Clinical Physicists must know and be involved in treatment planning.

Conflicts of Interest

Varian Medical: Honorarium

Why we need Physics Proton Planning?
Help make sense out of this

Educate your colleagues!
Develop 101 lectures to clear up nomenclature mess
Delivery Techniques - The old and the new
Proton Uncertainties - Scary!
Proton planning basics – How to handle uncertainties
Site specific technology - Wow

Who else but Physics?
Educate your colleagues!

Develop 101 lectures to clear up nomenclature mess

Delivery Techniques - The old and the new
Proton Uncertainties - Scary! Drives how we plan
Proton planning basics – How to handle uncertainties
Site specific technology - Wow

This does not need to be so scary!

Range Uncertainties

First problem:

Stopping power (MeV cm²/g) determine how “fast” proton loses energy

CT HU to stopping power ratio calibration has 3.5% uncertainty

Translates into 3.5% range uncertainty
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Stopping power (MeV cm$^2$/g) determine how “fast” proton loses energy

CT HU to stopping power ratio calibration has 3.5% uncertainty

Translates into 3.5% range uncertainty

- 3.5 mm at a range of 10 cm
- 7 mm at a range of 20 cm

depends on depth!

Management (1):

Use margins = 3.5% range

Larger distal margin than proximal margin

For prostate @ 20 cm depth: margin= 7 mm
Range Uncertainties

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Range Uncertainties

Management (2):

Do not stop beam in front of organs at risk

This is why lateral beams are used to treat prostate in proton therapy

Second problem:

Complex tissue heterogeneities degrade Bragg peak
Second problem (cont.):

Pflugfelder et al, Med Phys, 34 (2007), 1506

Range Uncertainties

Management:
Avoid beam entrance through regions of complex heterogeneity
Even if setup is reproducible

Third problem:
Setup error can change the dose distribution itself
**Photons**

Tumor at 10 cm sees 67% of max dose  
Patient roll: bone  
“appears” at 5 cm depth  
Add 1 cm bone  
Density is twice that of water  
(1 cm water => 2 cm)  
Pull back PDD by an additional 1 cm

Tumor at 10 depth still sees 64% of dose

**Protons**

Tumor at 10 cm sees 100% of max dose  
Patient roll: bone  
“appears” at 5 cm depth  
Add 1 cm bone  
Density is twice that of water  
(1 cm water => 2 cm)  
Pull back PDD by an additional 1 cm

Tumor at 10 depth still sees 0% of dose

**Dose distribution is not static**
Beam specific PTV?

Dose distribution is not static

Nominal Plan  Patient shifted posteriorly by 5 mm

PTV?

To ensure CTV coverage, PTV (or dose distribution) may have unintuitive shape.

Traditional PTV concept is not helpful in proton planning.

Most conformal plan may not be best plan.
Robustness

Ask

What if range is wrong by 3.5% and/or patient is setup is off

Evaluate Plan for Robustness

Robustness is a plan metric!
Plan robustness replaces traditional PTV concept
Robustness optimization?

Include robustness as an objective in planning
Available in commercial treatment planning systems

Range Uncertainties

General principle to deal with all end-of-range uncertainties:
Use multiple beams to geographically spread out uncertainties
Be careful when ranging out into OAR

Proton planning starts at the CT scanner

Robustness, Robustness, Robustness
Avoid sharp edges (Devices and Patient)

Setup limitations:
CSI, avoid sharp fall off

Obese Patient

Hip implant, needed oblique beam
8 mm depth difference

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8 mm depth difference

Recommended VMAT plan
Difficult Setup

Elderly Female
Frog-legged setup
Hip replacement

Difficult Setup

Difficult Setup

Transferred patient to Photon Clinic
Simulation

Physics and/or Dosimetry goes to CT-sim

Treatment Planning

Physics reviews each treatment plan before it is presented to Physician

Example: MFO plan

- **Multi Field Optimization** (similar to IMRT)
- In MFO plans it is not possible to control the dose contribution from each beam
- For $n$ beams, dose from each beam is likely $\neq 1/n$ of dose
- Check dose from each beam manually
MFO plans (4 fields)
Field doses

93.9% of px dose

Lessons learned meeting

• What is working, what is not working
• Near misses
• Continue to improve process
• All of physics and dosimetry
• Time well spent

Quality treatment

• Physicians, Therapists, Dosimetry: all need to know and understand uncertainties
• Drives how we set up and simulate patients
• Drives how we plan patients
• Drives how we evaluate plans
• Drives how we treat patients
• Drives how we monitor patients during treatment course

Physics needs to facilitate this discussion