Clinical Significance of In-Vivo Proton Range Detection and Potential of MRI Scanning After Proton Therapy

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Disclosure

- No financial conflict of interest with data in this presentation
- No off-label use of any drug described

Why is it so important to understand proton range?

- Tumor Control requires complete coverage of at-risk volume
- Normal Tissue Complication Probability needs to be calculated from accurate DVHs

Risk of Missing Target

- Undertreatment of a 1% subvolume may decrease TCP by as much as 20% (Tome, Med Phys 2000)
- Sparing previously unspared structures can lead to recurrences
In-Parotid Recurrences with IMRT

Where are uncertainties coming from?

- Distal edge of the Bragg peak
- Set-up variation (interfraction variability)
- Organ motion
  - Particularly important at an interface of markedly different densities, like the diaphragm, where the range of protons may change dramatically

Moving Targets are More Challenging

- Need for dose verification
  - Target coverage verified
  - Accurate DVH’s
MGH Phase I Trial
Gated 4D Proton Therapy

Eligibility:
- Childs A/B
- 3 lesions or less
- Primary tumor < 6 cm in size (primary hepatoma or mets)
- No extrahepatic mets

Why are protons and moving targets tricky?

Liver - Ungated vs. Gated
Room’s eye view

Liver - Ungated vs. Gated
Tumor’s Eye View

Ungated
Gated
Ungated
Gated
Liver- Ungated vs. Gated
Tumor’s Eye View

Ungated
Gated

DVH impact of motion

What did we treat? MRI
Changes After Proton Beam

T1 hypointensity
T2 hyperintensity
3 mo post 75 CGE gated proton beam

Protons
Photons

Courtesy of Tom Delaney, MD
Can we find the true dose-signal intensity curve?

1) Dose calculation is much more accurate in lateral penumbra than distal dose fall-off region.

2) We have sacrum MRI scans for some patients that show the lateral penumbra.

CT/MRI registration

- L5 vertebral body
- Dice coefficient: 0.90
- Mean surface distance: 1.1 mm
- Max surface distance: 5.9 mm

Monte Carlo simulation

- 54 Gy (RBE)
- 1 Gy (H&N)
Creation of dose-signal intensity curve

Conclusions

- In vivo verification is important for proton beam therapy given uncertainties
- Importance is for both tumor coverage and generating accurate DVHs
- MRI may be one commonly used modality that can provide feedback to physicians

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