Photon Therapy is More Versatile and Delivery is More Precise Than Proton Therapy

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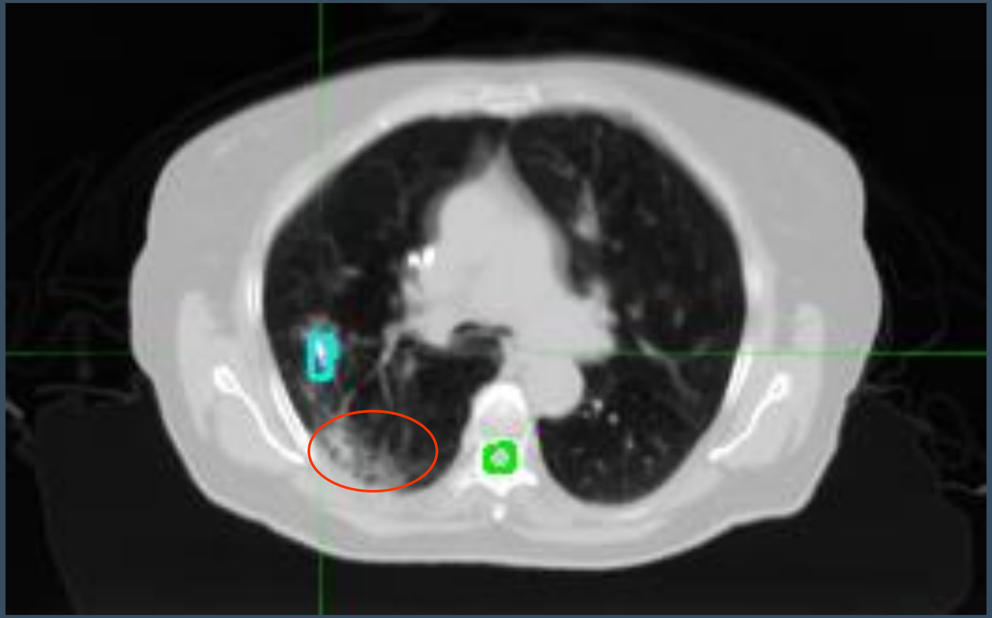
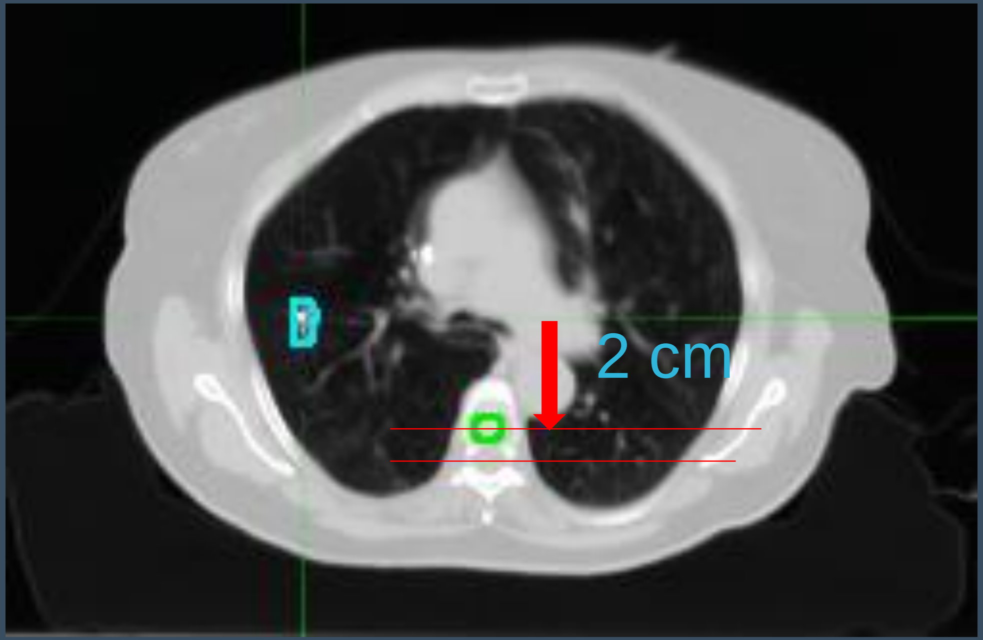
Main Statements

- With multiple photon energies (including FFF beams), modern Linac can treat various size tumors, as small as 0.5 cc (e.g., brain mets), to as large as 1000 cc (e.g., whole abdomen), and to whole body treatment.
- On-board and in-room imaging improve precision of modern photon radiotherapy, using KV-CBCT, in-room CT, and MRI.
- With motion strategies, modern photon radiotherapy can treat moving targets effectively with breath-hold, gating, or ITV.
- With imaging guidance and tumor motion management strategies, modern photon therapy is more versatile and treatment delivery is faster with less uncertainties.

Change in Lung
Can Shift Tumor Location



Planning CT on 3/14

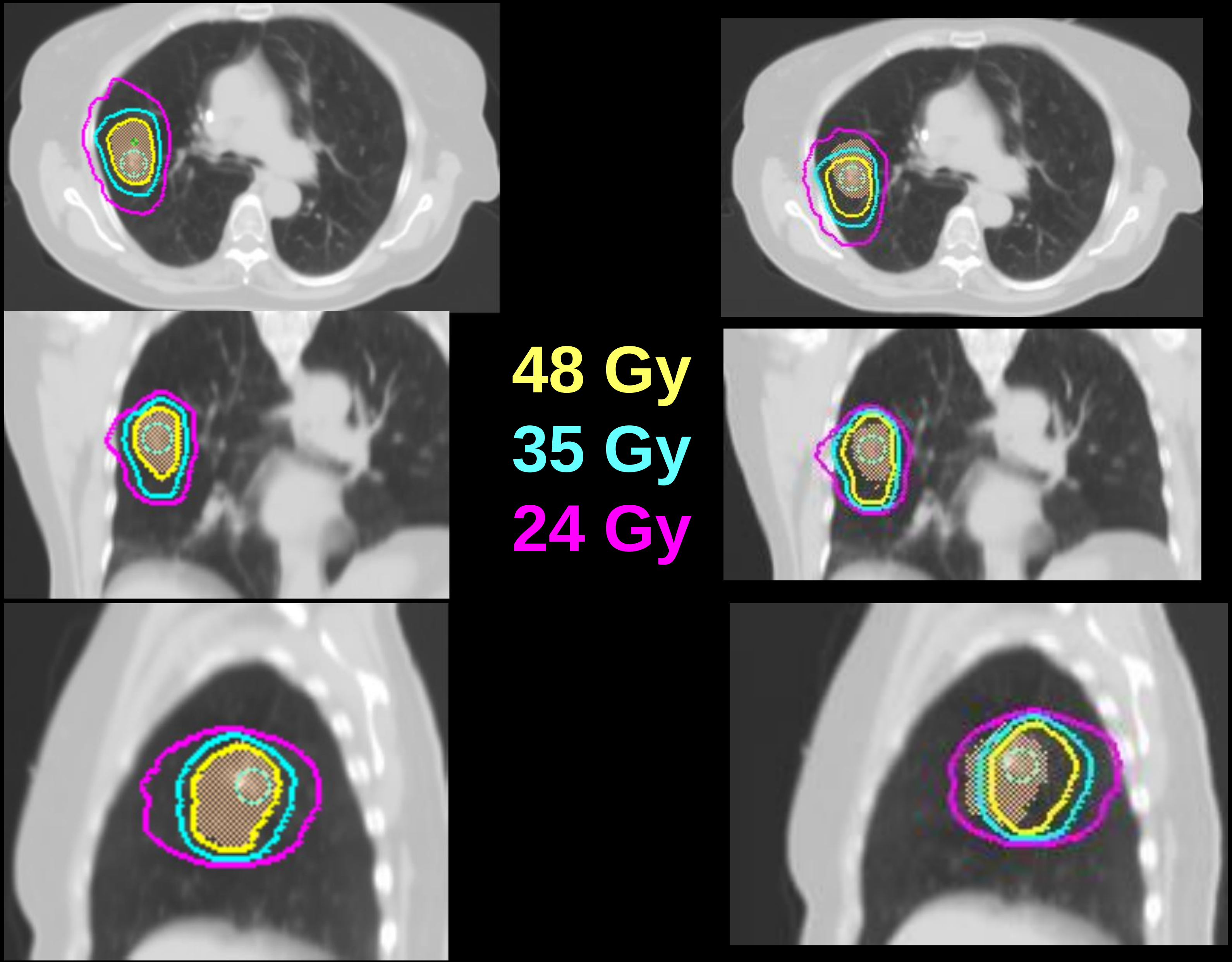


Repeating CT on 4/2

Due to pleural effusion or lung collapse

Align to Marker

Align to Bone



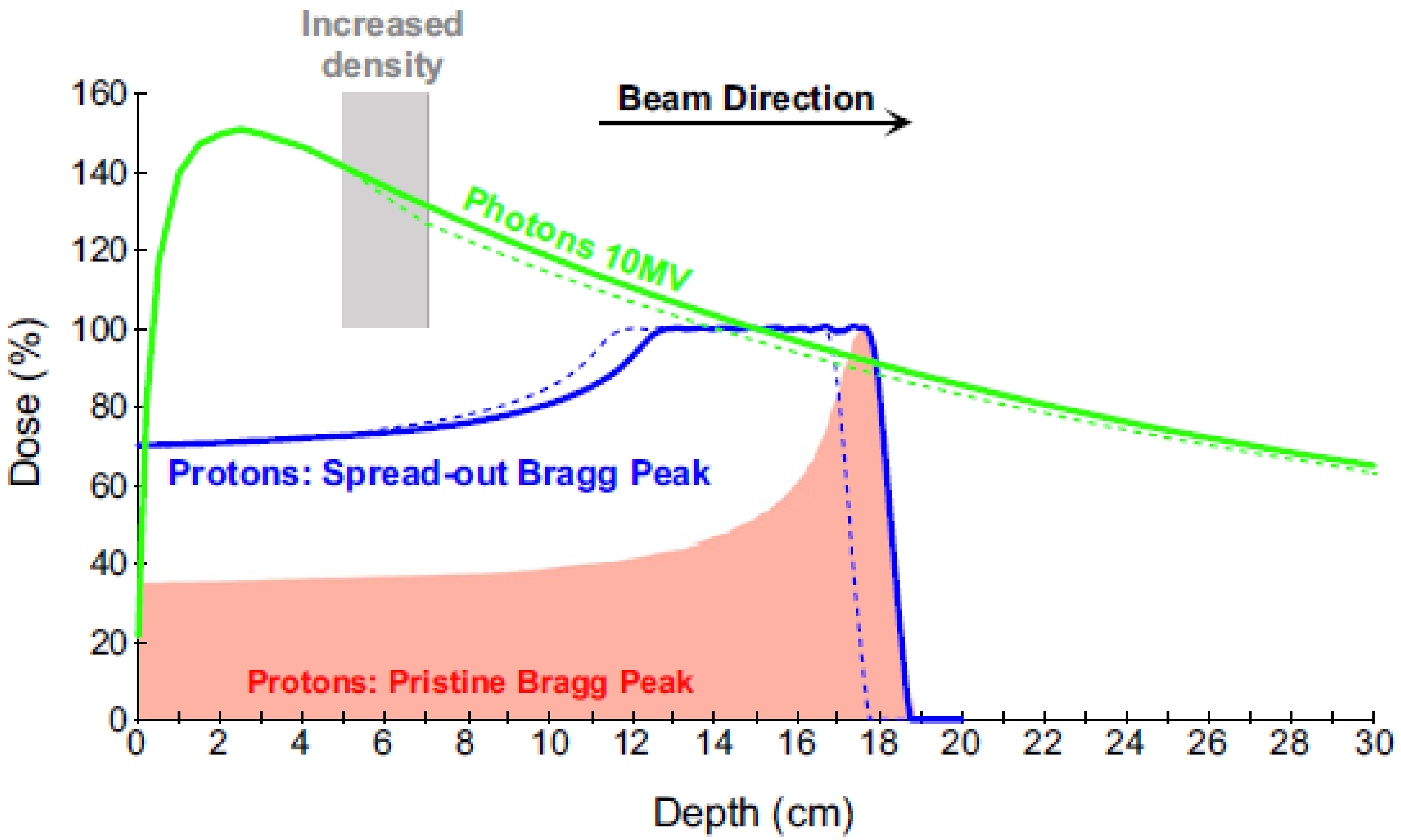


Figure 1 Depth–dose curves without (solid line) and with (dashed) an anatomical density variation in the beam entrance region. (Color version of figure is available online.)

Engelsman, M., M. Schwarz, and L. Dong, Physics controversies in proton therapy. Semin Radiat Oncol, 2013. 23(2): p. 88-96.

IGRT alone cannot resolve range uncertainties

- For deep-seated targets, range uncertainties can be as great as 1 cm, preventing sparing of an organ at risk that is in proximity (i.e. 1 - 2 cm) to the target volume.
- Image guidance for target localization provides only a partial solution for proton treatment.

Lateral Penumbra and Spot Sizes

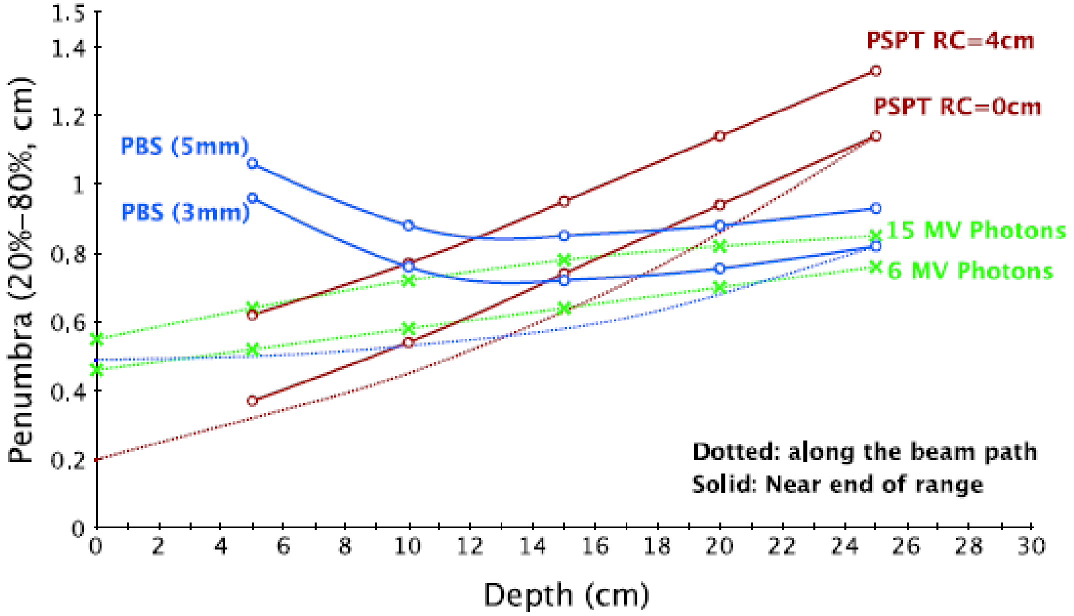


Figure 2 Lateral penumbra as a function of depth for a single photon beam, for a passively scattered (PSPT) proton beam, and for uncollimated proton pencil-beam scanning (PBS) with 2 different spot sizes (1 sigma). Please note that exact values depend on the beamline optics. Proton data based on Safai et al.[6] RC, range compensator thickness. (Color version of figure is available online.)

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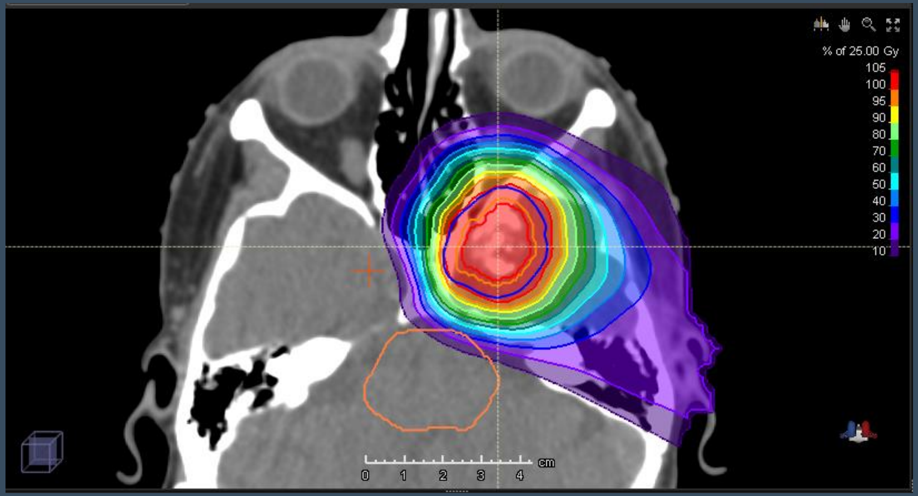
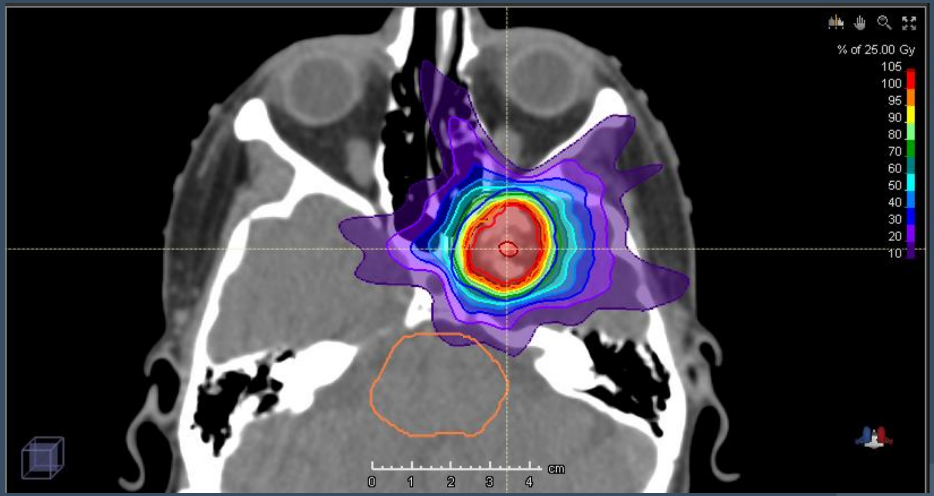
Treatment Planning

- Proton therapy is *disadvantageous* for tumors abutting critical structures



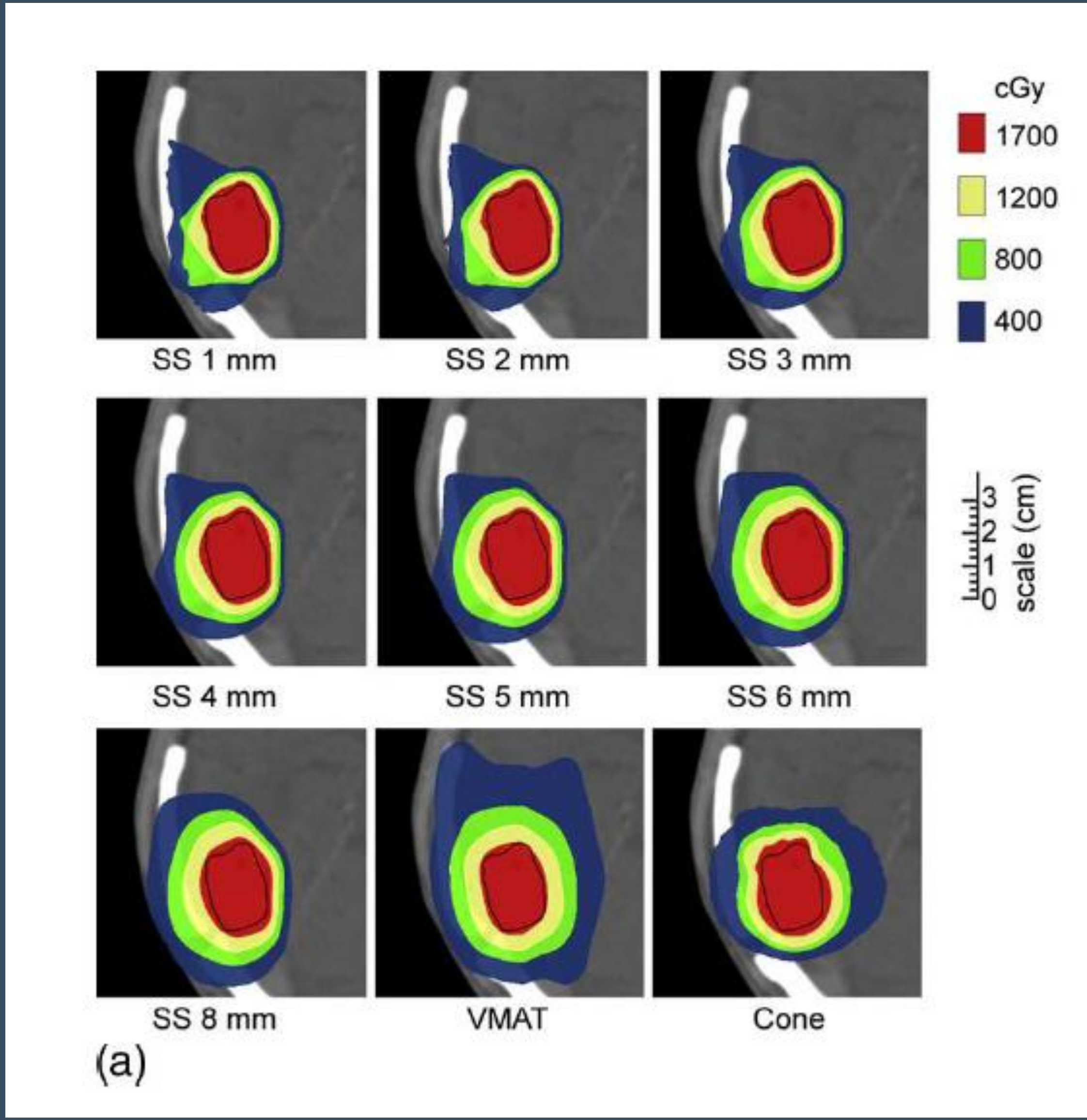
PROTON THERAPY



CYBERKNIFE

Courtesy of MCI (R. Kotecha/Man Yam)

Brain Necrosis is More Important Issue than Secondary Cancer



- Brain necrosis is more important metric than secondary cancer.
- Spot size < 4.3 mm is required to produce better than cone-based and VMAT photon plans.

Impact of spot size on plan quality of spot scanning proton radiosurgery for peripheral brain lesions

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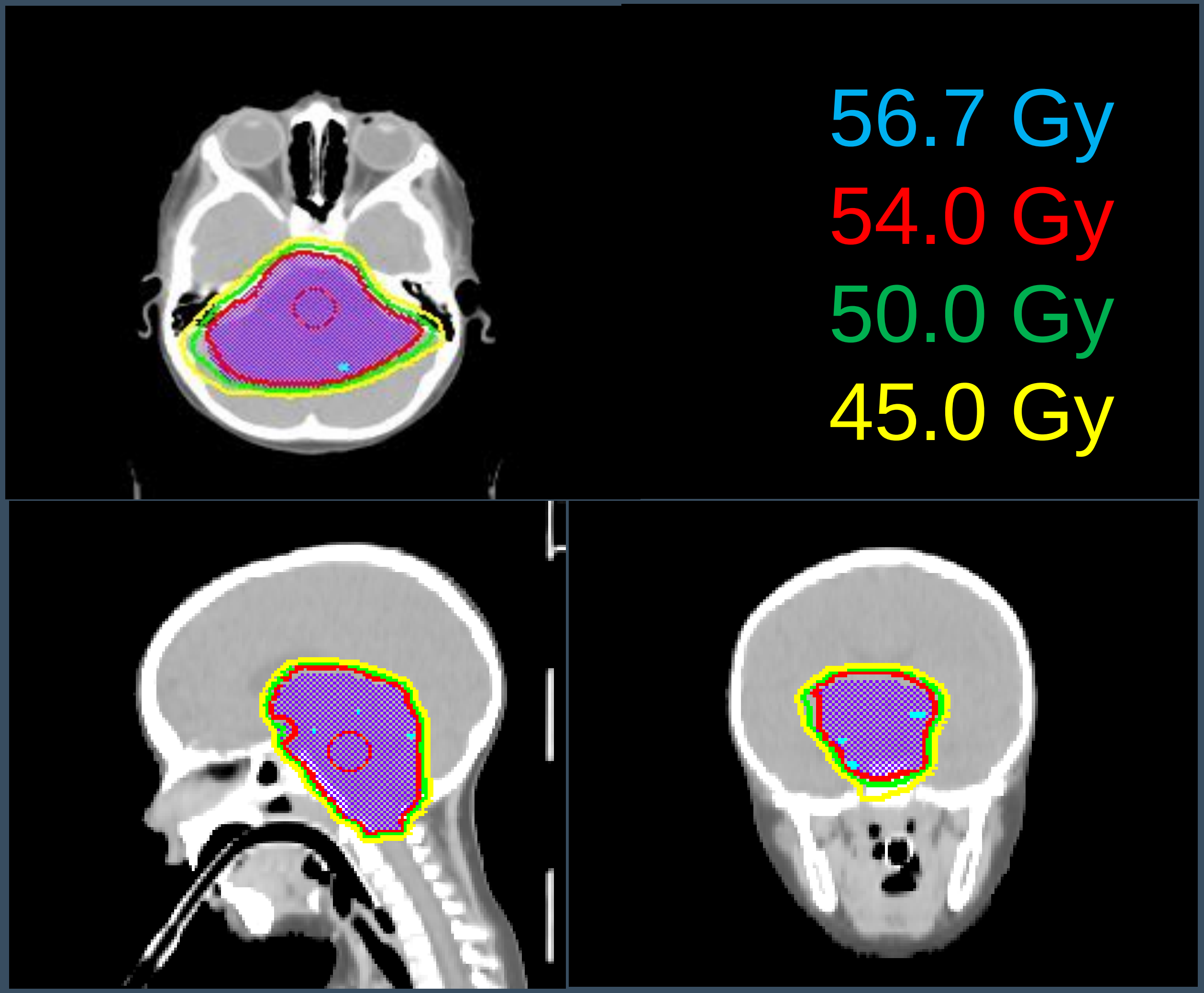
IMPT is not an ultimate solution

- Similar to electron beams, the lateral penumbra of the proton beam is a function of the proton energies and treatment depths.
- Scanned pencil beam has finite spot sizes (1-3.5 cm), which depend on energies and beam line configurations.
- In comparison, the penumbra of photon beams remain approximately constant at all depths.
- Technical challenges in IMPT are much more complex than intensity modulated photon beams

VMAT plans are sufficient for many pediatric patients



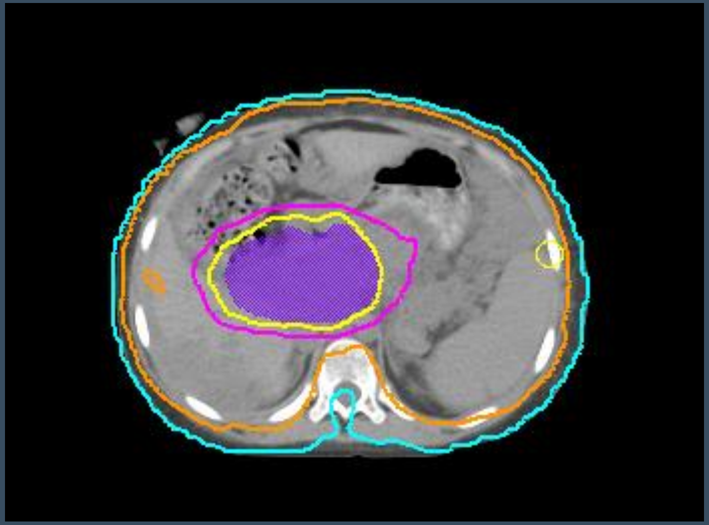
- 3 year old female diagnosed with diffused intrinsic pontine glioma, treated with 54 Gy in 30 fractions

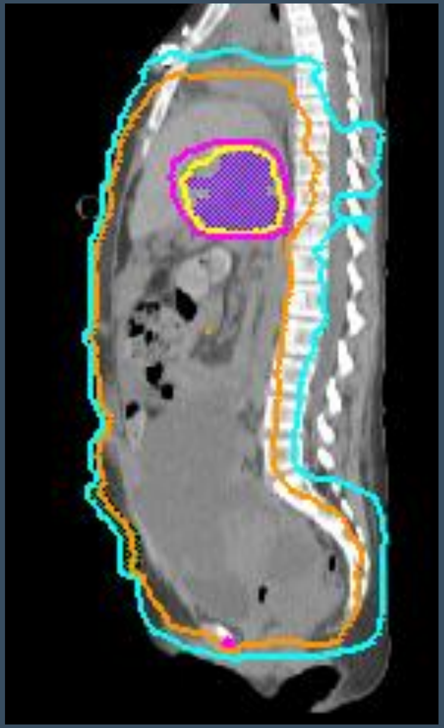
Brainstem Toxicity with Protons

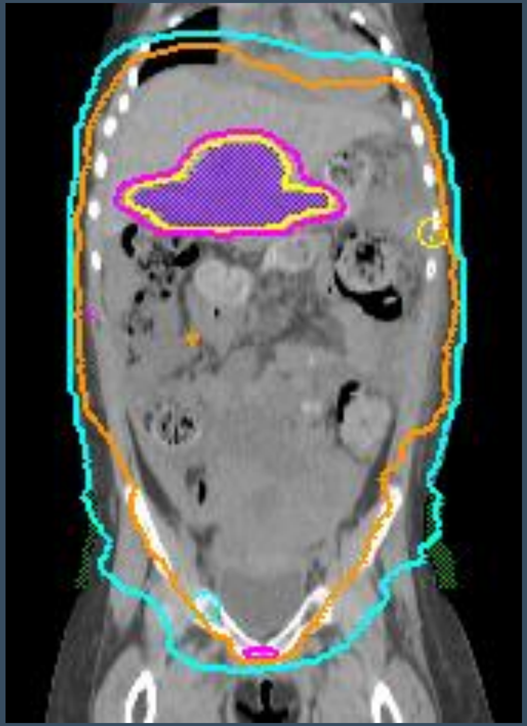
Proton Center	Posterior Fossa Primary Pts N	Brainstem Toxicity N(%)	Toxicity Grade N	Median time mos	Prescribed Dose Gy (RBE)	Brainstem Max Gy (RBE)
MDACC[1]	43	5 (11.6%)	Gr 3 =2 Gr 4 =1 Gr 5 =2	4	*50.4- 59.4	52-62.8
Florida[2]	114	11 (10.7%)	Gr 2 =7 Gr 3 =1 Gr 4 =2 Gr 5 =1	3	NR	>56.6 Gy
MGH[3,4]	111	4 (3.6%)	Gr 2 =1 Gr 3 =3 Gr 4 =1	9	54	55-56.17

[1] Boehling et al, ASTRO 2014, *2 patients treated with 50.4 Gy for ATRT with high-dose chemotherapy
[2] Indelicato et al, Acta Oncol 2014,
[3] MacDonald et al, Neuro Oncol 2013
[4] MacDonald et al, IJROBP, submitted 2015, ASTRO 2014

Slide courtesy of Shannon MacDonald, MD



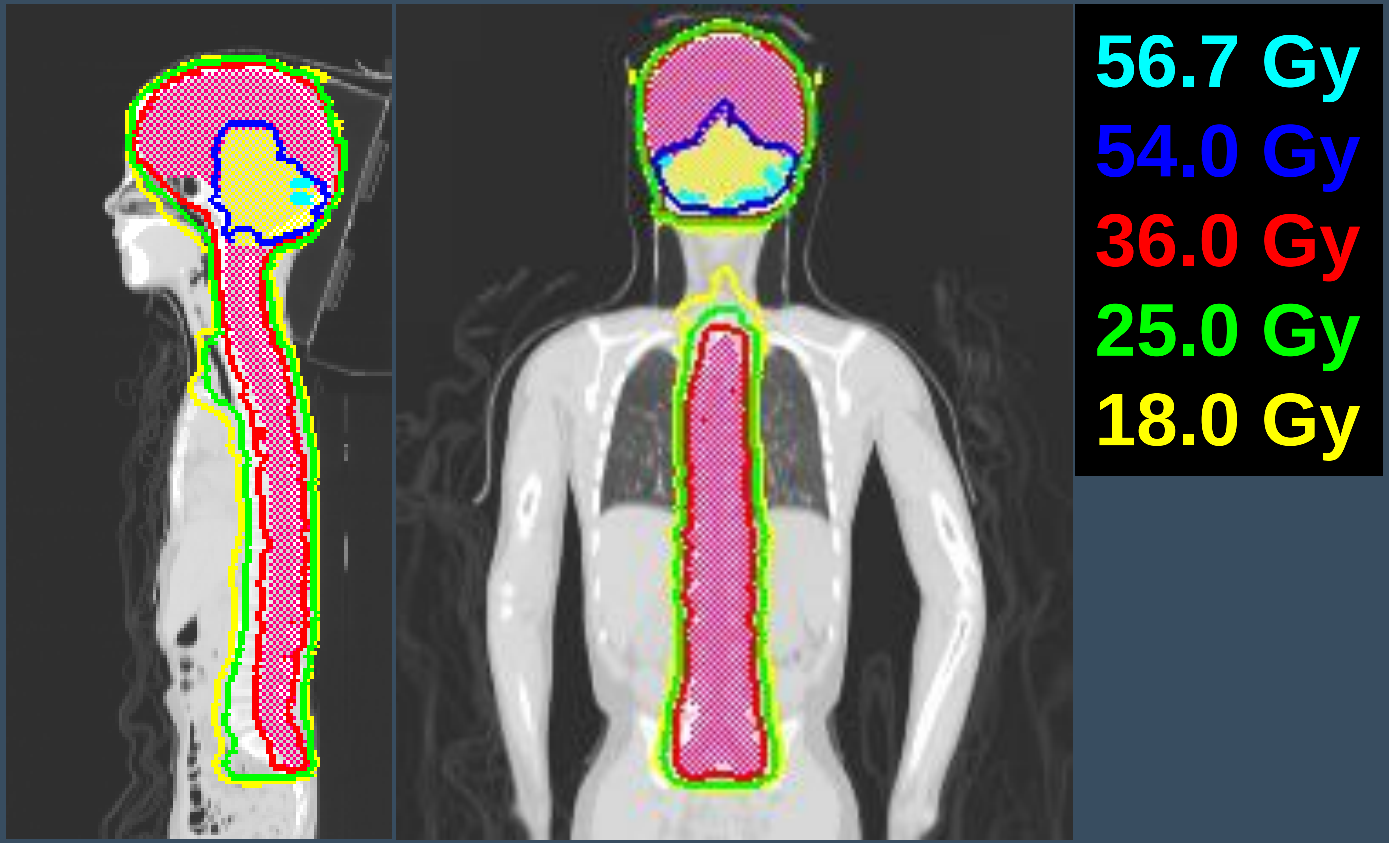




32.0 Gy, 28.8 Gy, 24.0 Gy, 12.0 Gy

10 year old female with rhabdomyosarcom had tri-modality treatment but has metastases in the abdomen, treated with whole abdomen to 32 Gy in 16 fraction to to the HD-PTV and 24 Gy in 12 fractions to the whole abdomen.

VMAT CSI has improved dose conformity and uniformity



Conclusions

- Modern Linacs are available every where, easily accessible by most patients.
- Modern Linacs are versatile with multiple photon and electron energies that can treat small, large, shallow and deep seated tumors, and mobile tumors.
- Without daily adaptive planning, IGRT is more effective for photon treatment than proton treatment.

Acknowledgment

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