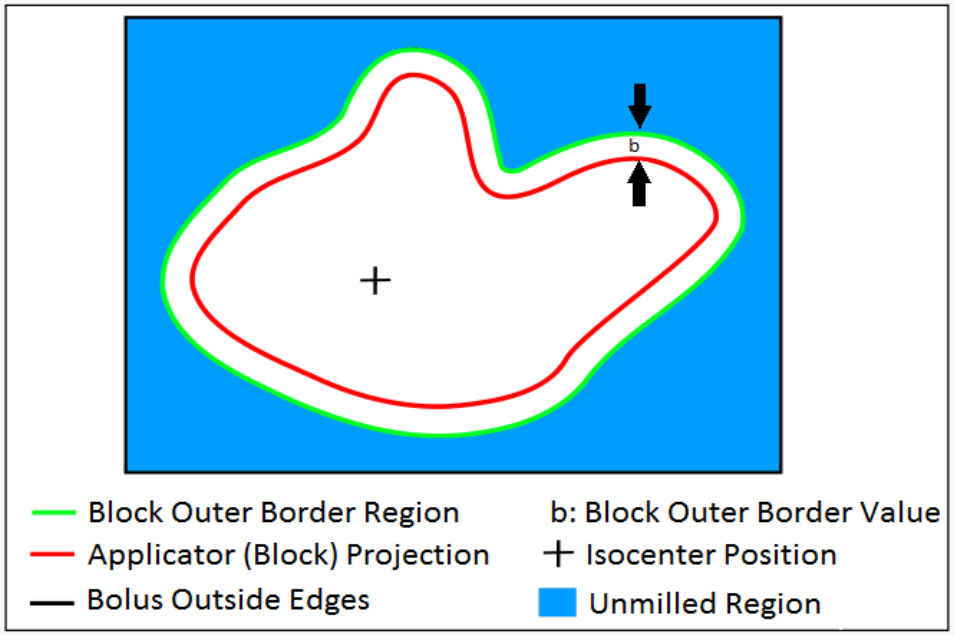

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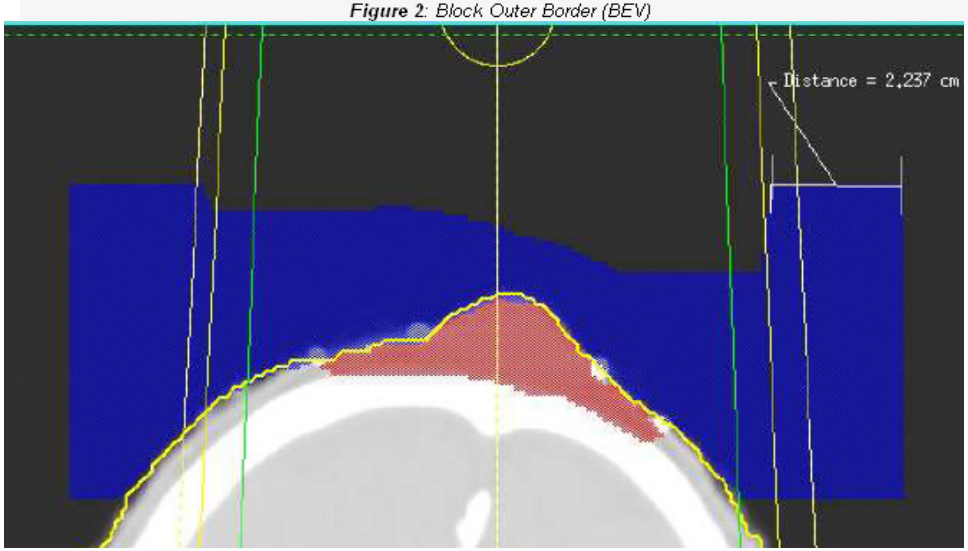
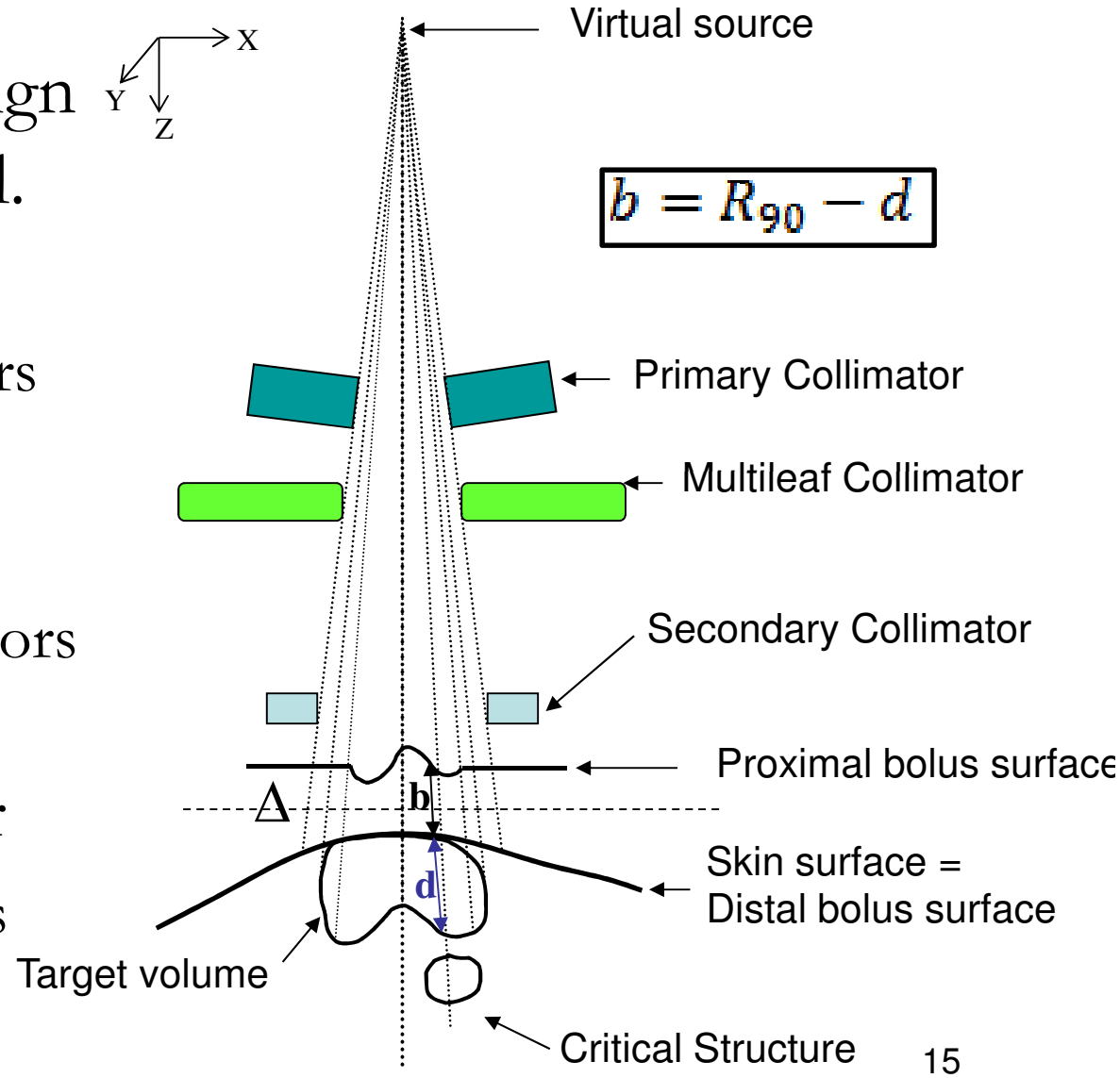


Bolus Electron Conformal Therapy

- Uses a series of design operators (Low et al. 1992)
  1. Creation Operators
  2. Modification Operators
  3. Extension Operators

1. Creation Operator
   - Defines initial bolus thickness (b)



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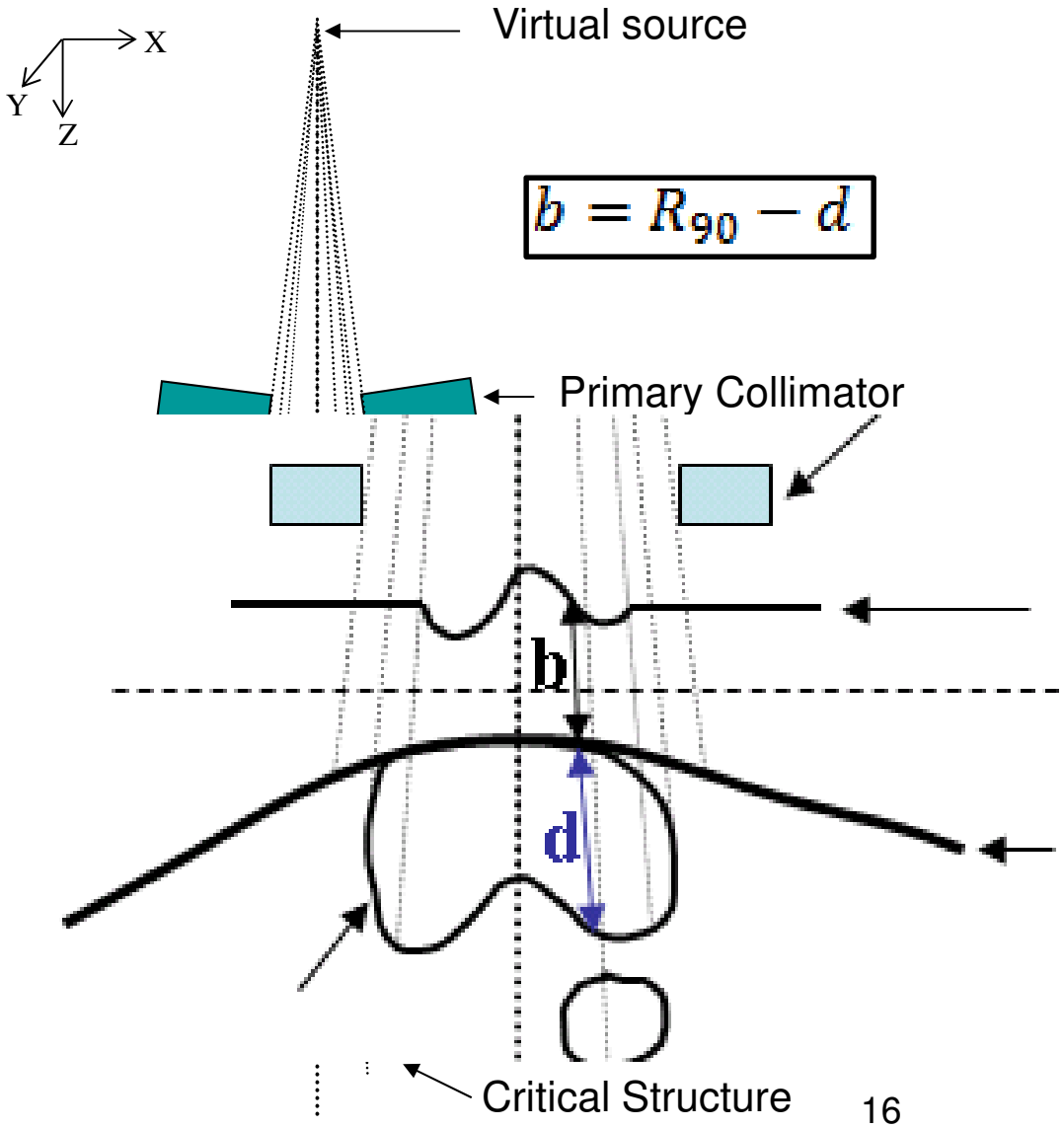

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Outline

- Bolus ECT Background
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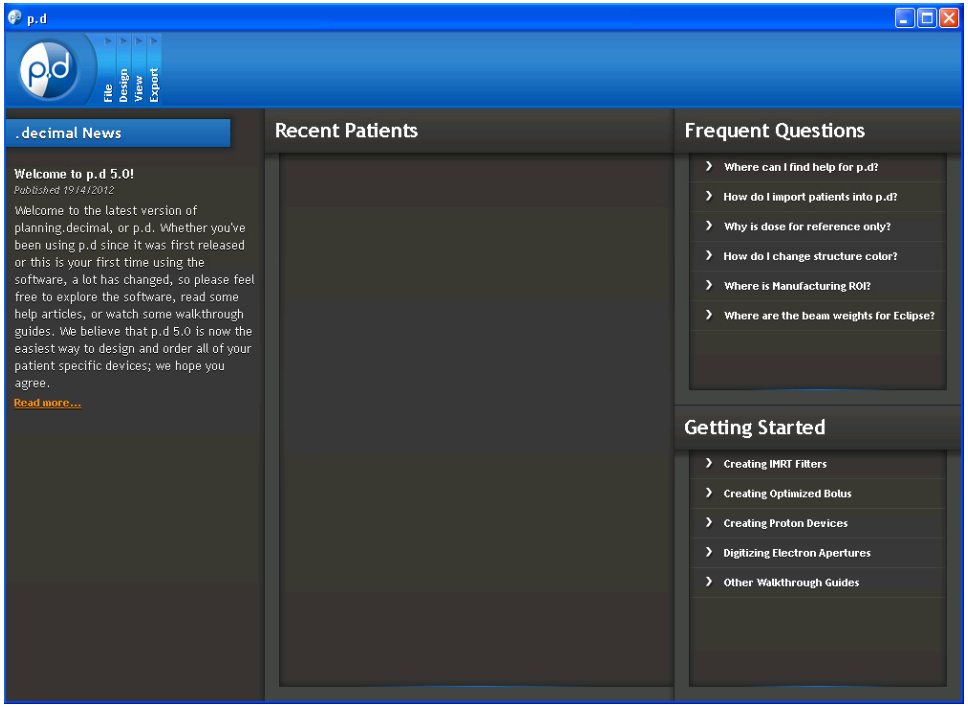
  - Simulations
  - Treatment Planning/Ordering
  - First Fraction
- Special Cases
  - Nose
  - Back
  - Foot

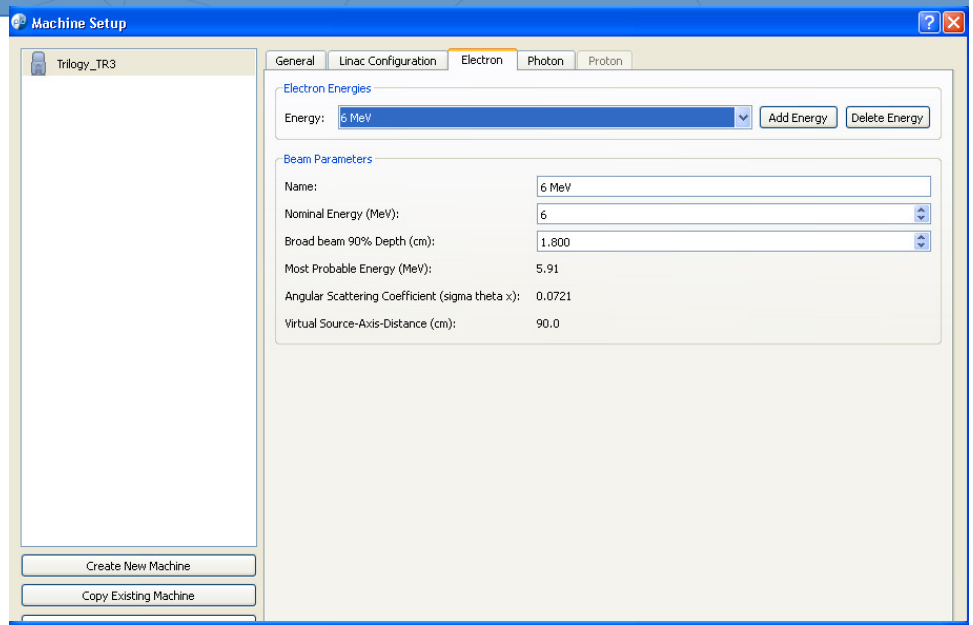
BECT Commissioning Process

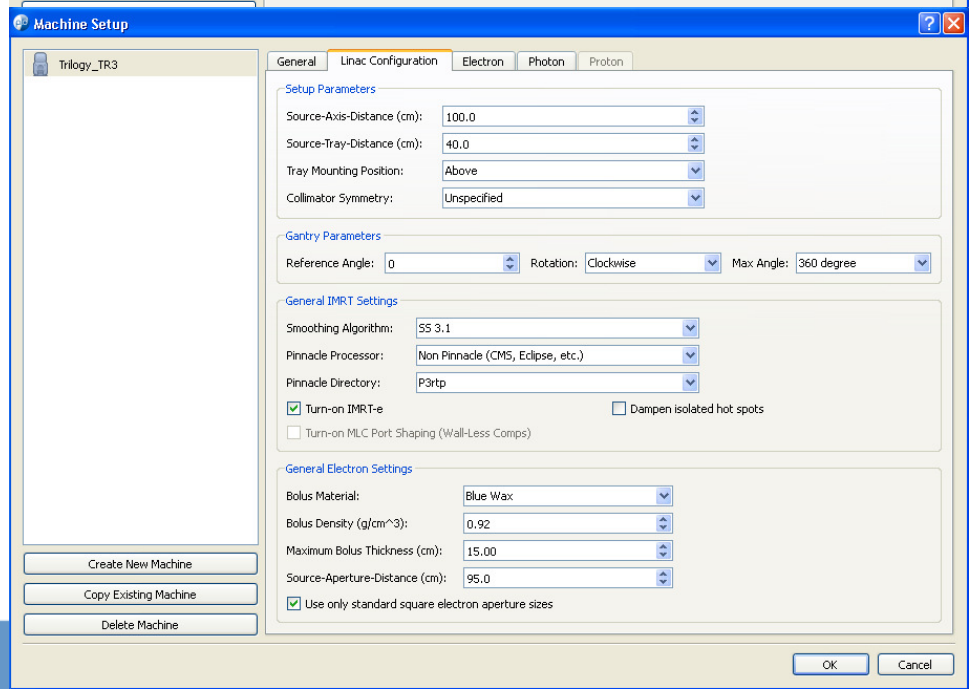
- Installation of free software via remote upload.
  - Windows-based PC
  - Internet access needed
- No additional hardware needed
  - Utilizes existing TPS and electron energies
- Approximately one hour
- Software training/demo via Webex upon request



BECT Commissioning Process

- Commission linac in P.D 5.0 software
- Standard parameters are necessary for bolus creation
  - Source-aperature distance
  - Nominal electron energies
  - Nominal depth of 90% for a broad beam
  - Bolus density
- Input values should match clinical data





BECT Commissioning Process

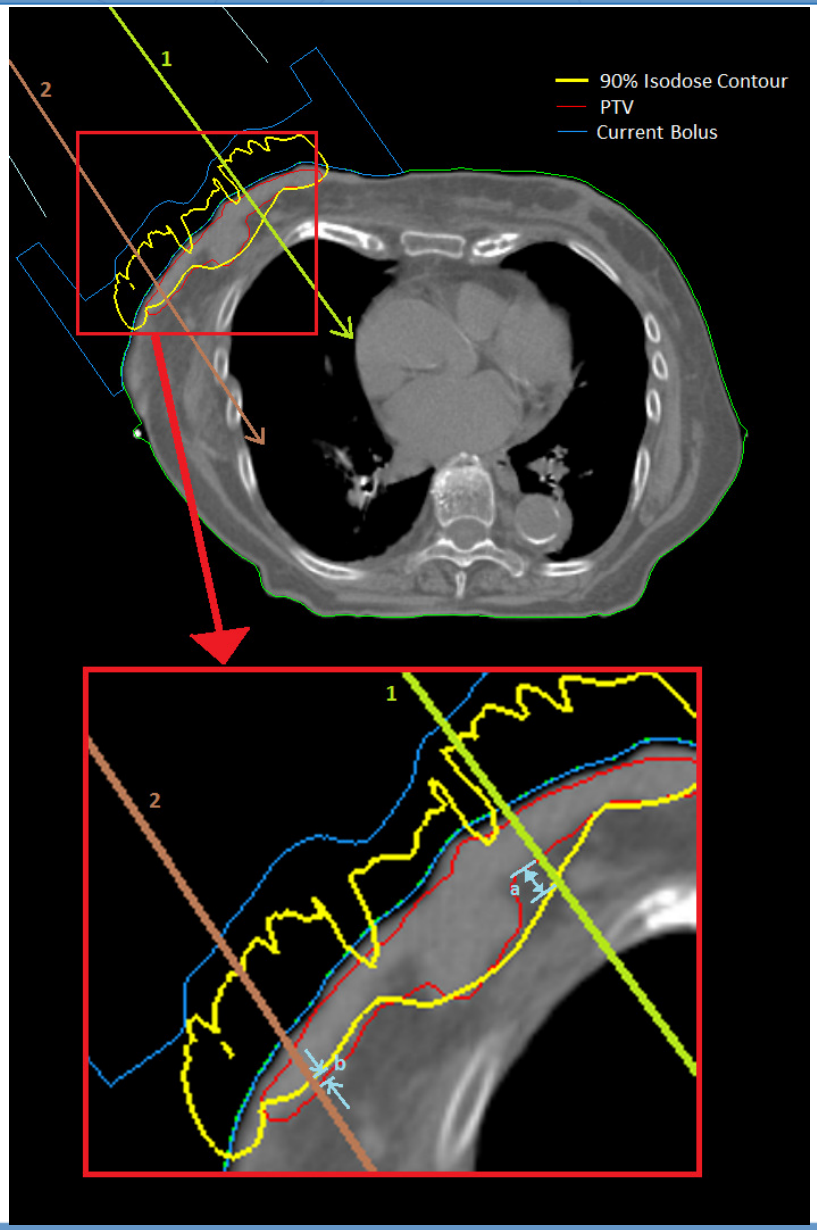
- Verify PDDs for all energies.
  - Scan supplied blue wax PDD BolusECT phantom
  - Create electron plans for all energies
  - Measure PDDs for all energies using film
  - Compare film PDD measurements to TPS calculated PDDs
- Verify conformal dose profiles
  - Scan supplied modulated nose phantom
  - Create electron plans for all energies
  - Measure dose profiles for all energies using film
  - Compare film profile measurements to TPS calculated profiles

General Clinical Workflow

- Patient consult
  - Physics consulted
  - Patient educated
- Initial CT simulation (Day 1)
- Initial treatment planning (Day 2 – 5)
  - Multi-modality fusions
  - Contour creation
  - Beam selection
  - Virtual bolus creation (p.d software)
- Bolus fabrication and shipping (Day 5 – 7)
- Verification simulation (Day 8)
- Final treatment planning (Day 8 – 10)
- First treatment fraction (Day 10)

Selection Criteria

- Target volume depth less than 6cm
  - It is possible to use electrons
- Target volume depth varies throughout the field
  - Uniform thickness bolus not sufficient.
- Critical structures distal to target volume
  - Modulation necessary to reduce dose to critical structure
- Patient skin surface has significant variation or defects
  - Bolus ECT can minimize hot/cold spots



Initial Patient CT Simulation (Day 1)

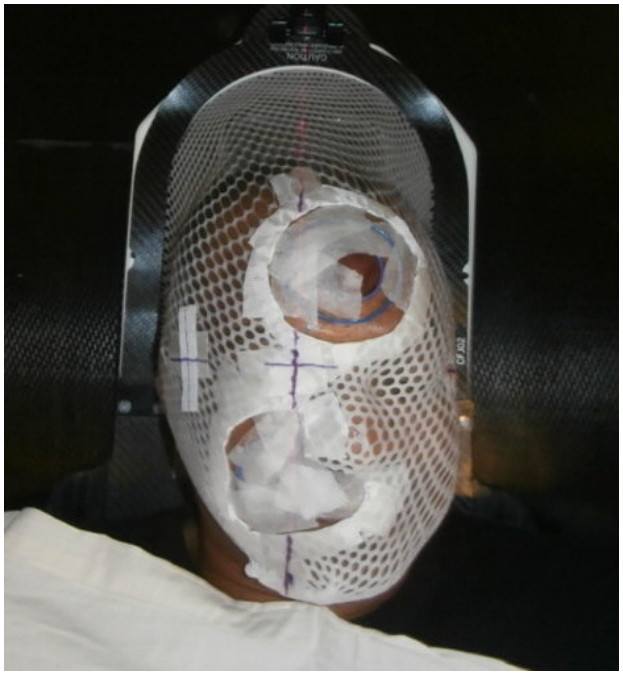
Patient setup

- Physician present to delineate treatment volume
  - Typically wires skin
- Oriented to maximize bolus stability
  - Gantry angle close to AP ($0^\circ \pm 20^\circ$)
  - Split difference between
- Consider and minimize possible collision of patient anatomy
  - Shoulder issues when treating neck

Initial Patient CT Simulation (Day 1)

Immobilization devices

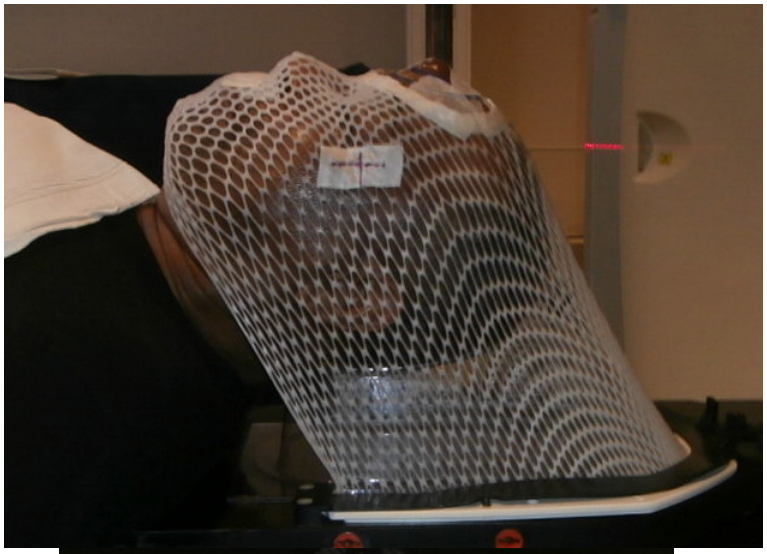
- Dependent upon treatment site
- Mask used for head and neck treatments
  - Cutout mask 1 cm beyond delineated treatment volume
  - If using eye shields, remove mask above eyes
- Alpha cradle/vac loc for torso and extremities
  - Important when treating areas that can flex and bend
  - Register other devices with AC if used.

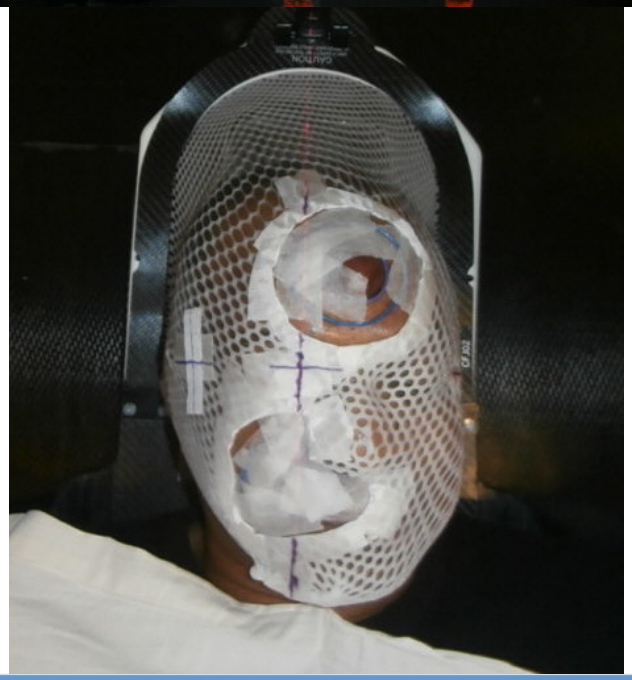


Initial Patient CT Simulation (Day 1)

Special Considerations

- Slice thickness
  - Typically 3mm
  - Reduce to 1.5mm for small targets
- Scan length
  - Scan at least 5cm – 7cm beyond treatment volume
  - Especially important for superior or inferior extent of anatomy
- Eye shields
- Ear and nose taped/filled
- Patient marked for alignment
- Many setup images taken

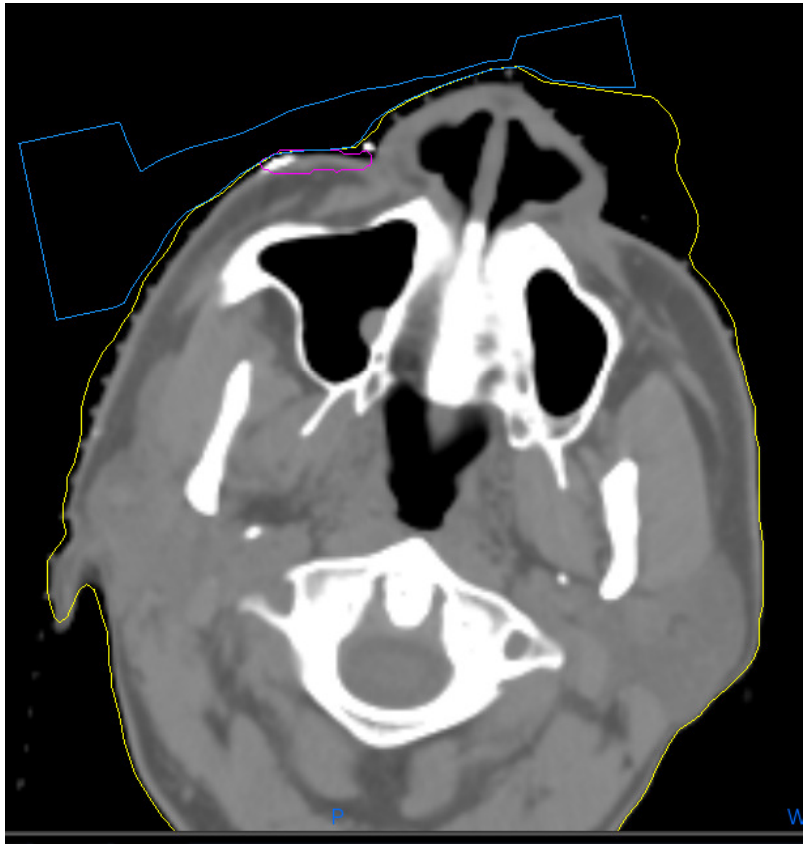




Initial Treatment Planning (Days 2 – 5)

Contour creation

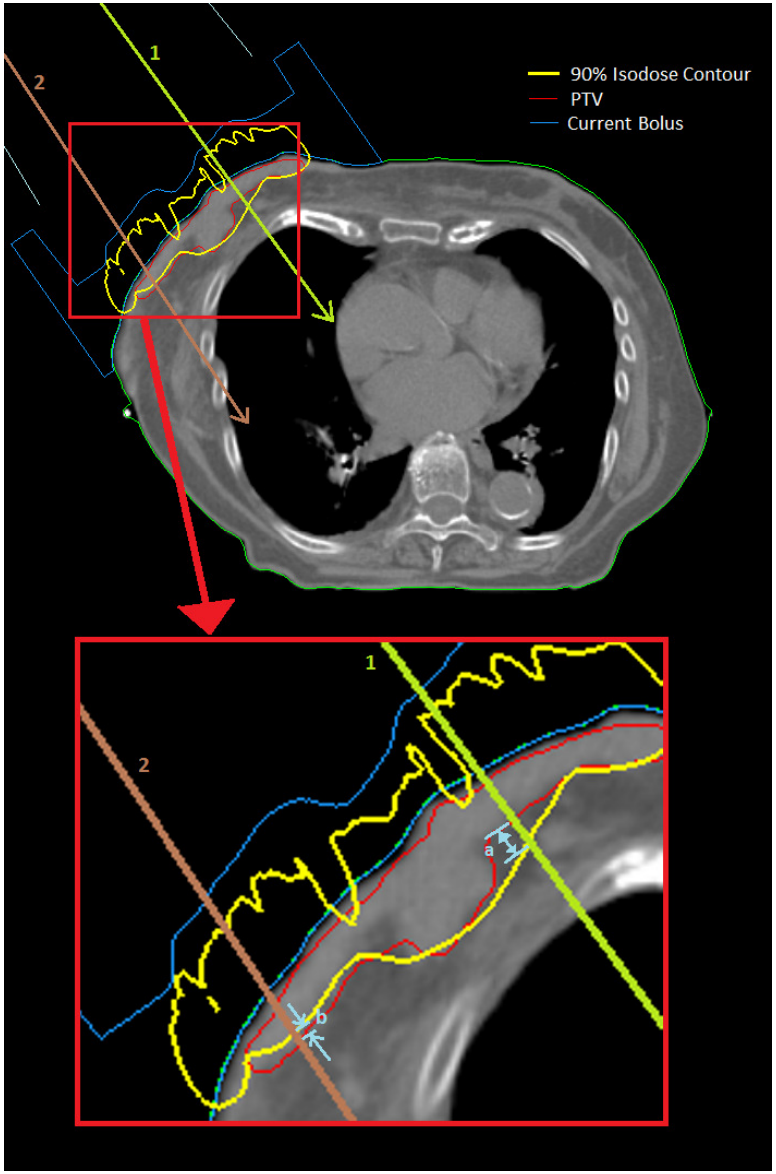
- External contour modifications
  - Includes mask
  - Extended to allow for breathing and above eyes
  - Smooth to minimize sharp edges
- Wire contour
  - Inside/Outside
  - Override densities
- PTV contour
  - Variations from transverse slice
  - Causes hotspots if not smoothed



Initial Treatment Planning (Days 2 – 5)

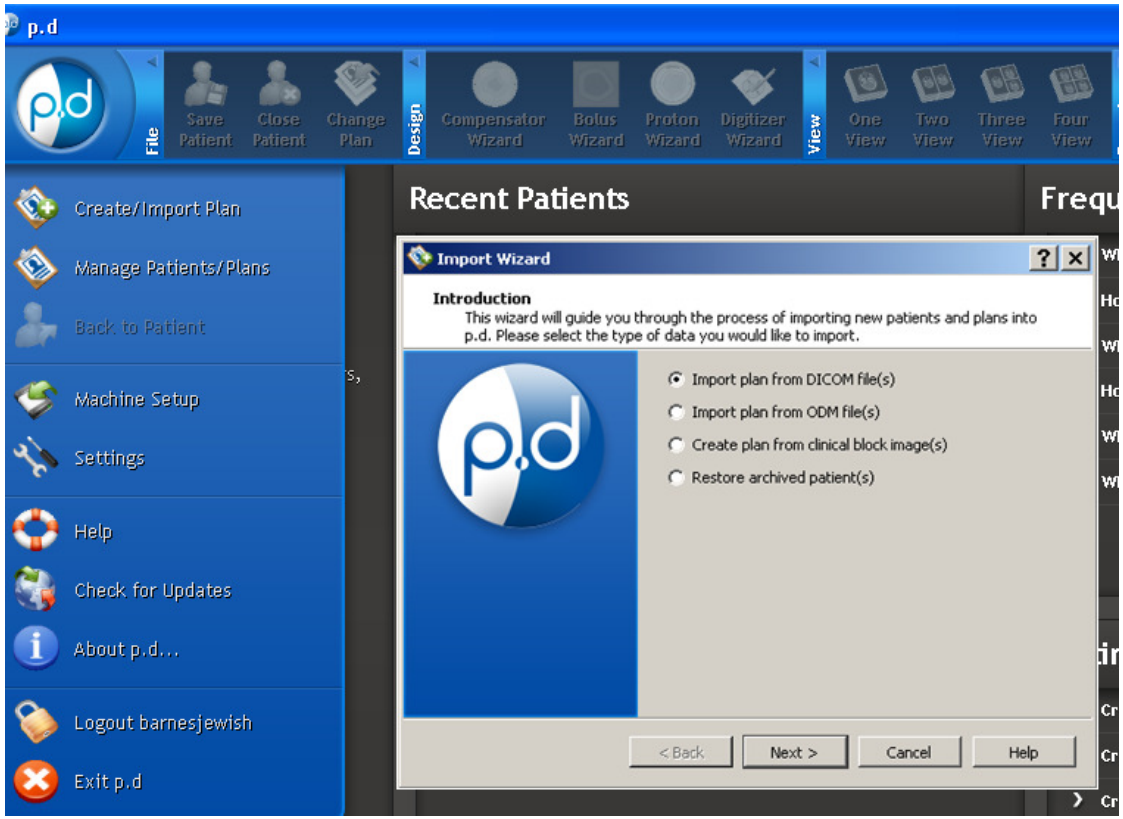
Beam selection

- Angle should be perpendicular to distal PTV surface
- Determine energy from deepest part of target volume
  - d = deepest target + 3mm
- SSD typically set to 105cm.
  - Allows for bolus clear electron applicator
  - Extended SSD for large targets or clearance



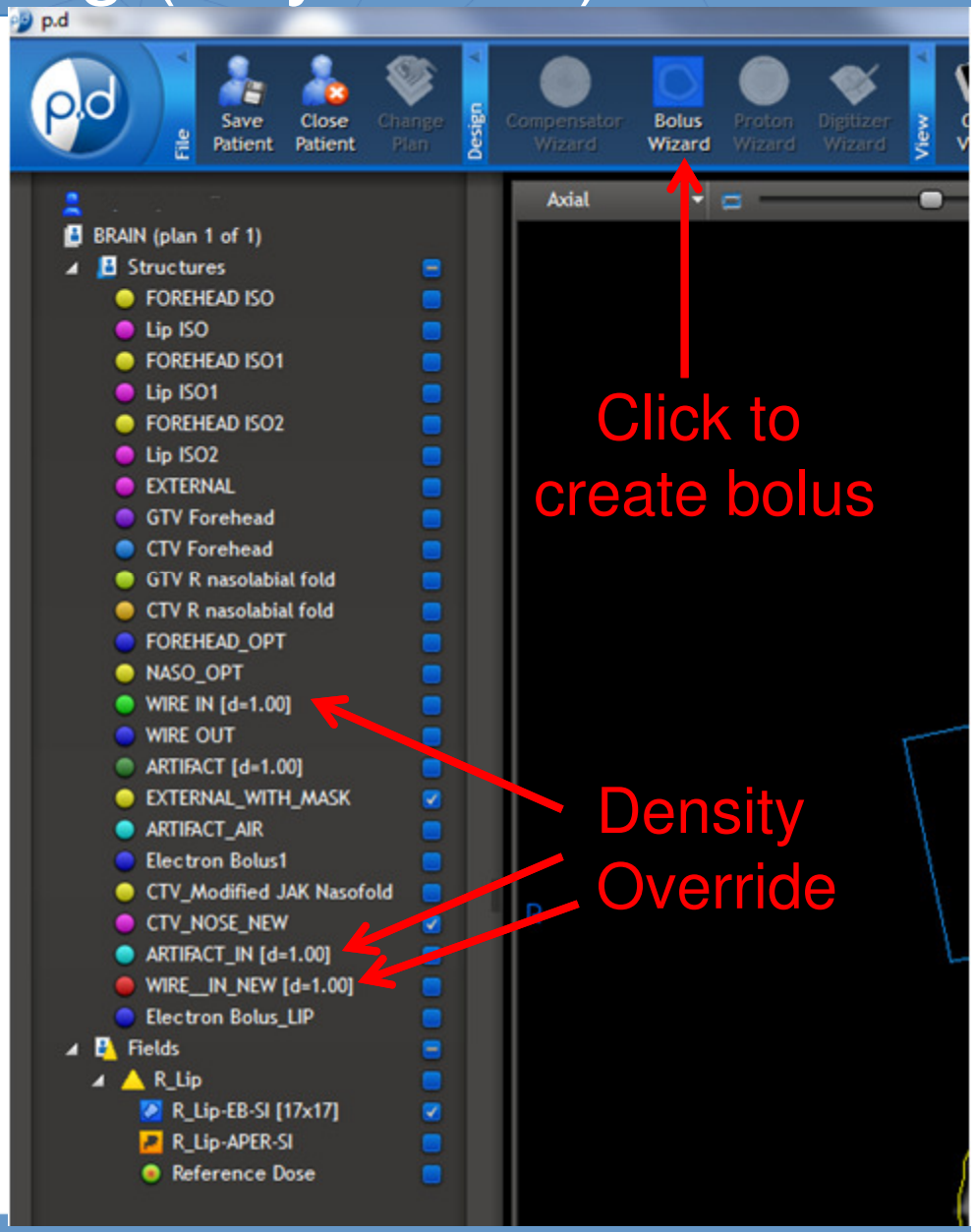
Initial Treatment Planning (Days 2 – 5)

- Export in DICOM format
  - Plan, structures, and CT images
  - Save these in a protected patient archive
- Import into P.D software using the import wizard



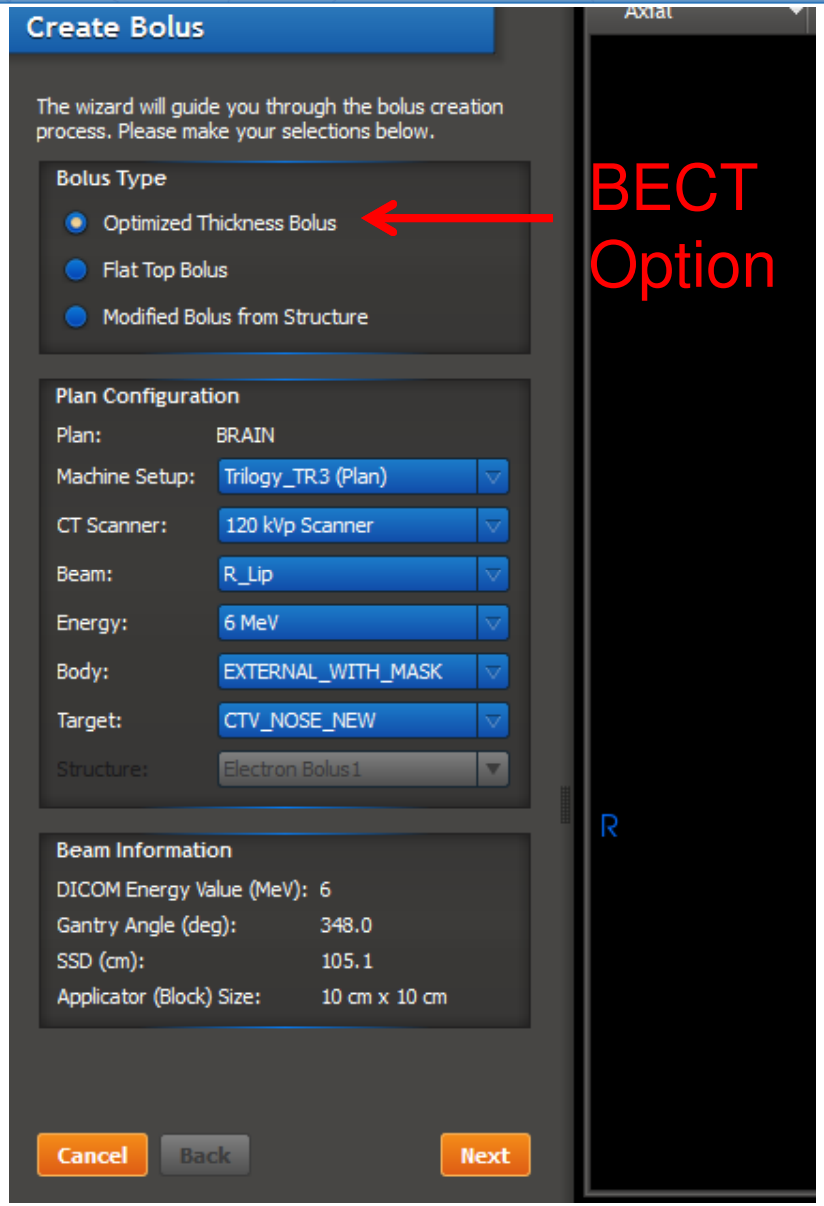
Initial Treatment Planning (Days 2 – 5)

- Right click structures requiring density over ride and set correct density
- Not necessary to over ride structures outside of external contour
- Select Bolus Wizard



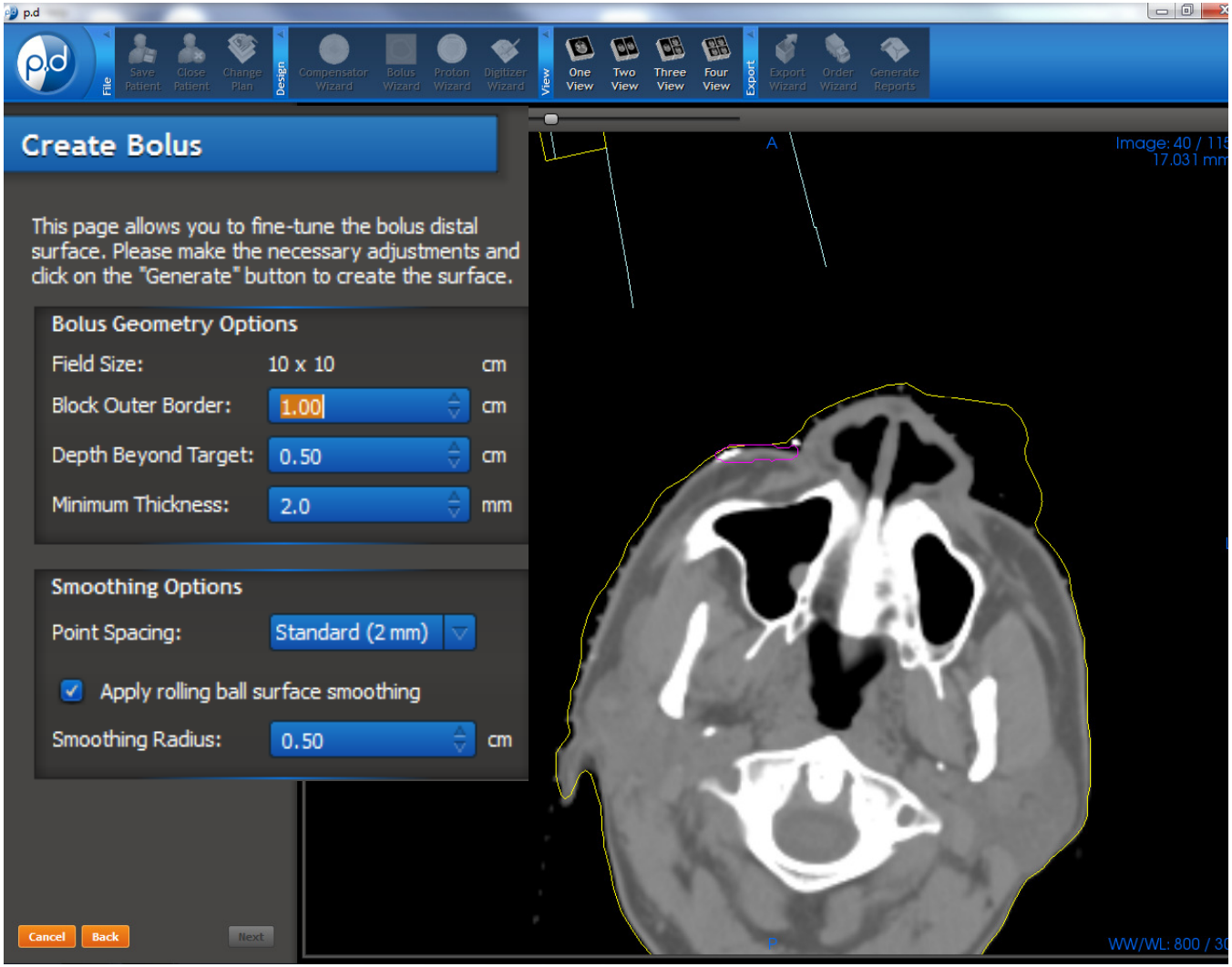
Initial Treatment Planning (Days 2 – 5)

- Two Step Process
  - Distal bolus surface design
  - Proximal bolus surface design
- For BECT, select "Optimized Thickness Bolus"
- Verify plan configurations parameters and make changes as necessary



Initial Treatment Planning (Days 2 – 5)

Distal Bolus Surface Design



Initial Treatment Planning (Days 2 – 5)

Distal Bolus Surface Design

- Bolus Outer Border
  - Defaults to 1cm to allow for block modifications
  - Increase for large targets

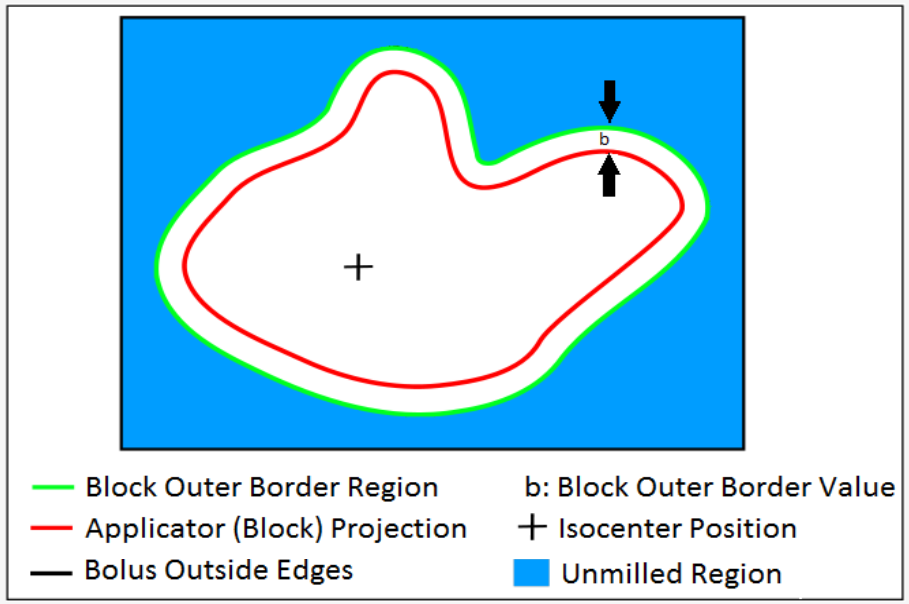
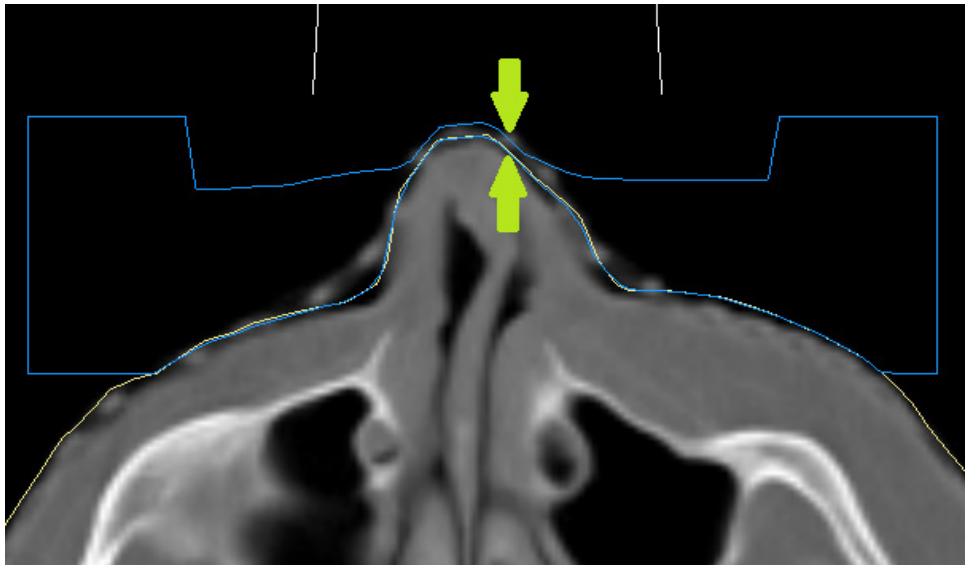


Figure 2: Block Outer Border (BEV)

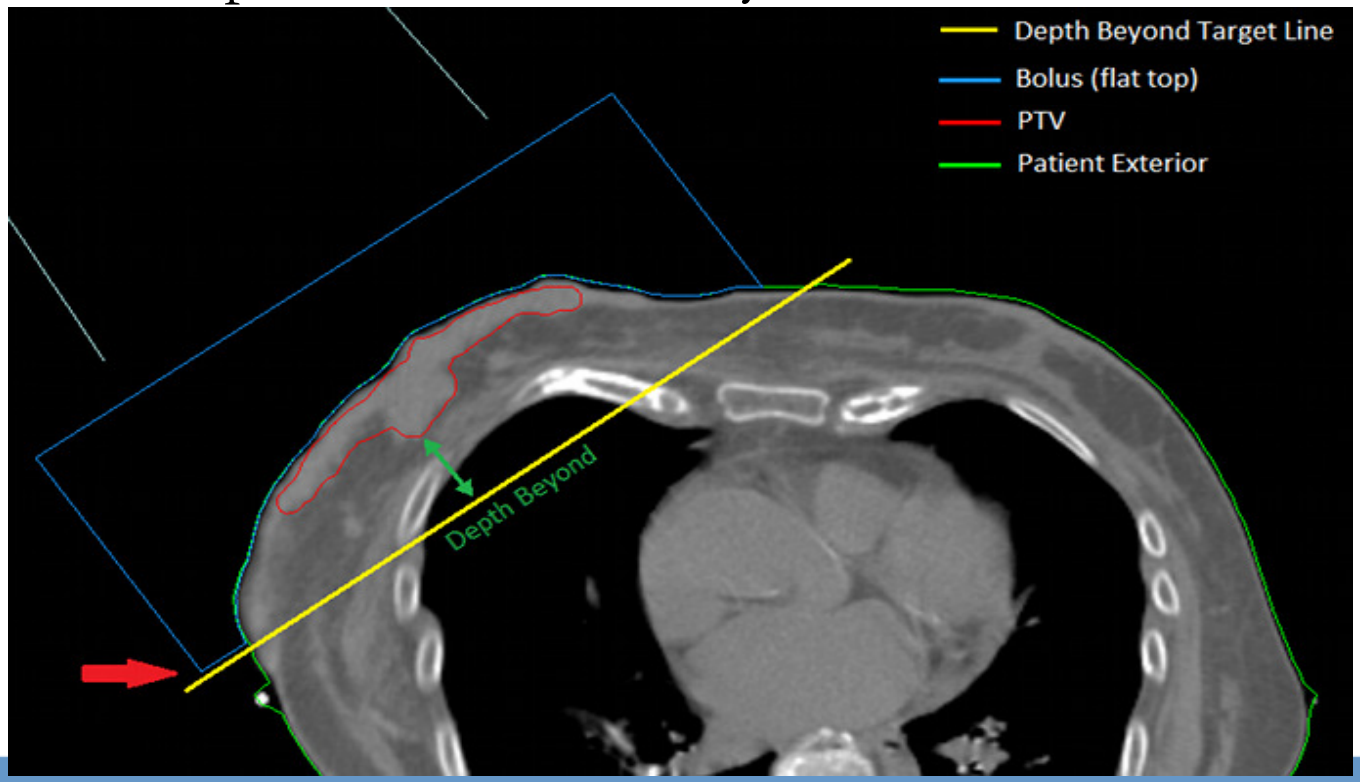
- Minimum Thickness:
  - Minimum allowable thickness of the bolus
  - Measured along a beam aligned rayline



Initial Treatment Planning (Days 2 – 5)

Distal Bolus Surface Design

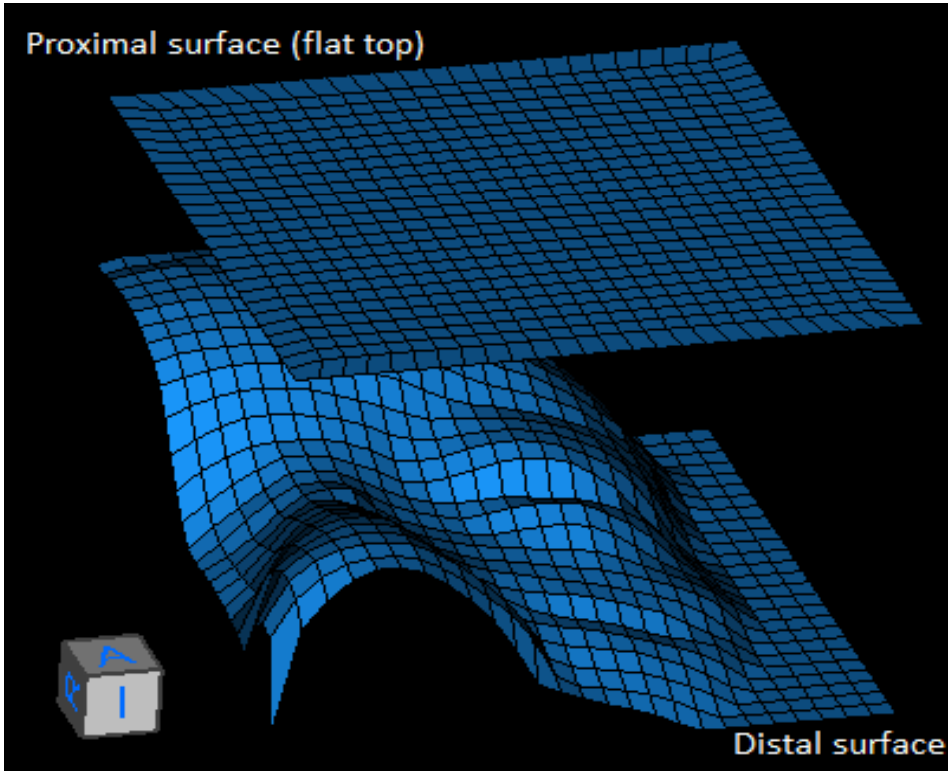
- Depth Beyond Target
  - Extension of the distal side bolus surface past the PTV
  - Reduce to minimize bolus weight
  - Increase to provide more stability



Initial Treatment Planning (Days 2 – 5)

Distal Bolus Surface Design

- Point Spacing
  - Approximate point spacing that will be used for the bolus surface meshes.



Initial Treatment Planning (Days 2 – 5)

Distal Bolus Surface Design

- Rolling Ball Smoothing
  - Creates the effects of rolling a ball of radius R, across the entire patient surface
  - Smaller R = less smoothing

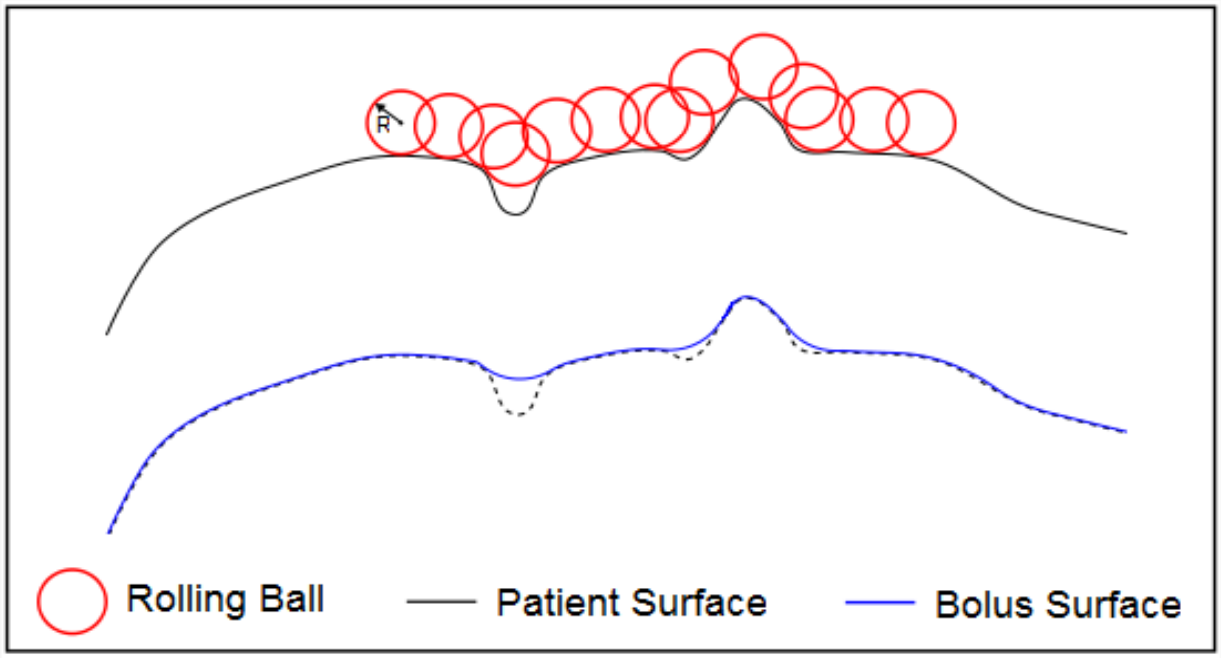
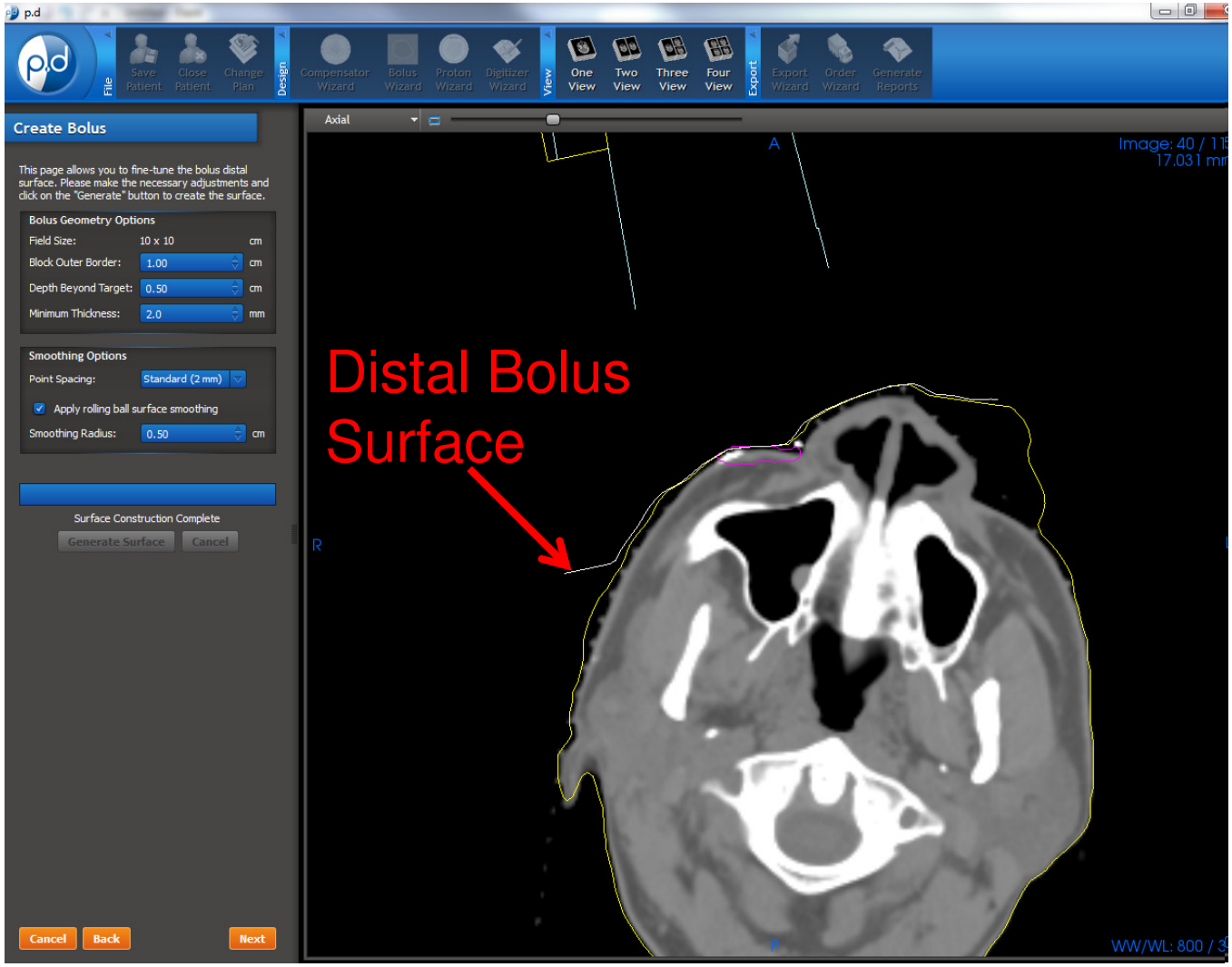


Figure 7: Rolling Ball Smoothing Algorithm

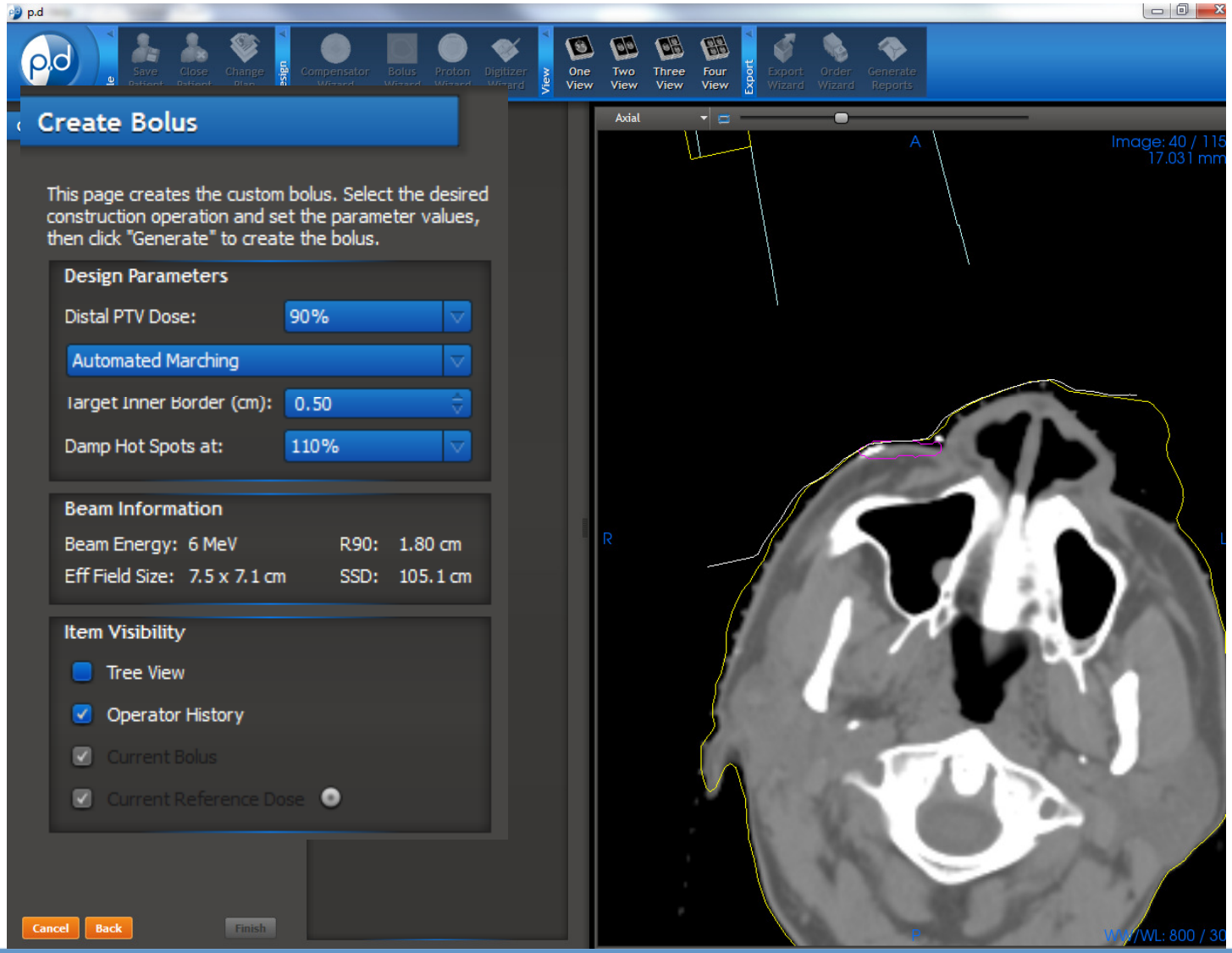
Initial Treatment Planning (Days 2 – 5)

Distal Bolus Surface Design



Initial Treatment Planning (Days 2 – 5)

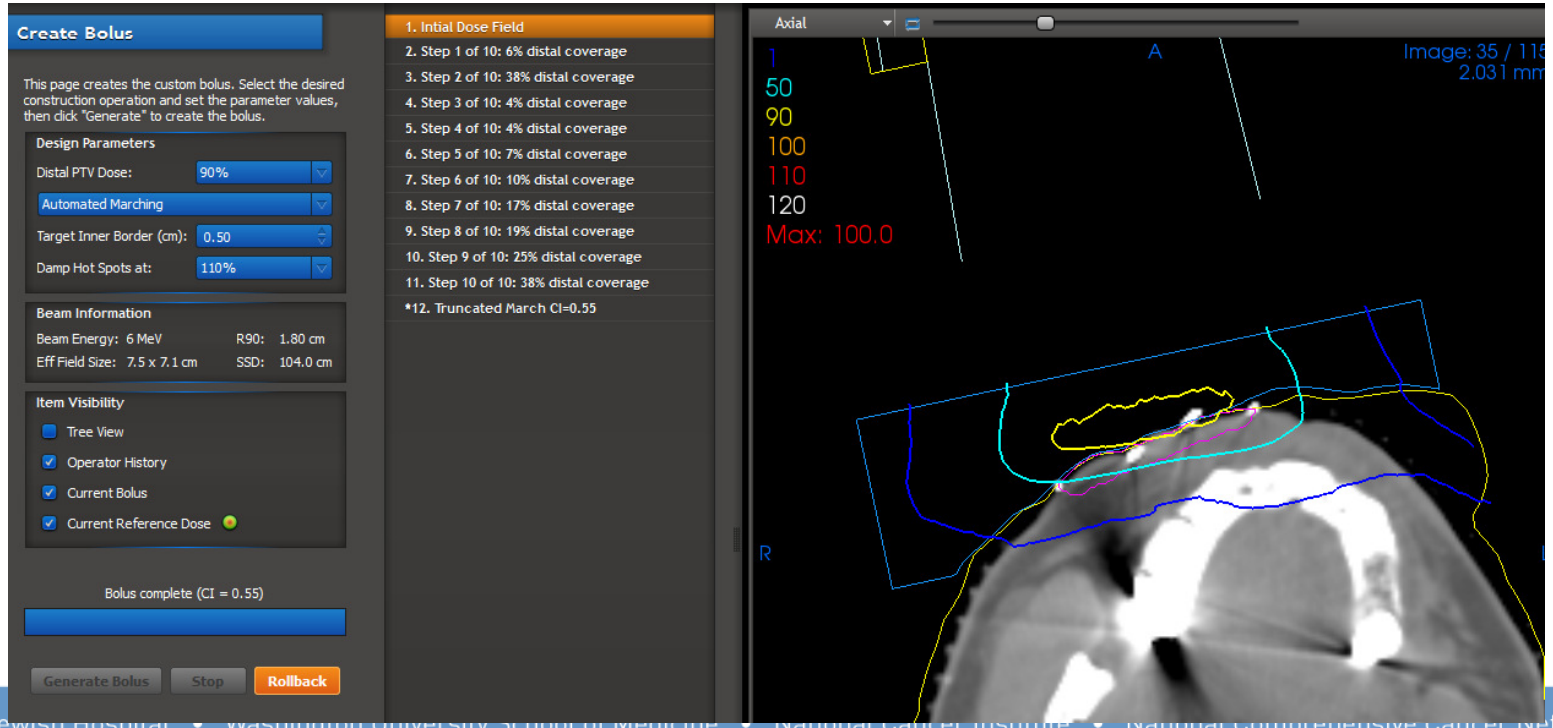
Proximal Bolus Surface Design



Initial Treatment Planning (Days 2 – 5)

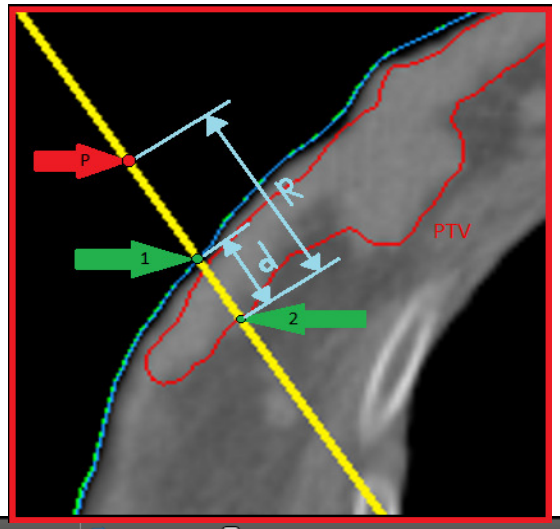
Proximal Bolus Surface Design

- Automated Marching
  - Attempts to construct an optimal proximal bolus surface
  - Uses a series of incremental surface reduction steps.
  - Begins with construction of a flat top bolus.

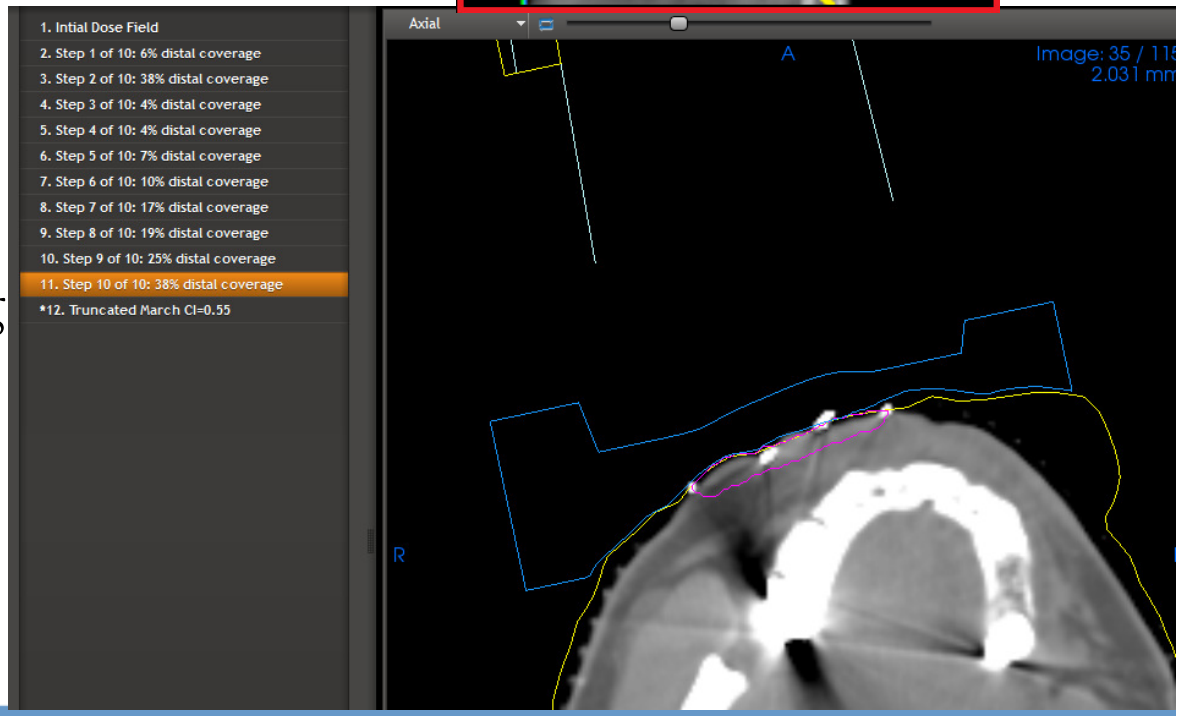


Initial Treatment Planning (Days 2 – 5)

Proximal Bolus Surface Design



- Each step then reduces the bolus thickness along any ray lines that intersect PTV.
- Max of 10 steps
  - Creation operators
  - Dosimetric damping
- Bolus truncated
- Final dose recalc'd



Initial Treatment Planning (Days 2 – 5)

Proximal Bolus Surface Design

- Truncate Operator
  - Reduces the height of the bolus in the unmilled region.
  - Typically 2 – 6mm above peak proximal surface

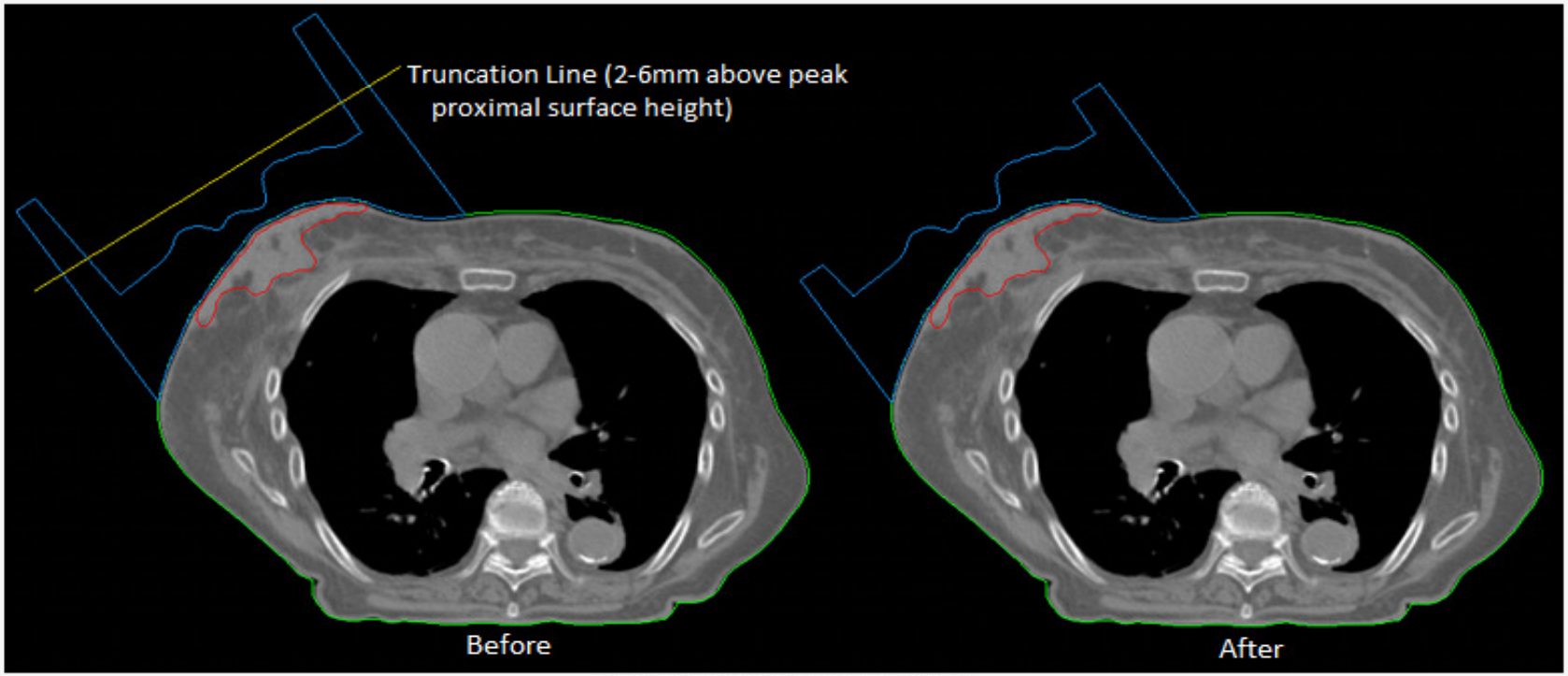
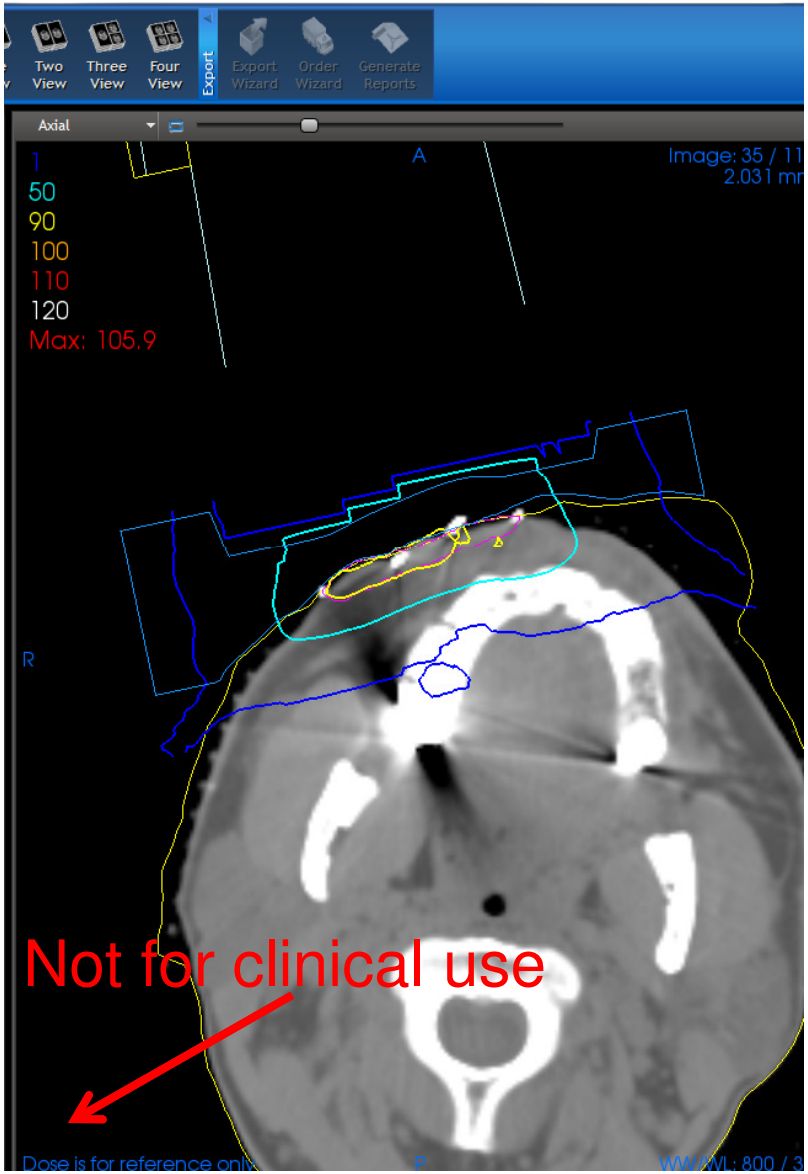


***Figure 8**: Truncate Bolus Operator*

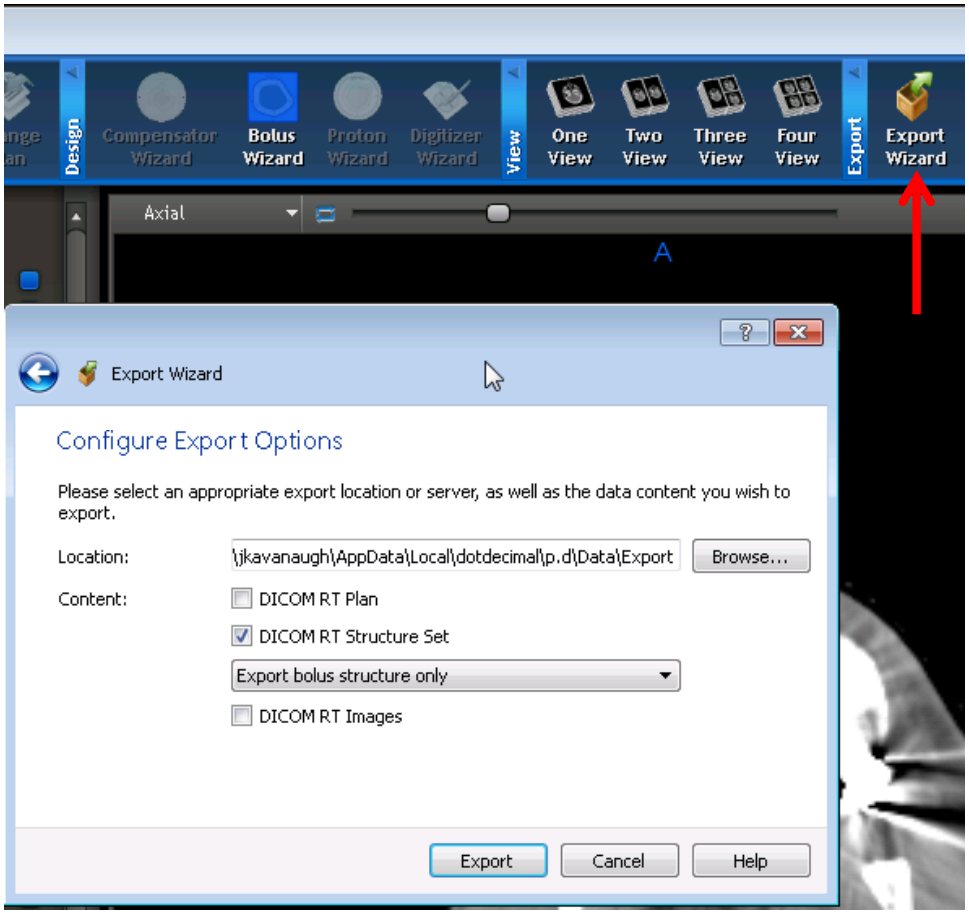
Initial Treatment Planning (Days 2 – 5)

- P.D dose calculation uses Hogstrom Pencil Beam Redefinition Algorithm
  - High degree of accuracy
  - PTV typically under covered at R_{90}
    - P.D reports 30% to 60%
    - Visually examine R_{88}
  - Not commissioned for clinical use
- Must assess plan quality using clinically commissioned electron dose algorithm



Initial Treatment Planning (Days 2 – 5)

- Export bolus in DICOM format
- Import into treatment planning system
  - Pinnacle requires FTP into DICOM folder
- Override density
  - 0.92 g/cc
- Assess PTV coverage
  - Typically MUs need slight adjustment
- MD reviews plan



Fabrication and Shipping (Days 5 - 7)

Design | Compensator Wizard | Bolus Wizard | Proton Wizard | Digitizer Wizard | View | One View | Two View | Three View | Four View | Export | Export Wizard | Order Wizard | Generate Reports

Axial

A

Image: 34 / 115
-0.969 mm

L

Order Wizard for: IRONS SAMUEL

Welcome to the ordering wizard

This wizard will help you order your devices through .decimal Direct. Please make your selections to continue.

	Comp ID	Part Type	Material	Quantity
☑	R_Lip-EB-	Bolus	Wax	1
☐	R_Lip-APER-	Electron Aperture	Copper	1

Please select the treatment site: Breast

☑ I agree to the Terms and Conditions and Processing Agreement

☑ I agree to test each device prior to use on a human

Next | Cancel | Help

Order Wizard for: IRONS SAMUEL

Shipping Information

Please enter and verify the shipping information below (* = required).

Site ID: 990070 Saved Address:

Institution Name*:

Address Line 1*:

Address Line 2:

City*:

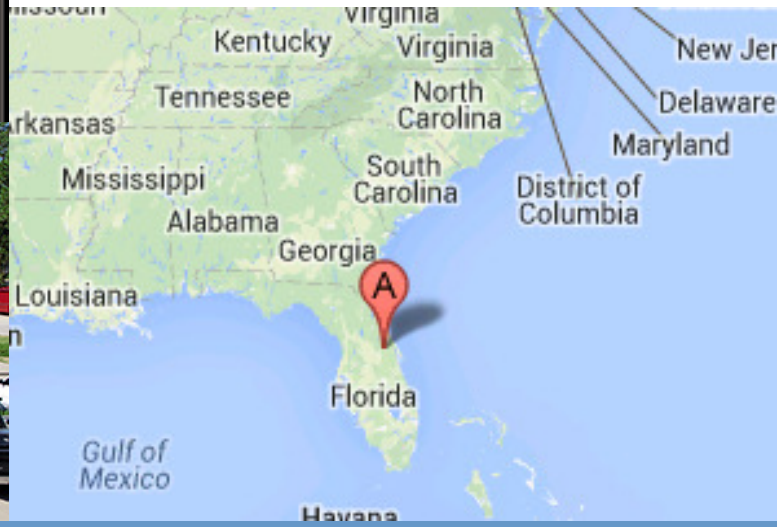
State*:

Zip Code*:

Required Delivery*: 48 Hour — Additional shipping charges may apply.

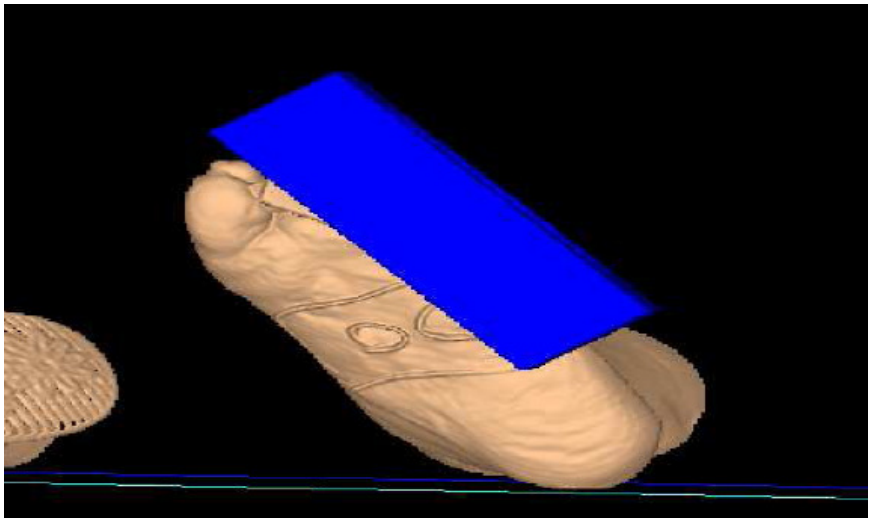
Select an option
72 Hour
48 Hour
Rush (24 Hour)

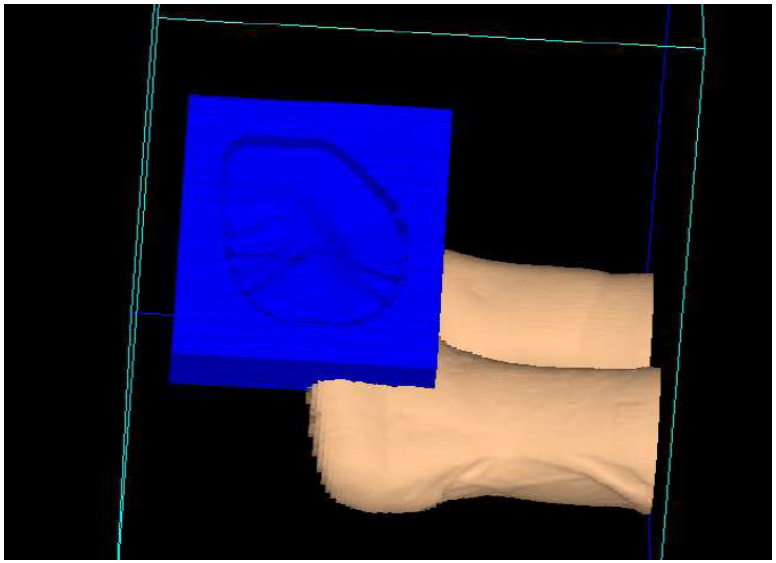
Next | Cancel | Help



Verification Simulation (Day 8)

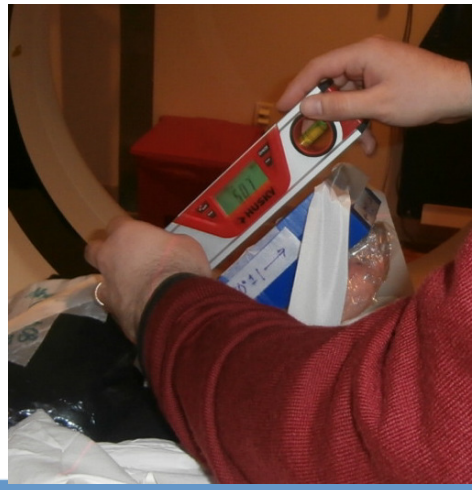
- Examine bolus for defects
- Reduce sharp edges if needed
  - Only on patient side
  - Typically no alteration needed
- Prepare bolus for simulation
  - Add BBs on unmilled surface
- Useful printouts
  - 3D rendering of patient and bolus in multiple orientations





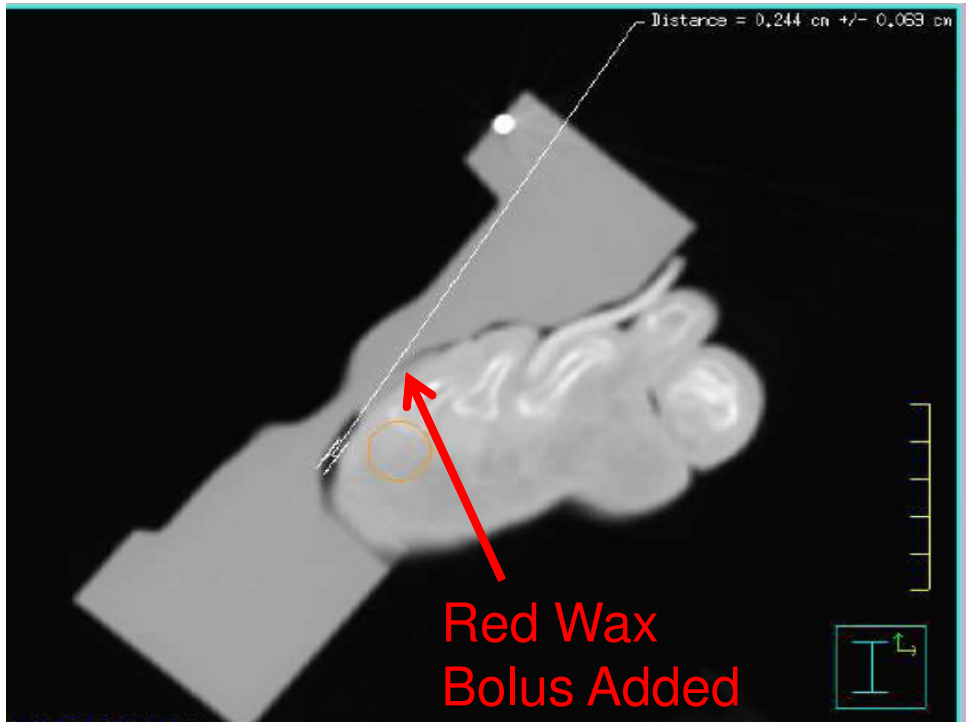
Verification Simulation (Day 8)

- Setup patient
- Register bolus to patient
  - Align lasers to bolus X-hairs
  - Delineate lasers position on immobilization device
  - Draw bolus edge on mask/skin surface
- Measure bolus rotation
  - Transverse (within 1 degree of planned gantry angle)
  - Record sagittal angle



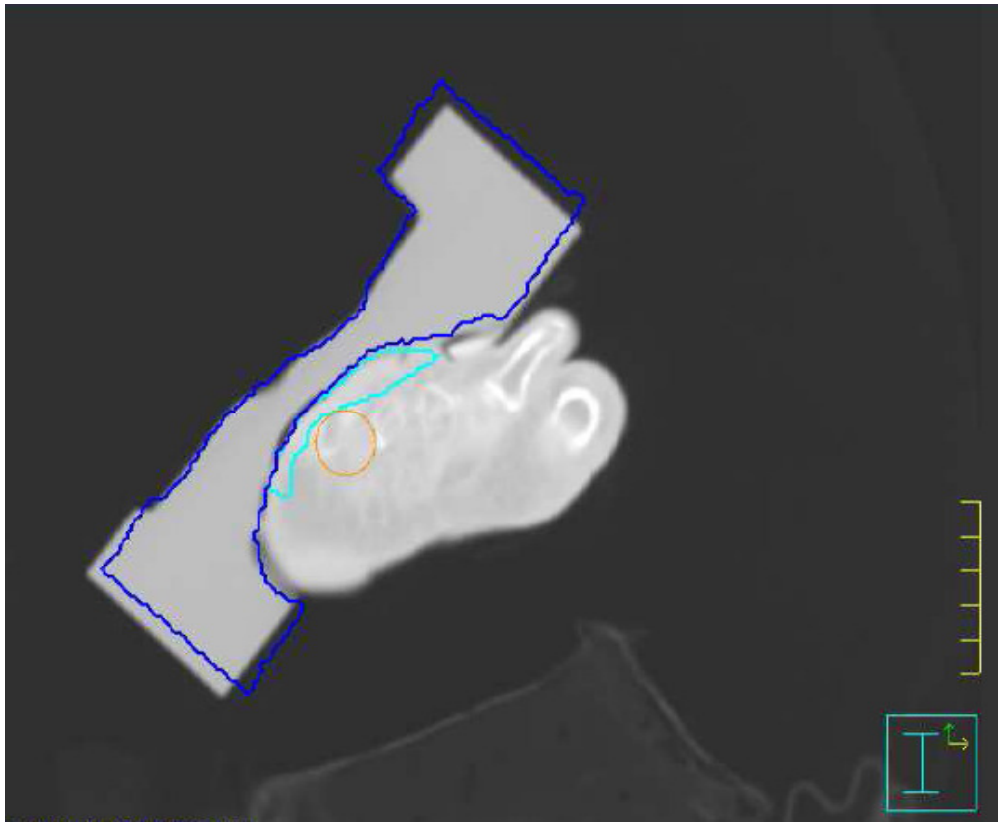
Verification Simulation (Day 8)

- Scan patient
  - Use same slice thickness as initial scan
  - Extend 5cm above and below bolus
- Examine bolus fit
  - Use lung window/level
  - Air gaps should be <3mm
  - Reposition and rescan if necessary
- Rarely alter bolus
  - Add red wax bolus to fill in large gaps



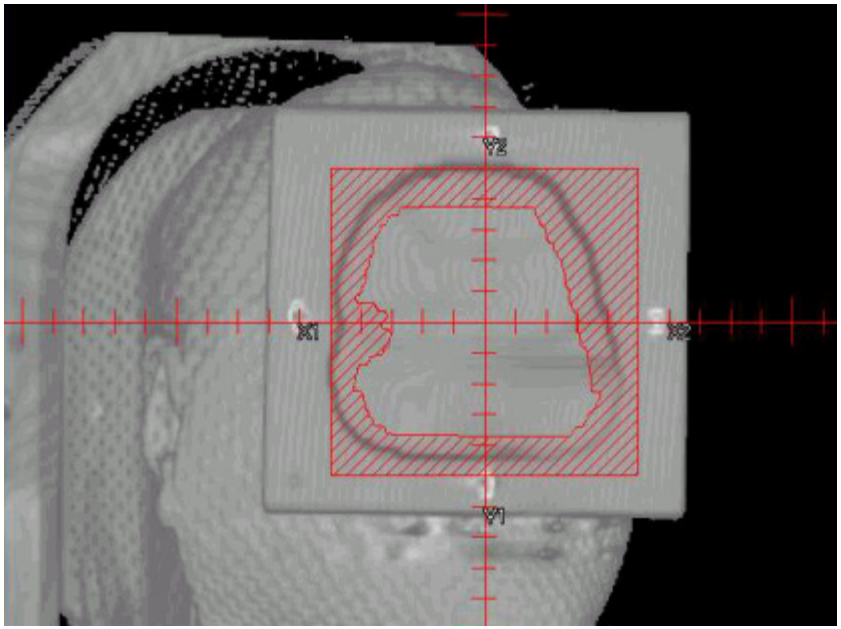
Final Treatment Planning (Day 8 – 10)

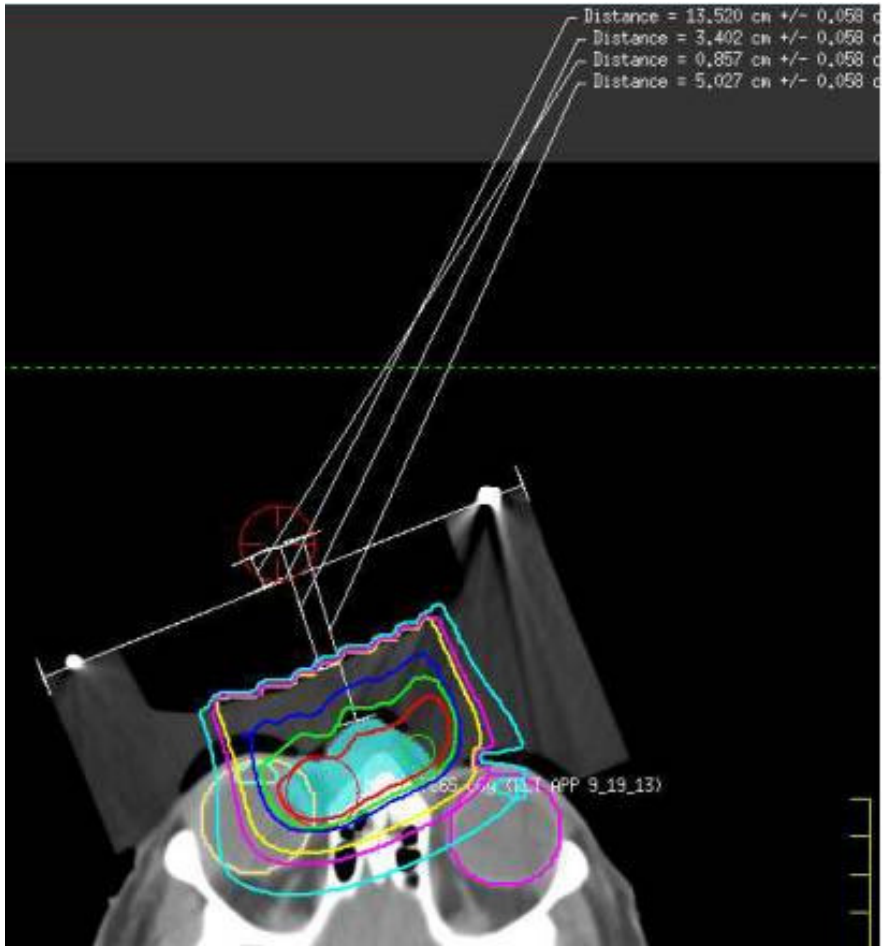
- Fuse verification and initial image sets
- Transfer structures
  - Compare bolus contour to bolus position
  - MD verifies accuracy of PTV
- Transfer initial plan
  - Adjust block and beam angle
  - Recalculate dose



Final Treatment Planning (Day 8 – 10)

- Record SSDs in R & V
  - Skin surface
  - Bolus Flattop
- Projection of light field to bolus surface





First Treatment Fraction

- Setup patient and bolus to marks
  - Compare to 3D printouts and setup images
- Record bolus rotation
  - Within 1 degree of verification simulation
- Align light field to bolus surface
- Verify SSDs
- Image
  - MV/KV/CBCT

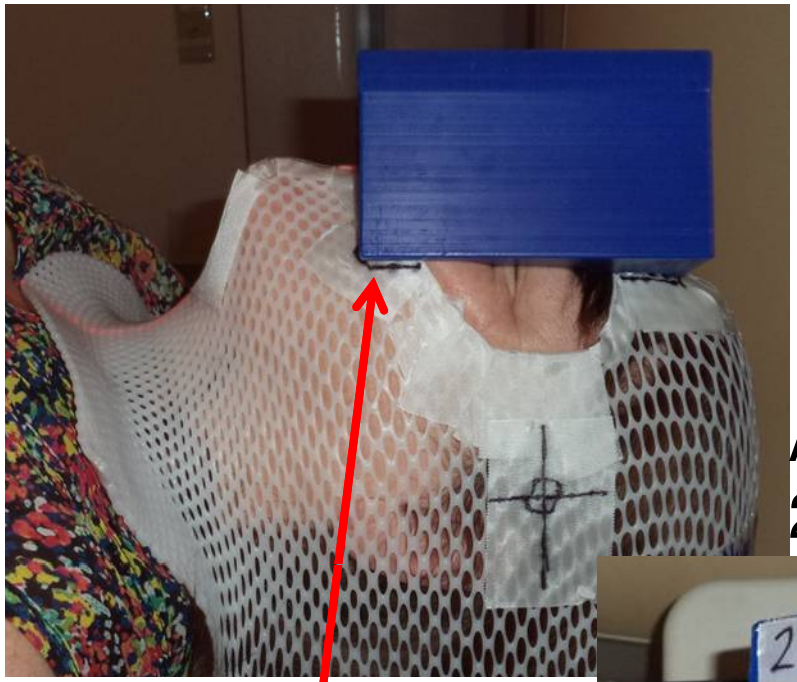
Outline

- Bolus ECT Background
- Clinical Workflow
  - Simulations
  - Treatment Planning/Ordering
  - First Fraction
- Special Cases
  - Nose
  - Back
  - Foot

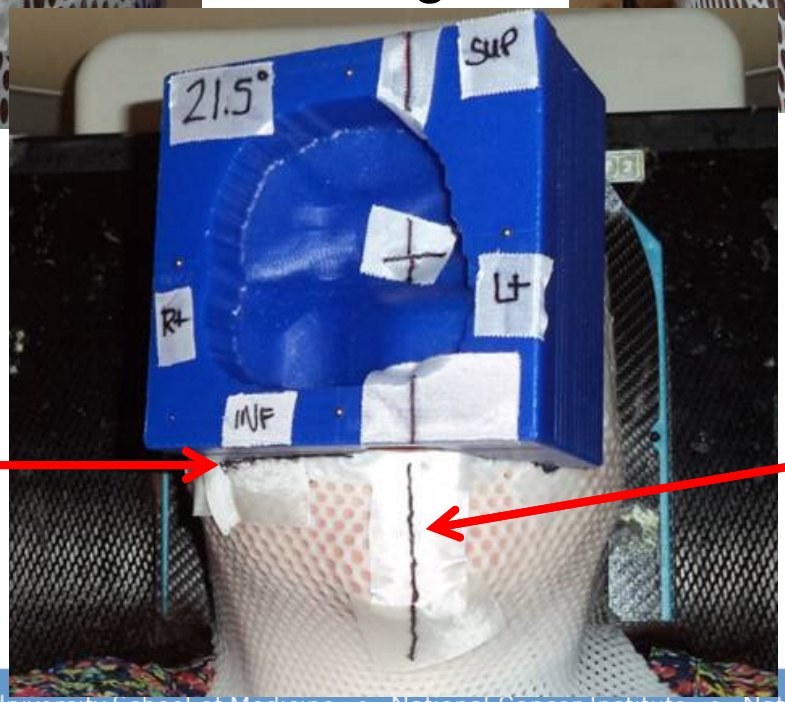
Case 1: Nose Initial Simulation

- 58 y/o F with cutaneous squamous cell carcinoma at nasion with extension towards R medial canthus.
- 12 MeV treated to 66 Gy in 2 Gy daily fx

Case 1: Nose Verification Simulation



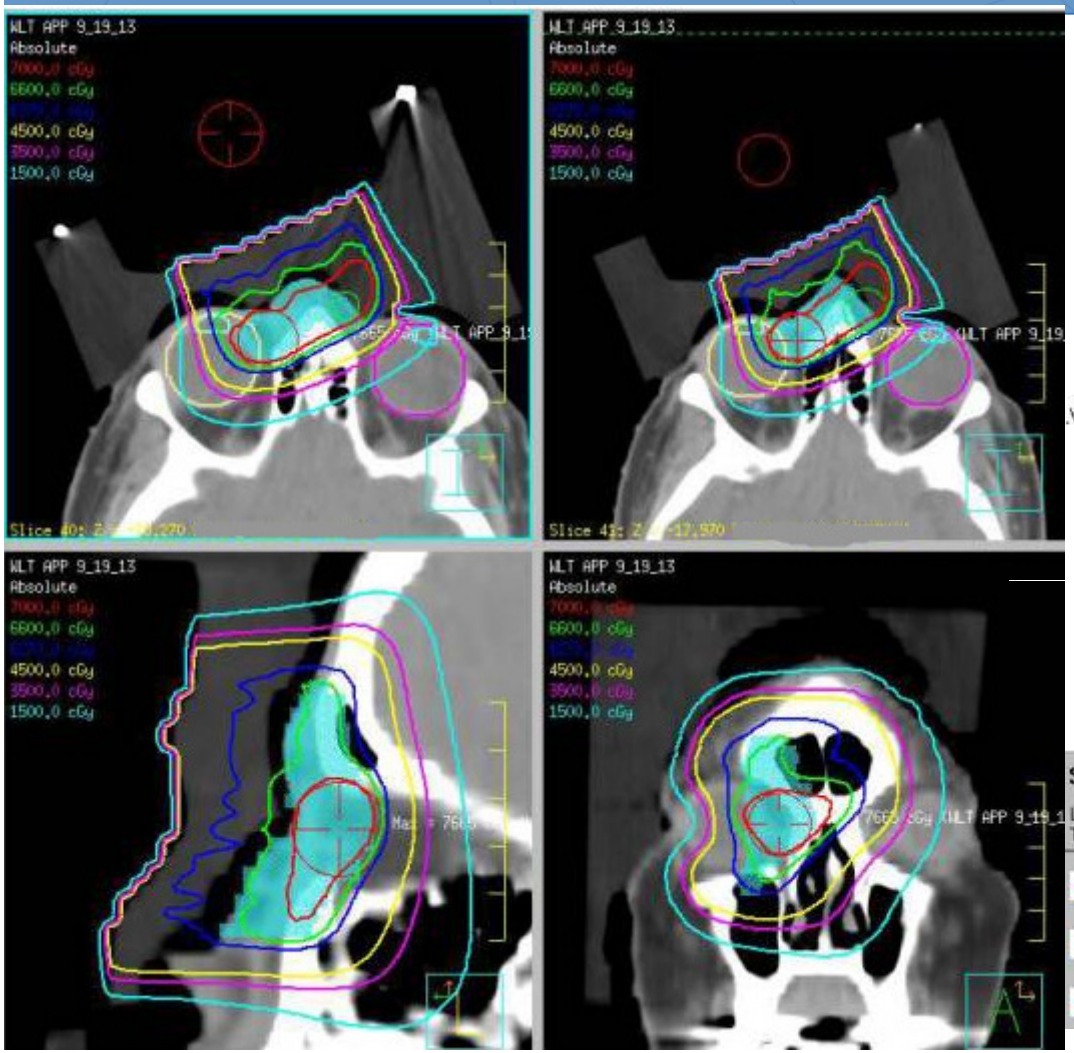
Angle L to R:
21.5 degrees

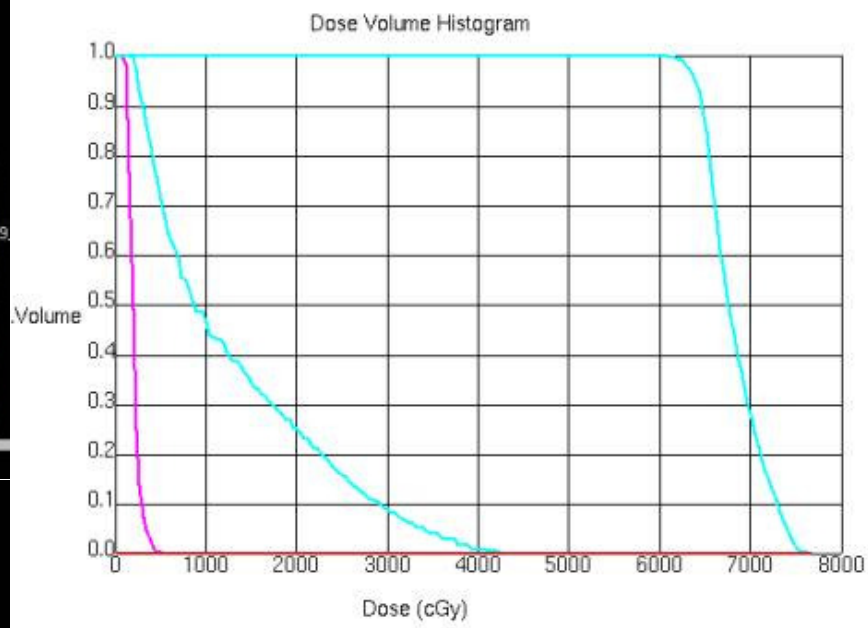


Marks align
to bolus edge

Marks align
to bolus x-hairs

Case 1: Nose Treatment Plan



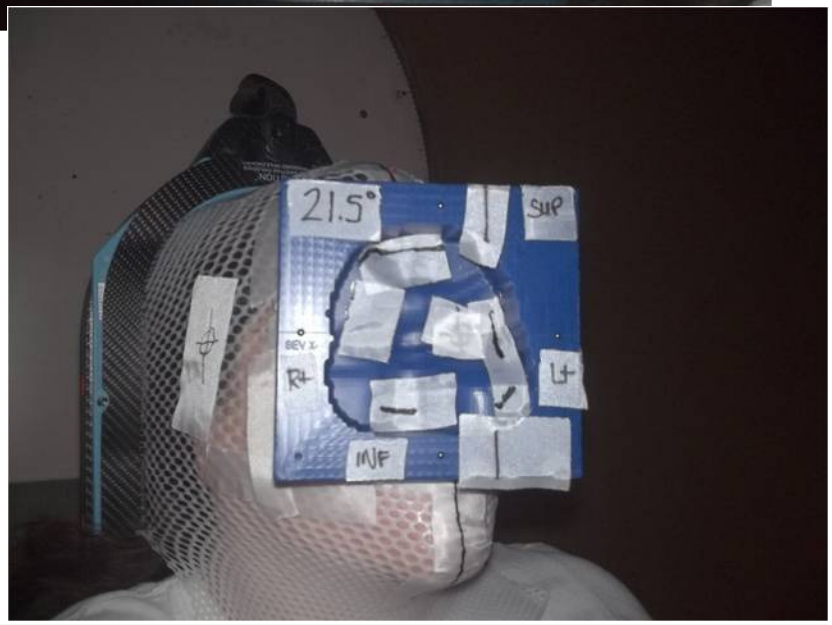


Statistics

Line Type	ROI	Trial	Min.	Max.	Mean	Std. Dev.
	ORIG_Lacrimal L	WLT APP 9_19_13	66.1	506.7	204.0	66.3
	ORIG_Lacrimal R	WLT APP 9_19_13	184.6	4239.3	1292.0	1020.4
	PTV-SKIN	WLT APP 9_19_13	5921.2	7642.6	6815.4	312.4

- Eye shield considered but not used due to electron energy and uncertain impact on dose distribution near PTV

Case 1: Nose First Fraction



Response to Treatment

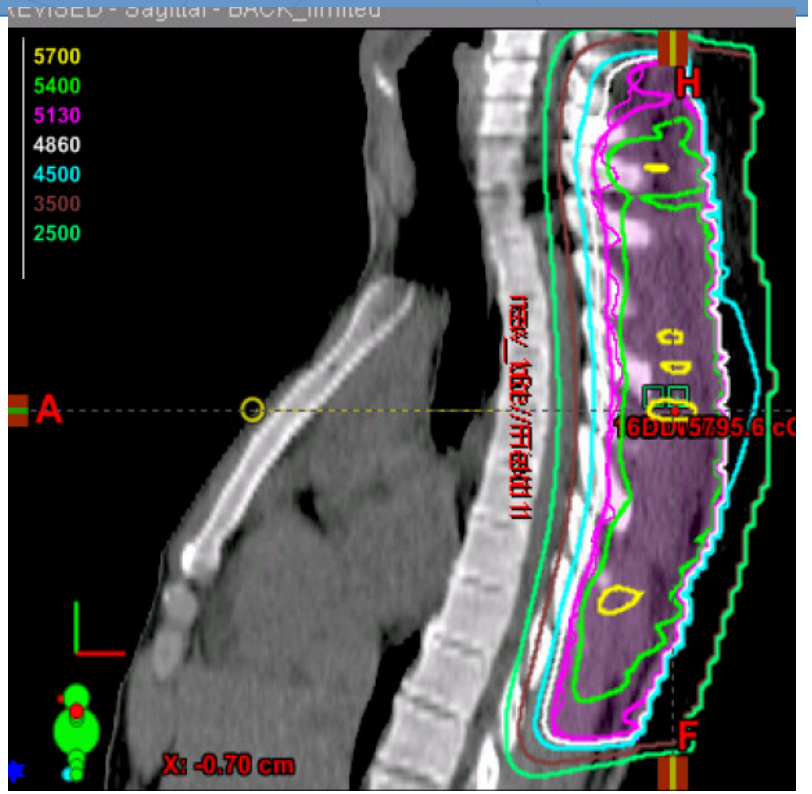
- Grade 2 skin reaction
- Completely cleared up at 6 week followup

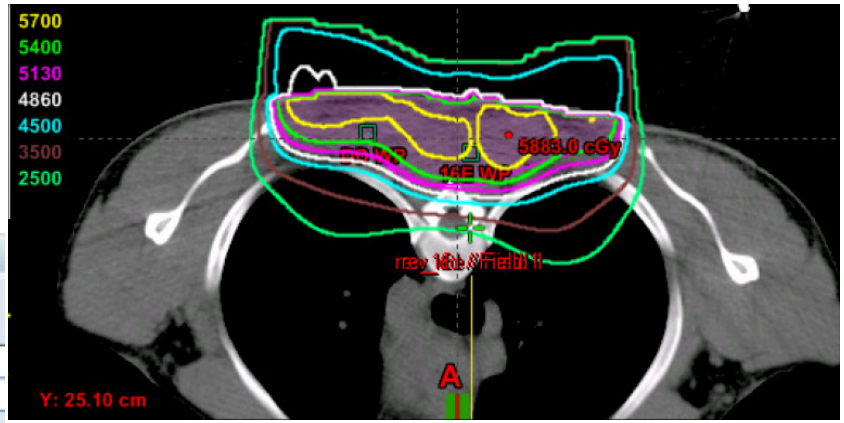
Case 2: Back Initial Simulation

- A 34-year-old African-American male with dermatofibrosarcoma protuberans to the upper back
- Reversed prone pillow registered to Alpha Cradle

Case 2: Back Treatment Plan

- Treatment 80% using DD and 20 MeV, 20% using not bolus with 16 MeV.
  - Planning goals: 95% of PTV covered by 95% of Rx
  - RX = 54Gy @ 2 Gy fractions
  - Lung Dmean < 10Gy, V20 < 20%
  - Heart Dmean < 5 Gy, V20 < 5%
  - Mixed bolus with non-bolus to reduce dose to skin graft

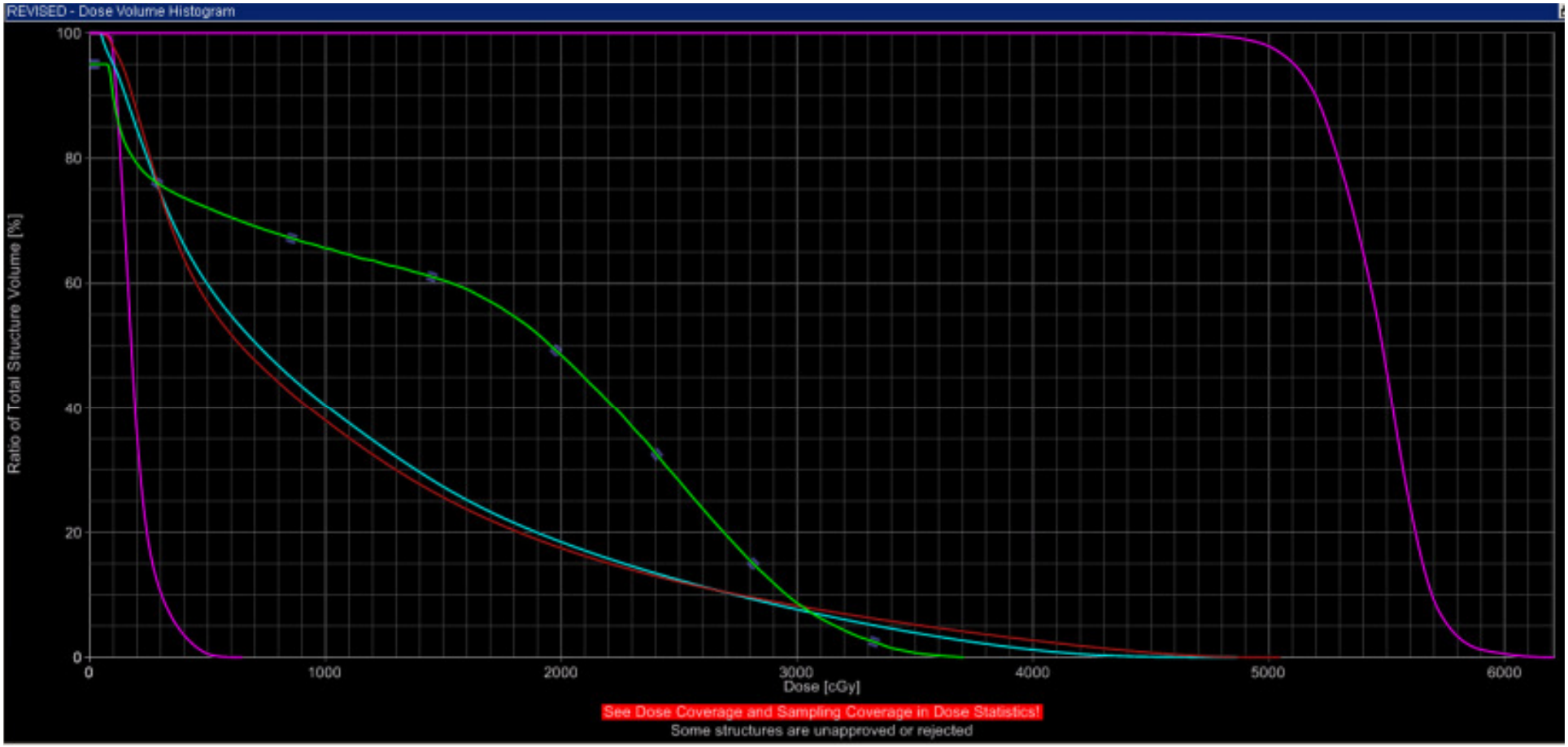




Fields | Dose Prescription | Field Alignments | Plan Objectives | Optimization Objectives

Plan ID	Fractionation Id	Dose / Fraction [cGy]	Number of Fractions	Total Dose [cGy]
rev_16e	F1	1413.5	1	1413.5
rev_dd	F1	5201.6	1	5201.6

Case 2: Back Treatment Plan

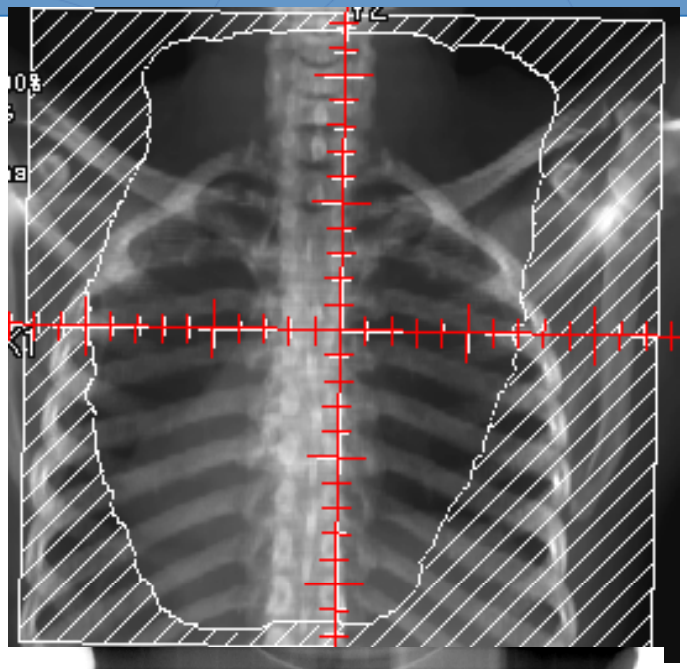


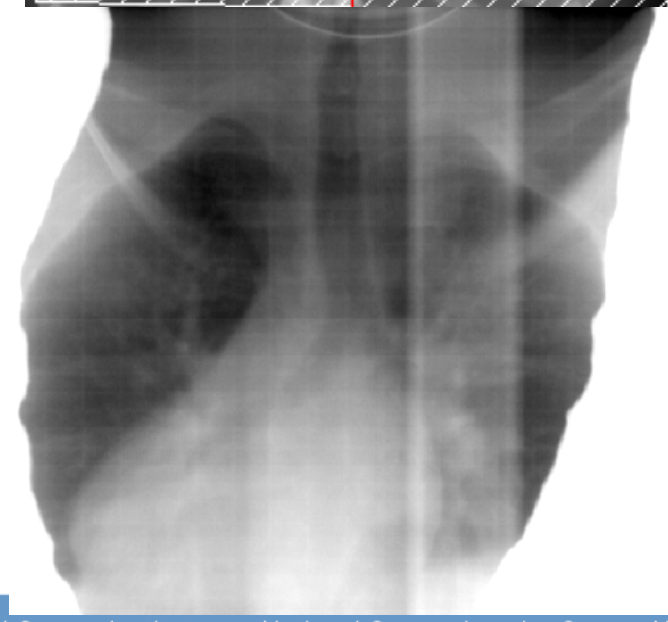
HEART	Unapproved	REVISED	C1	629.6	100.0	99.9	50.1
LUNG_L	Unapproved	REVISED	C1	1616.6	100.0	100.0	38.1
LUNG_R	Unapproved	REVISED	C1	1830.5	100.0	100.0	52.0
PTV INSIDE SKIN	Unapproved	REVISED	C1	1251.9	100.0	99.9	2577.6
SPINALCORD	Unapproved	REVISED	C1	36.8	95.0	101.1	74.3

Case 2: Back Verification Simulation

Case 2: Back Treatment

- Dry desquamation along surgical incision lines.
  - Went on 4 day break between 21st and 22nd fraction.
- 6 week follow up
  - Skin recovered from treatment

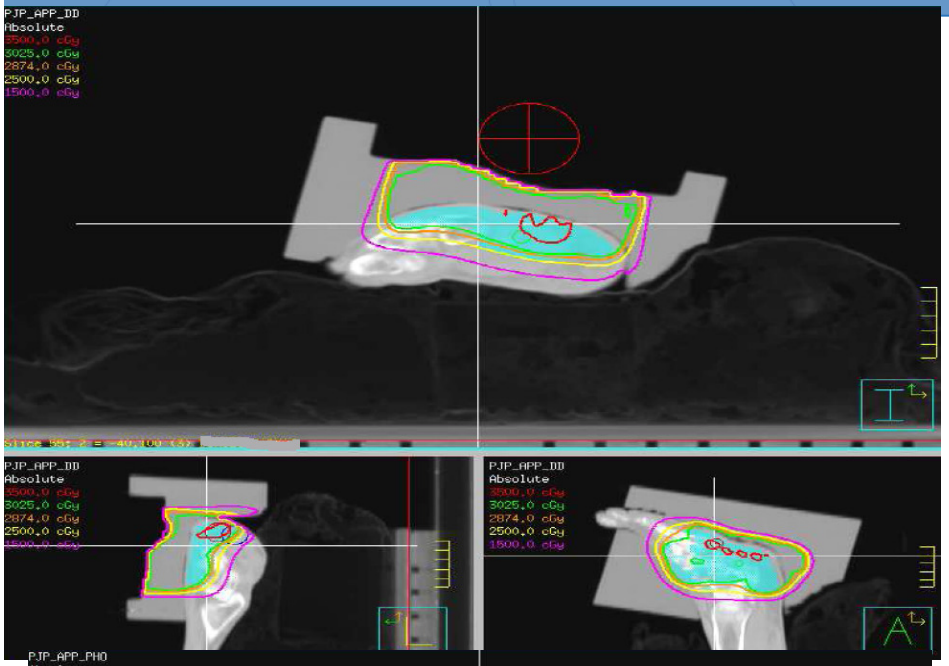


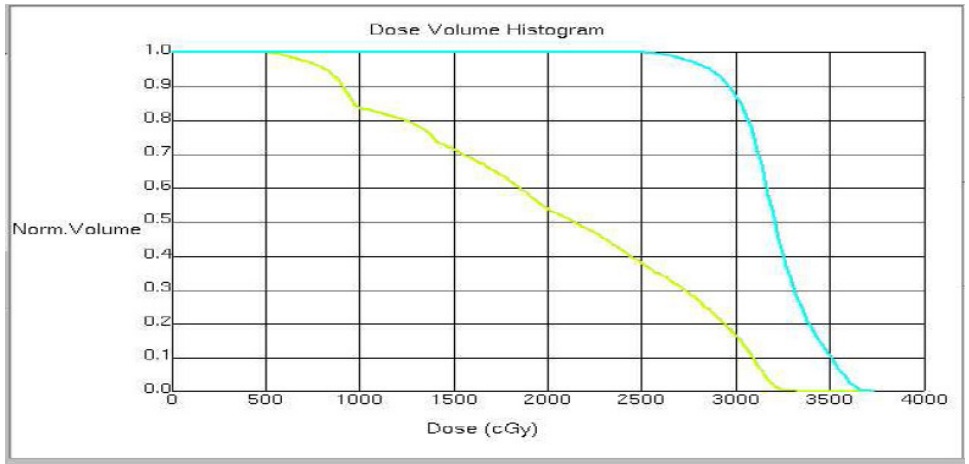


Case 3: Foot Initial Simulation

- 71 yo otherwise healthy female with 2cm clear cell sarcoma of the right lateral foot
- Conservative local excision with positive margins.
- 2:1 .decimal to 6X weighting
  - 95% of PTV covered by 95% Rx
  - 45Gy initial plan in 1.8 Gy fx.
  - PTV retracted 3mm from skin
  - 16 MeV (137MU) used and 6 X (61MU).
  - Mixed to reduce dose to skin

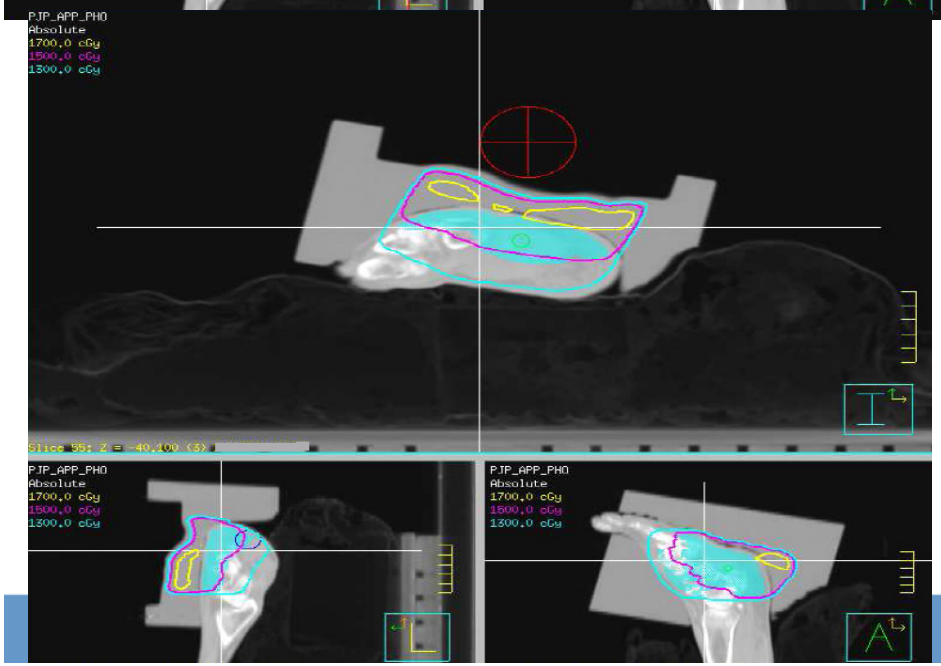
Case 3: Foot Treatment Plan

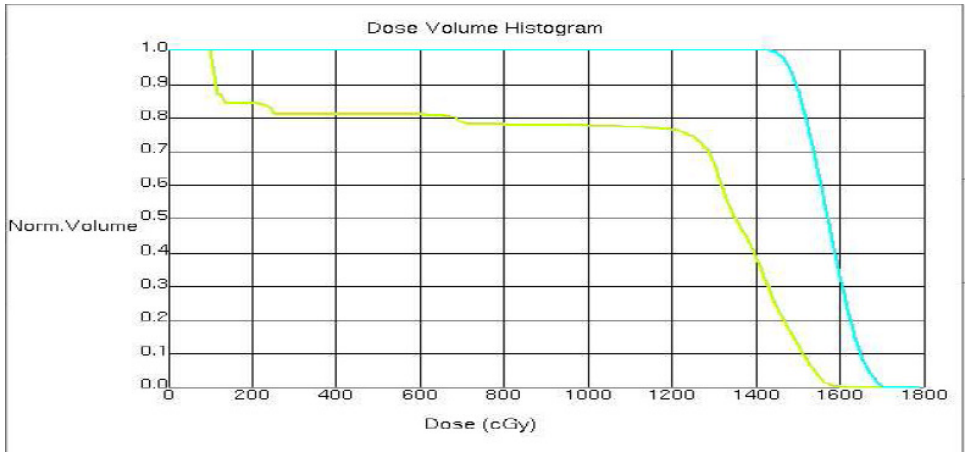




ROI Statistics

Line Type	ROI	Trial	Min.	Max.	Mean	Std. Dev.
	Foot and Ankle joints	PJP_APP_DD	455.6	3328.2	2074.0	802.6
	PTV45(SKIN-3)	PJP_APP_DD	2317.4	3728.9	3213.6	209.9





ROI Statistics

Line Type	ROI	Trial	Min.	Max.	Mean	Std. Dev.
	Foot and Ankle joints	PJP_APP_PHO	88.8	1605.7	1131.6	509.0
	PTV45(SKIN-3)	PJP_APP_PHO	1399.8	1707.8	1571.4	57.5

Case 3: Foot Verification Simulation

- 12 degre L/R
- 3.5 Degree Sup/INF

Case 3: Foot First Fraction Treatment

Case 3: Foot Treatment Plan

- Results: Erythema resolved at time of 6 week follow-up.
- Patient has maintained an active life, retained ability to walk/hike.

Questions

- Thank you!