Challenges of Post-Treatment and Real-Time Imaging of Dose Deposition in Proton Therapy

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Sources and magnitude of range uncertainties
- Differences between treatment preparation and treatment delivery (~ 1 cm)
  - Daily setup variations
  - Internal organ motion
  - Anatomical/physiological changes during treatment
- Dose calculation errors (~ 5 mm)
  - Conversion of CT number to stopping power
  - Inhomogeneities, metallic implants
  - CT artifacts

Photon planning:
“Static dose cloud” approximation

Proton planning:
Tumor shrinkage
Initial Planning CT
GTV 115 cc
5 weeks later
GTV 39 cc

S. Mori, G. Chen
Proton planning:
Tumor shrinkage results in proton overshoot

Planning CT (T40%)
CT after 5 weeks (T40%)

Beam stops at distal edge
Beam overshoot

S. Mori, G. Chen

Adding a distal margin

IMPT plan – “proximal patching”

Bussiere, Adams (MGH)

Sensitivity analysis


Solutions to range uncertainties:

Solution 1:
- Account for range uncertainties during treatment planning
  - Compensator smearing (thinning)
  - Field patching
  - Robust planning for range uncertainties

Solution 2:
- Reduce range uncertainties through imaging
  - In-vivo dose imaging:
    - MR imaging and other techniques
    - PET: offline and in-room
    - Prompt gamma imaging

Reducing range uncertainties: Measurements

MR scan after treatment

Krejcarek, Yock, et al.
IROBP 2007;68(3):646-649

Nuclear interactions of protons

Krejcarek, Yock, et al.
IROBP 2007;68(3):646-649
Symposium “Imaging of dose deposition…”

- Theodore Hong  
  (Mass. General Hospital, Boston, USA)  
  “Clinical Significance of In-Vivo Proton Range Detection and Potential of MRI Scanning After Proton Therapy”

- Katia Parodi  
  (Heidelberg Ion Therapy Center, Germany)  
  “Latest Developments in PET Verification of Proton Therapy”

- Jong-Won Kim, H. Kubo, T. Tanimori  
  (National Cancer Center, Korea)  
  “Prompt Gamma Measurements for the Verification of Dose Deposition in Proton Therapy”