



Photons Will Be Dosimetrically Superior

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Has Photon RT Hit the Limit?

VISION 20/20: Planning and delivery of intensity-modulated radiation therapy
Cedric X. Yu, Christopher J. James, and Michelle Svatos
Med. Phys. 35, 5233 (2008);

Based on 10 years of experience with IMRT, we have learned that the opportunities in improving plan quality are limited within the constraint of present linac/MLC delivery. To improve the quality of IMRT treatment plans, we must inject new degrees of freedom. This may require an overhaul of existing technologies.

Future: Inject New Freedom, NOT Protons



Why not Protons?

- Technology
 - More complicated, therefore harder to advance
- Physics
 - Penumbra, Bragg Peak uncertainty
 - Sensitive to anatomical variations
 - Interplay effects with organ motion
- Biology
 - RBE uncertainty

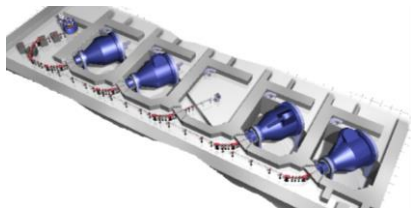


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Proton Treatment Facility



Treatment Control

1. At a given time, only one room can have proton beam
2. All treatments in all rooms are centrally controlled
3. Techniques common with photons are difficult with protons
 - Arcs
 - MRI guidance
 - Motion tracking/gating



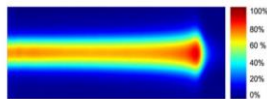
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Lateral Penumbra

The dose penumbra at deeper depth is less steep for Proton beam (6-10mm) than for photon beams

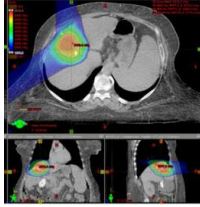


Med Phys. 2013 Apr;40(4):041723

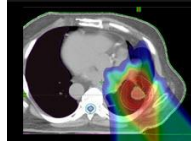


Effects of large penumbra

Protons



S.J. Gandhi et al:
Practical Rad Oncol,
2015 1-10.



Adapted from iba-protontherapy.com

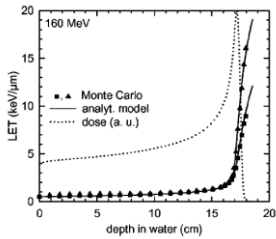


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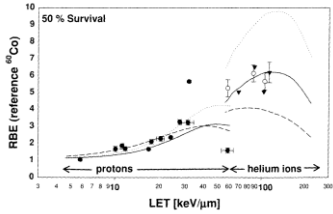
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LET



Published RBE Proximal to SOBP



From H Paganetti PMB 47(5)



Assumption: $RBE_{Co-60}^{Proton} = 1.1$

- For target cell killing – may be true
- For normal structure preservation – may not be true because the goal and biology are different
- In radiation protection, we have been using a quality factor of Q = 20!
- If we use a RBE of 1.5 - 2 for normal tissue dose, the physics advantage of protons v.s. photons will be reversed!



Economic Considerations

“Describe a mechanism to figure out how to pay for proton therapy. Something that will get us out of this mess.”

Anthony Zietman, July 20, 2015



Social/Accessibility Considerations



Uganda's only radiotherapy machine used for treating cancer is broken beyond repair, the country's main cancer unit says. This leaves thousands unable to get potentially life-saving treatment.

Kenyatta National Hospital to resume cancer treatment

One of the best machines that had broken down has been repaired, says acting CEO Elinora Omondi.



Advancing Photon RT Is the Answer!



How to Improve Photon Plan Quality?

Intensity-modulated arc therapy with dynamic multileaf collimation: an alternative to tomotherapy

Chieh X Yu
Wilcox Research Hospital, Royal Oak, MI, USA
Received 9 February 1995; in final form 20 April 1995

"The DVHs or subsequently derived biological scores depend on the total number of strata, which is defined as the product of the number of beams and the intensity levels within each beam. As the number of beams increases, the number of intensity levels required to obtain optimal dose distribution is reduced."

We just need to increase the number of independent fields!



4π RT

International Journal of
Radiation Oncology
Biology • Physics
www.ijroper.org

Physics Contribution

4π Non-Coplanar Liver SBRT: A Novel Delivery Technique

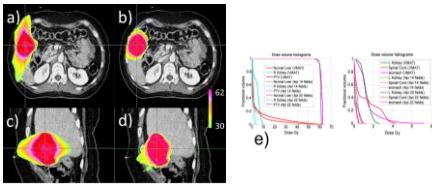
Peng Dong, PhD,* Percy Lee, MD,* Dan Ruan, PhD,* Troy Long, BS, Edwin Romeijn, PhD,†
Yingli Yang, PhD,* Daniel Low, PhD,* Patrick Kupelian, MD,* and Ke Sheng, PhD*

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Received Jan 8, 2012, and in revised form Aug 17, 2012. Accepted for publication Sep 24, 2012



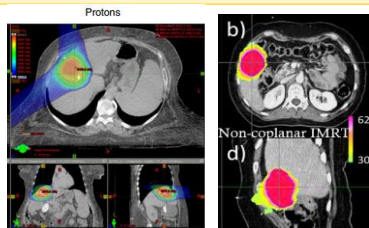
4π RT for Liver Cancer



Peng Dong et al: Int J Rad Oncol Biol Phys. 85(5), 2013



Compared with 4π RT

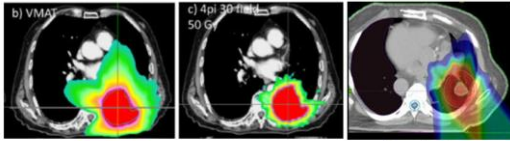


S.J. Gandhi et al: Practical Rad Oncol. 2015 1-10.

Dong P, Int J Radiat Oncol Biol Phys 2013; 85: 3360-6



Compared with 4π RT for Lung Cancer

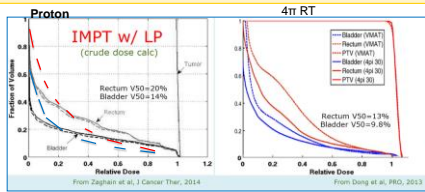


Dong P, et al. Int J Radiat Oncol Biol Phys 2013; 86(3):pp.407-413

www.iba-protontherapy.com



Compared with 4π RT: Prostate Cancer



	$V_{0.1}$	$V_{0.2}$	$V_{0.5}$	$V_{1.0}$	$V_{1.5}$
Rectum	36%	26%	20%	18%	11%
Bladder	20%	15%	14%	12%	9%

	$V_{0.1}$	$V_{0.2}$	$V_{0.5}$	$V_{1.0}$	$V_{1.5}$
Rectum	38%	19%	13%	10%	7%
Bladder	21%	13%	10%	7%	5%



Conclusion

- Constrained by the delivery technology and techniques, photons appear to have hit a limit
- By injecting new degrees of freedom, photons could be dosimetrically superior to protons for most common sites
- Protons are extremely expensive, complicated, and cumbersome, thereby harder to advance
- Protons has many shortcomings, some cannot be changed by technology
- The dosimetric advantages of protons will be short lived, photons will be dosimetrically superior!