FIG. 1. Sagittal CT reconstruction shows perineal proton boost technique and how beam high dose region incorporates prostate, prostatic urethra and bladder neck.
Proton Therapy in the Modern Era

- Better pencil beam scanning delivery
- Better Rx planning…Intensity modulated proton therapy
- Better Image-guidance…On-board volumetric imaging (CBCT)
- PBS + Apertures for sharper penumbra
- Smaller (and less expensive) proton units

Advances in technology have expanded clinical indications

Increased utilization of SBRT/Hypofxn regimens with x-rays will benefit particle therapy

More protons users have resulted in increased advocacy

* Better CT imaging would be cost-effective method to improve proton therapy
The pencil-beam scanning mode of proton beam delivery

Advantages of *modern* pencil beam therapy

- Improved conformality (e.g. concave dose distribution)
- Faster delivery
- Less hardware
- Fewer neutrons
- Intensity-modulation
- Gradient matching for LARGE fields
- Structure & Metal avoidance
- Multiple targets
- FAST Layer- & Volumetric RE-painting
Any randomized trials between IMRT vs. Protons should be done with PBS (IMPT)

<table>
<thead>
<tr>
<th></th>
<th>2 D X-rays</th>
<th>3 D X-rays</th>
<th>IMRT</th>
<th>CONVENTIONAL PROTONS (Passive-scattered)</th>
<th>IMPT Intensity modulated proton therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conformity</td>
<td>+</td>
<td>++</td>
<td>++++</td>
<td>+++1/2</td>
<td>++++</td>
</tr>
<tr>
<td>Normal tissue exposure</td>
<td>+++</td>
<td>+++</td>
<td>++++</td>
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Highly conformal but less tissue exposure
Pencil beam have expanded clinical indications: Breast + lymph nodes w/ pencil-beam proton therapy
Cranio-spinal radiation is a lot of work and typically requires at least 4 fields x 2-3 junctions
Cranio-spinal radiation therapy with gradient matching using IMPT (virtual “dose-feathering”)

Upper spine field
Lower spine field

Region of gradient match on spine
Faster and safer
Protons for stage II seminoma: Para-aortic lymph nodes and ipsilateral pelvic lymph nodes
LARGE field PBS
Example: Consolidative RT Peds HD
Better treatment planning: IMPT for structure avoidance of tissue expander in Breast Ca
On-board CBCT helps with volumetric image guidance
Why do you need CBCT with protons?

**Volumetric targeting**
- Lung tumor
- Liver

**Improve fine 6-degree corrections**
- Brain
- Skull base
- Brain stem

**Image and validate PROXIMAL anatomy in beam path**
- External contour (e.g. breast)
- Image changing anatomy (HN, pleural effusion)
CBCT on FULL PBS gantry

CBCT reconstruction in adaPT Insight
Daily CBCT for targeting
Impact of breathing on radiologic path length
TCPT treatment for MOVING tumors (e.g. lung, liver)

4D CT for treatment planning

Abdominal compression to minimize respiratory motion

Volumetric on-board imaging with cone-beam CT (CBCT)

+- Fiducials for liver

“Robust” treatment planning on different phases of respiratory cycle

FAST re-painting (layer, volumetric)

Breath-hold in select cases
Respiratory gating for 4D CT acquisition and gated treatment

Free-breathing 4D-CT
Layer and Volumetric repainting

Tumor divided in layers
Each layer, dose delivered in spots & scans over target

Proton beam scanner setting

layer

spot

target
50GyE in 4 fx with layer (x15) and volumetric repainting
Proton planning with “4D robustness” to improve tumor coverage in all respiratory phases
>99% CTV coverage in different respiratory phases
Gated proton beam during exhale…but actually may prefer beam-on during inhale for lung Ca

UBTI offers opportunity to gate beam or use breath-hold techniques

Lei Dong, PhD
Liver Rx (4.5 CGE x 15 fx) using breath-hold PBS delivery

Requires **fast** PBS delivery

Jared Sturgeon, MD, PhD
Multiple brain lesions treated in 3-5 fractions (Why even consider this...Following photon example)
SBRT and Hypo-fractionation

As clinical indications* for this type of Rx increases with x-rays, proton therapy’s role should also increase

*Brain, Lung, Liver, Prostate, Oligo-metastatic (better systemic Rx)

When delivering relatively few fractions, the cost differential may be negligible compared to SBRT with x-rays

Spare normal tissue

Leaves more room for subsequent treatments
Lymphopenia Association With Gross Tumor Volume and Lung V5 and Its Effects on Non-Small Cell Lung Cancer Patient Outcomes

Chad Tang, MD, MS,* Zhongxing Liao, MD, * Daniel Gomez, MD,* Lawrence Levy, MS,* Yan Zhuang, MD,* Rediet A. Gebremichael, BS,* David S. Hong, MD,† Ritsuko Komaki, MD,* and James W. Welsh, MD*

![Graph showing the association between lymphocyte count and date from RT start.](#)
TCPT NEW STARTS

695 New Starts
As of August 2017

Brain / CNS / Base of Skull 25%

Head & Neck 16%

Lung 12%

Breast 4%

Gastrointestinal 11%

Lymphomas 5%

Prostate 22%

Sarcoma 3%

Gynecological 2%

17% PEDIATRIC

17% RE-IRRADIATION
Modern proton therapy combines advances in Beam delivery, Image-guidance and Treatment Planning to **OPTIMIZE** treatments & **EXPAND** clinical utility.

- **Pencil beam delivery**
  - Conformality, Avoidance, Faster, RE-painting

- **Image guidance**
  - 2D-3D, Volumetric

- **Treatment planning**
  - IMPT, Gradient-matching, Robust planning, APERTURES

- **Compensation for respiratory motion**
  - Gating, Breath hold
Team effort

Therapy Staff
Clinical Staff
Financial Office
Administrative

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