Defining The Future of Radiation Oncology

*Latest Updates on Proton Arc Therapy*

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Beaumont
Disclosure

• The SPArc research project was supported by:
  – Ion Beam Application S.A.
  – Beaumont Herb and Betty Fisher Research Seed Grant Award

• A patent related to the Proton Arc Therapy
Proton Beam Technology

• Passive double scatter
  – Modulation/Spread Out Bragg Peak (SOBP)
  – Brass aperture
  – Lucite Compensator
  – Patching planning technique very demanding

• Pencil Beam Scanning-IMPT
  – No spinning modulator, brass aperture, or lucite compensator are needed.
Proton Arc Therapy Concept

- IMPT-PBS provides superior radiotherapy however
  - Robustness and dosimetric quality rely on # of fields and beam angles
  - Using higher number of fields is limited by planning and delivery technique and machine efficiency

- To improve the quality of proton beam therapy, the concept of arc delivery remains of interest
RT in the Era of Precision Medicine
Define Proton Arc Range (start/stop angle)

Proton arc coarse sampling using static beams

Robust optimization

Random control point re-sampling, energy layer re-distribution and filtration mechanism:

1) Control point re-sampling
2) Energy layer re-distribution
3) Energy Layer Filtration
4) Energy layer re-sampling

SPArc

Figure a: Coarse Control point sampling
Figure b: Split control point. Beam 1 → Beam 1a & 1b
Figure c: Proton Arc sampling frequency
Beam delivery time

5 years ago

Synchrotron Limitations

New generation of energy selection system or multi-energy layers extraction technique from synchrotron

Total Delivery time (s)

Energy Layer Switching Time (s)
Proton Arc Therapy

• The potential to provide superior treatment to cancer patients
  – Better Conformality
    • Dose Escalation
    • Better normal tissue sparing
  – Better Treatment Robustness
  – Better Tumor Motion Management
    • Decreasing interplay effect
  – Better Delivery and Workflow Efficiency
    • Shorter treatment time
    • Improved patient satisfaction
    • Increasing the efficiency of treatment room
  – Better Control of LET/RBE Distribution
Proton Arc Therapy in CNS
Whole Brain Radiotherapy with Hippocampal and cochlea sparing

<table>
<thead>
<tr>
<th></th>
<th>VMAT</th>
<th>ro-IMPT</th>
<th>SPArc</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean Dose</strong></td>
<td>10.89Gy</td>
<td>9.38Gy</td>
<td>6.2 Gy</td>
</tr>
<tr>
<td><strong>D100%</strong></td>
<td>9.16Gy</td>
<td>7.02Gy</td>
<td>4.5Gy</td>
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<tr>
<td><strong>Maximum Dose</strong></td>
<td>13.84Gy</td>
<td>14.55Gy</td>
<td>11.14Gy</td>
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Ding, Li, Kabolizadeh et al. 2018, Acta Oncol
RT in the Era of Precision Medicine
Spot-scanning proton arc (SPArc) therapy: extreme dose escalation in glioblastoma
SPArc: A Tool That Allows for Dose Escalation

clival chordoma

IMPT

Proton Arc

VMAT

IMRT

Beaumont
Proton Arc Therapy in Head and Neck Cancer
HNC: Dosimetric comparison

The spot-scanning proton arc therapy was able to provide equivalent or better robust target coverage while demonstrating significant dosimetric improvements over RO-IMPT in most of OARs sparing.
Proton Arc Therapy in Breast Cancer
Proton Arc Therapy in GU
SPArc could complete the treatment delivery through only one arc, and therefore, it would potentially save the patient’s time on the treatment table for the beam waiting time for each fraction in a multi-room center when compared to ro-IMPT.

SPArc in Anal Cancer
Proton Arc Therapy in Lung Cancer
IMRT

VMAT

Proton Arc

IMRT
Interplay effects for proton therapy

- The motion of the beam could interfere with the motion of target
- May result in distortion of the planned dose distribution, target over- and under-dosage
- One of the major concerns for treating lung cancer with scanning beam proton
Single-fraction 4D dynamic dose

SPArC
Patient 6, ITV volume of 402cc, S-I motion of 1.2 cm

IMPT

Li et al. Rad Onc 2018, AAPM 2017
Both SPArc and RO-IMPT plans achieved similar robust target volume coverage for all patients, while SPArc significantly reduced the doses to critical structures as well as decreasing the interplay effect.
Road to Clinical Testing
Prototype Proton Arc Delivery

Deliver sequence optimization

On August 29th 2018, 2:30am
World First Proton Arc Delivery

Proton arc therapy proof of concept in collaboration with Beaumont Health Proton Therapy Center in Royal Oak, Michigan. Plan delivered in August 2018.

Simulation

Target volume: 123 cc
Target diameter: 9.5 cm
Target thickness: 3 cm

Target dose: 6 Gy
Number of spots: 2624
Number of energy layers: 58

Delivery time: 4m27'
Minimum energy: 100 MeV
Maximum energy: 166 MeV

Irradiation on a Gafchromic film
SPArc, delivered in 4 mins
IMPT, 3 beams, one non co-planar beams, 11 mins
The iso-dose lines comparison for measured (solid) and calculated (dashed) doses.

Gamma index map
The gamma index map using 3% and 3mm criteria between measured and calculated doses.
The gantry speed (blue line) and the cumulative MUs (orange) delivered relative to the gantry angle, where stars stand for the angle where energy switches from low to high.

The DVHs comparisons from the log file for reconstructed (solid) vs planned (dashed) doses.
Technical and clinical Challenges

- Quality Assurance technique and device
- Hardware and system control software improvement to further increase efficiency of delivery
- Low dose bath
Potential sites with most benefits

- Targets abut critical OARs such as in head and neck and base of skull malignancies
- Targets that need dose escalation
- Non-mobile and mobile targets
- Targets that need high conformality
  - arc reduces the range uncertainty and ultimately improves the target conformality
- Better Delivery efficiency and simplified proton clinical work flow
- Better control of LET distribution
Future of SPArc

- All QA data is being processed
- Phase I/II clinical trial is being written undergoing IRB evaluation
- Further improvement of hardware and software basis for SPArc
- Further improvement of QA procedures and devices
- Development of advisory committee by IBA to define the role of SPArc in clinical practice
- Potential role in LET/RBE optimization
Proton Therapy Center

Physicians:
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IBA:
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