Proton Treatment Planning for Pediatric Patients

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Outline

What makes protons different?
-Austin Faught
  • Comparison of photon and proton dose
    • Emphasis on how physics governs the differences
    • Discussion of delivery techniques

How is the planning process affected?
-Jackie Faught
  • Introduction of concepts unique to protons
    • Robustness
    • Plan setup considerations
    • Treatment accessories

Case studies and practical applications
-Erika Bowers
  • Review of patient cases that illustrate the uses of proton therapy
    • Cranial case
    • CSI case
    • Soft tissue (body site)
The Bragg Peak

- Protons stop in matter
  - Increase in dose at distal end
  - Near zero dose after they stop
- Lower integral dose
- Significant reductions to OARs in some scenarios

Acknowledgements

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Why do protons deposit dose differently?

Protons
- Have mass
- Have positive charge
- Can give up portions of their energy

X-Rays
- No mass
- No charge
- Catastrophic collisions

X-Ray Dose

- Attenuation – change in number of x-rays is proportional to:
  - Number of x-ray’s present
  - Perceived size of particles
  - Thickness traversed
  \[ \Delta N \propto \Delta t \times \sigma \times N_0 \]
  \[ \frac{\Delta N}{N_0} = \Delta t \times \lambda \]
  \[ N = N_0 e^{-\lambda t} \]
Proton Dose

- Two components impacting proton dose
  - How many protons
  - How much energy they give up
    - At the start they’re moving very fast and give up a small, consistent amount
    - As they slow down, they have more time to interact

Proton Dose Calculations

- Analytical algorithms require an HU to relative stopping power conversion
  - CT’s are made from photon transmission
  - Large uncertainty 2-5% associated with conversion
Delivery Techniques

**Passive Scattering**
- Range Modulator
- Aperture
- Compensator

**Scanning Beam**
- Scanning Magnets
- Target Volume
- Critical Structure

Courtesy P. Tsiamis

Proton Facility Layout
St. Jude Proton Gantry

Counter weight
C-Shape frame
Retractable Floor

St. Jude Proton Treatment Room

Orthogonal System
Nozzle
X-Ray Tube
Robotic Couch
How is the planning process affected?

Jackie Faught, PhD, DABR

Proton beam arrangements

- Fewer beam angles than IMRT (commonly 2-3)
Proton beam arrangements

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IMPT

IMRT

Proton beam arrangement considerations

• Beam path (protons are more sensitive!)
  • Consider everything in the path of the protons – will it be stable?
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- Beam path
  - Consider everything in the path of the protons – will it be stable?

Effect of hair presence if planned without

Rx Dose Cloud
Proton beam arrangement considerations

- Beam path
  - Consider everything in the path of the protons – will it be stable?
  - Blankets, tubing, hair
- Flash
- Clearance
- Hinge angle

Density overrides

- Metal overrides
  - Generally avoid metals
  - Commonly have surgical clips near target
- CT image artifacts
  - Increased uncertainty
  - Small artifacts may be adequately overridden
Range shifters

• Use material in the beam path to bring the dose toward the patient surface
  • Nozzle mounted range shifters

Range shifters

• Use material in the beam path to bring the dose toward the patient surface
  • Nozzle mounted range shifters
  • Range shifters close to patient
    → Less spread in spot size and penumbra
Accounting for uncertainties in protons

• Sources of uncertainty:
  • Dose delivery (mechanical and radiation)
  • Patient setup
  • Dose calculation
  • PTV concept isn’t translatable to proton therapy
    • Uncertainty in range creates unique margins for each beam
  • Robust optimization to CTV
    • Robust = “capable of performing without failure under a wide range of conditions”

Robust optimization

• Perturb plan by a set of uncertainties
• Optimize plan to best achieve objectives under all scenarios
• Commonly used uncertainty perturbations for standard cases:
  • 3% range uncertainty
  • 3 mm
• Multi-iso plans: Beam specific robustness also used to account for potential movement of isocenters relative to one another
Robust optimization

- Robustness evaluated post-optimization by evaluating DVHs and corresponding dose distributions

Case Studies and Practical Applications

Erika Bowers, CMD
**Standard Cranium**

- Beam arrangements:
  - Typically 2 beams are chosen so that use the shortest and most homogenous path through healthy tissue.
  - Avoid entering through metal whenever possible.
  - All beams should avoid pointing the distal end toward OARs because of range uncertainty.
Standard Cranium

- Robustness Goal: 95% of CTV = 95% of RX

CSI – Standard

- Isocenter Placement
- Beam Angles
- Field Specific Targets
- Robustness
CSI – Standard

- Isocenters Placement:
  - CBCT Restrictions/Considerations
    - St. Jude = 14cm per jaw
    - DO NOT clip C-Spine/Neck Area
    - DO NOT clip Sacrum

- Keep all 3 Isocenters in the same plane
  - 3 Isocenters is best for patient set up, but can take longer to treat.
CSI – Standard

- Beam Angles:
  - Cranium Fields - Posterior Obliques
    - Beam 1 - Gantry 150° & Couch 0°
    - Beam 2 - Gantry 150° & Couch 180°
  - Spine Fields – PA
    - Beam 3 - Gantry 180° & Couch 180°
    - Beam 4 - Gantry 180° & Couch 180°

- Field Specific Targets:
  - CTV Cranium
  - CTV Spine
  - OTV Total
    - OTV Cranium
    - OTV Spine
    - VB (age dependent)
      - Under 13 = Treat
      - Over 13 = Spare
      - VB dose = 80% of Rx up to 20 Gy
  - OTV SUP
  - OTV MID
  - OTV INF

OTV SUP = 7 cm
OTV MID = 7 cm
OTV INF = 7 cm
CSI – Standard

- Robustness:
  - Optimize with **3mm & 3%** on OTV Spine and CTV Cranium
  - Additional **5mm** on middle field (upper spine) in the X direction (sup-inf).

CSI – Brainstem Sparing
CSI – Brainstem Sparing

- The addition of a lateral beam allows carving of the brainstem and previously treated area, while still giving adequate dose to the target anterior to these areas.

Soft Tissue

- Consider Anatomy and quickest/most stable path to the target.
Soft Tissue

- Consider Anatomy and quickest/most stable path to the target.

- Beam Angles
  - Anterior
    - Beam 1 - Gantry 30° & Couch 0°
    - Beam 2 - Gantry 30° & Couch 180°
  - Posterior
    - Beam 3 - Gantry 150° & Couch 0°
    - Beam 4 - Gantry 150° & Couch 180°
Soft Tissue

Questions?

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