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
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
Objective:
- Conform 90% isodose surface to distal PTV surface.

Case 1:
- Issue: $R_{90} > d_{PTV}$
- Solution: Constant thickness bolus
  - Decreases depth of $R_{90}$
  - Increases skin dose
  - SuperFlab, Aquaplast, red wax, wet gauze
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

- 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
Bolus Electron Conformal Therapy

- 9 MeV electron beam
- \( Rx = 800 \text{ cGy} \)
- 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
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
Bolus Electron Conformal Therapy

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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)

![Diagram](image.png)

\[ b = R_{90} - d \]
Bolus Electron Conformal Therapy

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

\[
b = R_{90} - d
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• **Bolus ECT Background**

• **Clinical Workflow**
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• **Special Cases**
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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-aperture 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
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**
  - \( d = \text{deepest target} + 3\text{mm} \)

- **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

- **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.
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

This page creates the custom bolus. Select the desired construction operation and set the parameter values, then click "Generate" to create the bolus.

- **Design Parameters**
  - Distal PTV Dose: 90%
  - Automated Marching
  - Target Inner Border (cm): 0.50
  - Damp Hot Spots at: 110%

- **Beam Information**
  - Beam Energy: 6 MeV
  - D90: 1.80 cm
  - Eff Field Size: 7.5 x 7.1 cm
  - SSD: 105.1 cm
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

Not for clinical use
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)
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

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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

- 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
Case 2: Back Treatment Plan
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
Case 3: Foot Verification Simulation

- 12 degree 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!