Clinical commissioning and operation of IBA Proteus®ONE: the Royal Oak's experience

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Conflict of Interests

• IBA sponsorship
Beaumont Health - Cancer Centers

• Royal Oak (Main campus + Proton)
  • Research and Developments (CBCT, ABC & IMAT)
• Troy
• Dearborn
• ......
Life in Michigan

The images depict various activities and landscapes found in Michigan, including kayaking, autumn foliage, and winter sports.
Proton Therapy Centers in U.S.A.

26th in Clinical operation; 11 or more under construction/planning
ProteusONE treatment room

- 220 degree Compact Gantry - 75 tons
- New Superconducting Synchrocyclotron
- Phillips Ambience light system
- Stereotactic imaging system and CBCT
- Rolling floor
- Pencil Beam Scanning
- 6 degree robotic couch
Timeline – Beaumont ProteusONE

- Board of Directors Approval: Mar. 2014
- Contract Signed: Nov. 2014
- Groundbreaking: Feb. 2015
- Cyclotron Arrival: May 2016
- Start PBS Calibration: Feb. 2017
- Acceptance and Commission: May 2017
- First Patient treated: Jun. 28th 2017

* Beaumont proton physics and IBA teams brought up the system online safely in 7 weeks (acceptance & commission as well as staff training) in record time.
Preparation

• Review the proton equipment contract (acceptance and service document)
  – Minimum energy range 70MeV or 100MeV (range shifter 4.1cm/7cm)
  – Review of the raw data of beam optics (important to multi-room)
  – Review the radiation measurement device package

• Radiation safety policy and procedure
  – Shielding survey and evaluation
  – State equipment registration

• Build the core physicist & dosimetrist team and design the detailed commission schedule
  – 3-4 good proton physicists (TPS modeling, treatment protocol, QA)
    • Dallas, Beaumont, Scripps, Cincinnati .etc.
  – 2-4 good proton dosimetrists
Instruments and Devices

- **Machine Installation, Calibration, and Commissioning**
  - Pristine Bragg Peak Scans: Large Parallel Plate Chamber
  - Spot characteristics&position: LynX
  - Spot vs Gantry iso: XRV-100
  - Absolute Dosimetry: PPC05 / Markus chamber
  - Range validation: Zebra
  - 2D Dose distribution: 2D detector array (Matrixx PT/MatrixxONE)

- **Daily QA / System QA**
  - Consistency checks: MatrixxPT/ONE (Sphinx)

- **Patient QA**
  - Pre-treatment dose verification: 2D detector array (Matrixx PT/ONE)
PBS Commission Lists

- Radiation safety policy and survey
- Treatment room neutron dose survey
- CT density table to proton stopping power
- Patient Position System verification
- Dose rate and linearity check
- Beam data library
- Gantry iso-centric check
- IGRT system commissioning
- TPS commissioning w/wo range shifter
- End to end test
- Patient plan/Machine QA protocol
- MD Anderson IROC TLD measurements
<table>
<thead>
<tr>
<th>Assignment</th>
<th>Priority</th>
<th>Personal</th>
<th>Started on</th>
<th>Due on</th>
<th>Progress</th>
<th>Percent</th>
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Beaumont Commission Timeline

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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<td>Beam Optics Acceptance</td>
<td>Beam Data Acquisition (Double shifts)</td>
<td>Imaging Acceptance</td>
<td>Safety Acceptance</td>
<td>Patient position system</td>
<td>Beam Modeling</td>
<td>Beam Model Validation</td>
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Ding et al. NA-PTCOG 2017 Ahead of Schedule
Collaborate and Synchronize the team schedule

- Combine the beam data acquisition procedure with acceptance test (IBA & Beaumont)
  - Lock beam optics settings
- Beam modeling and validations (Beaumont & RaySearch America & Sweden)
  - Dry run with current data format
  - Communicate with the RaySearch team
- Mosiaq integration and on-site therapist training
  - Address the bugs and workflow issues
- Independent Physics Check/IROC TLD check
  - Dr. Gao from Chicago Proton Center
  - IROC team (Beaumont commission and treatment schedule)
IMRT vs PBS

• MLC
  – Position accuracy
  – Leaf design
  – Leaf resolution
  – Speed limitation
  – Leaf leakage
  – Penumbra

• Spot & Energy
  – Position accuracy
  – Spot size (in air sigma)
  – Spot symmetry
  – Energy range accuracy
  – Energy layer switch time
Spot Size vs Energy and Gantry angles

Spot size (in air at iso) vs Energies at different gantry angles

Beaumont HEALTH
Gantry Rotation

- Gantry Sagging
  - Correct couch position (ProteusPLUS)
  - Steering the beam using magnet (ProteusONE)

X-Ray tube in Gantry
Beam-Eye-View

No X-Ray tube in Gantry
No Beam-Eye-View
XRV-100 Absolute Spot Position Calibration

- Conical scintillator-based detector
- Originally designed for CyberKnife QA

Ding et al. (AAPM 2015)

- A Quantitative analysis tool for Gantry Star Shot QA
- A good complement to the film QA system
- Potential QA tool for Proton SRS/SBRT

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<th>Energy</th>
<th>70MeV</th>
<th>160MeV</th>
<th>226MeV</th>
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<tr>
<td>Average Discrepancy (mm)</td>
<td>0.41835</td>
<td>0.4339</td>
<td>0.46188</td>
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<tr>
<td>Standard Deviation (mm)</td>
<td>0.11194</td>
<td>0.1834</td>
<td>0.28807</td>
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Beam model data acquisition

- 70MeV – 227.7MeV Energy Integrated Depth Dose
  - 33 measurements
- Absolute dose calibration
  - 33 measurements
- Spot size and position at iso, Z-/+10cm and Z-/+20cm (SAD)
  - 165 measurements
- Range Shifter 4.1cm WET at different air gap (for validation)
  - 40 measurements
- Total : 271 measurements
Goal of the commission

- Identify any weakness in the machine, software and clinical workflow
  - Treatment Planning System
    - Dose calculation model (PBC or MC)
    - Robust optimization algorithm
    - Planning & QA workflow
  - OIS (Mosiaq/ARIA)
    - Care path/Clinical workflow

None of the proton system is the same!
- Hitachi
- Sumitomo
- IBA
- IBA ProtuesONE
- Three IBA ProtuesONE are all different!
- VARIAN
- (Shreveport, Royal Oak, Nice)
- PROTom
- ProNova
- ... 

It is very important to understand the machine design and its limitations.
RayStation 6.0 TPS validation

- uniform dose phantom plan simulating common disease sites.
  - Distal ranges from 10-26 cm
  - Modulation from 2-10 cm
  - Field size from 4-20 cm
  - Spot spacing from 4-8 mm
  - MU from 340 – 4530
  - Prostate, Brain, Chestwall, CSI etc.
Depth Dose Profile

- Zebra/MLIC Measurements

Raystation plan vs measurements
Range Shifter Commission

- Energy Layer Range
  - 100-226.7MeV (7 - 32 g/cm²)
  - 70 – 226.7MeV (4 – 32g/cm²)

- Spot Size

- Beam Model Limitations

Two Golden Rules for RS PBS plan:

1. Minimize the Air Gap between patient surface and range shifter
2. Avoid potential collisions especially at shoulder and neck region!

Both et al Redjournal (2014)
Range Shifter Spot size vs Air Gap

- RS1 Water Equivalent Thickness (WET) = 7.37 g/cm^2 (100MeV)
- RS2 WET = 4.1 g/cm^2 (70MeV)
Range Shifter model limitations

- Due to the limitation of the secondary proton scatter model, surface dose calculation is not accurate.
- Raystation Solution: Monte Carlo algorithm in version 6

Ding.et al AAPM 2015
Build QA procedures

- 3%/3mm Gamma Index >95%
- Output in the midSOBP <3%

Brain Case (Range Shifter WET 4.1cm)

Prostate case
Challenges and Issues

• Pinnacle -> Raystation-> Mosiaq 2.64 -> IBA Adaptdelivery and AdaptInsight

  – QA field gantry overriding issue (solved in Physics mode)
  – MU rounding between Mosiaq and IBA AdaptDelivery
  – Stop and resume treatment delivery

......

Software BUG and Communication Issue between the platforms.
Stop and Resume Treatment

Example: Resume with 1833.8MU from DCEU but continue with OIS instead of Machine log file.

“Blind golfer algorithm” in S2C2 delivery is not implemented in Mosiaq
Proton Machine stability

- Beaumont ProteusONE

Period:
From: 2017-05-08 to: 2017-08-31

Time granularity

System availability analysis

1st treatment

CBCT Acceptance

Cyclotron quenched
ProteusONE Machine Downtime

• First 4 months
IBA Proton Society

• Credit to IBA
Proton Clinic Workflow

- Patient CT and MRI
  - INITIAL Evaluation
    - Proton Physicist
    - Physician
  - Target and OAR Contours
    - Physician
  - Proton Planning
    - Planning Physicist
- Photon Backup Plan
  - Dosimetrist
- Treatment
- Chart Check, Billing and QA
  - Planning Physicist
  - Proton Physicist
- Final Evaluation
  - Planning Physicist
  - Proton Physicist
  - Physician
Optimize the proton clinic workflow

- patient care tracking system

Credit to David Gersten
Optimize the proton clinic workflow

- Electronic chart check
Usage of proton beam (Radiation Safety)
Robustness
Build a robust and nice plan

- Weight changes
- Shoulder angle uncertainties
When and how to initiate the plan adaptive?

• Loss/Gain weight ~ 10lbs (H&N, Abdomen)
• Tumor shrinkage (Lung, H&N, Brain)
• Re-CT causes huge burden in a busy clinic
• Develop an efficient and effective tool to initiate the re-plan
Proton WET projection image

CT/CBCT images

Proton WET projection

Liu et al. AAPM 2016
Summary - Proton Project at Beaumont

- Machine Stability: 4.8
- Clinical Operation and Workflow: 4.8
- Imaging and Patient Position system: 2
- IBA engineer team support: 5
- Beam Delivery System and Software: 4.5
Proton Therapy in the next 5 - 10 years
Acknowledgements

Physicians
Craig Stevens, MD., Ph.D, Chairman
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Hospital Administration:
John Fox
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Xiaoqiang Li, Ph.D
Michelle Zhang, Ph.D,
Cheryl Schultz, RSO
Lisa Benedetti, M.S.

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Tony Frankenfield

Proton Therapists:
Faith Harrington
Alyssa D’ Angelo
Jennifer Martin