Towards a SMART proton PBS clinic

Stefan Both, PhD, FAAPM
Professor & Head of Medical Physics
Disclosures

- Department Research Agreements
  - RaySearch
  - IBA
  - Mirada
Groningen Proton Therapy Center

- Commissioning started in 20.10.2017
- First patient treated in 22.01.2018
Vision: A SMART Proton PBS Clinic

- **S**eamless: Patient centered technology for dynamic care
- **M**odel-based: Patient specific biomarkers for selection
- **A**utomated: Patient Treatment Planning, Delivery & QA
- **R**adiation: Superior Physics of the Patient Treatment Beam
- **T**herapy: Biologically guided personalized Patient Treatment
Vision: A SMART Proton PBS Clinic

- The Example of a SMART HN Clinic
- Much work underway..

Clinical operation (2018)  SMART (2023)
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Groningen Proton Therapy Center
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AlignRT (VisionRT)

KV imaging

6D couch (Leoni)
Commissioning of a PBS facility

Calender time ~3 months

- BDL acquisition
- Range shifters
- OIS implementation
- CT Calibration
- Modelling
- Validation
- End-end
- Mechanics
- Imaging
- Tabletop
Integral dose depth (Stingray)

\[ \Phi = 12 \text{ cm} \]
Spot profiles (Lynx)

0.5 mm resolution
30 x 30 cm²
Dosimetrically equivalent rooms

- Benefit: Flexibility in room usage / Shorter commissioning
  - Median spot size $\sigma$ within 0.2 mm
  - Bragg peaks positions and widths within 0.2 mm
  - Output variation within 0.5%

A. Meijers
Robotic couch commissioning

- Deviation < 0.8 mm, mean 0.4 mm
- Tested for:
  - 100 and 60 kg load
  - Different couch angles 30° apart

A. Meijers / J. Free
Oncology Information System

- Resume of partial PBS treatments is not properly supported.
- Lack of seamless workflow for adaptive plans.
- Multi-isocenters workflow has some high risk aspects.
- Unable to solve these problems in our current OIS
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Model-based: NTCP model

Example: Tube feeding dependence at 6 months
Model-based: Selection procedure

Patient referral

Photon planning

Selection TOOL

RT

No difference

IMRT

Plannings-CT
Contours
Dose distribution photons

Report indicative
plan comparison

Proton planning

Difference

IMPT

Proton center

J.A. Langendijk
Model-based: Selection tool

Photons

Protons

PCM superior 23.8 → 1.3 Gy
Oral cavity 36.2 → 17.1 Gy
Model-based: NTCP model

Example: Tube feeding dependence at 6 months

- **T-stage:** T4
- **Weight loss:** NO
- **Modality:** Accelerated RT
- **Total ΔNTCP:** 17.9%
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Atlas contouring

Deep learning contouring improved for:
- Parotid glands
- Suproglottic
- Submandibular glands
- PCM
- Thyroid
- Esophagus
- Glottic area
- Crico
- Carotids

C.L. Brouwer
Automated planning comparison

- PBS plan required for each patient considered for referral given a photon plan

Start


This dose mimicking algorithm is an extension to the work by Fredriksson 2012
Beam Angle Optimization

- Robust pareto-optimal beam angle optimization
Automated planning comparison

- Automated patient selection
- Using dose mimicking
- Adding NTCP & LET work in progress

Poster: PV-0201: R.G.J. Kierkels / E.W. Korevaar
Robustness evaluation method
Multi-scenario error simulation

Setup variation, anatomical changes...

Patient description

Dose calculation

Treatment evaluation

Treatment evaluation?!

E.W. Korevaar
Robustness evaluation scenarios

• Systematic error plus day-to-day variation
  – Van Herk’s recipe: \( M_{90\%} = 2.5\Sigma + 0.7\sigma \) → dose blurring

  Systematic day-to-day

  – Shift magnitude: CTV-PTV margin size

• Limited directions: \( 6 + 8 = 14 \)

• Range error (protons)
  – Up & down density (HU) scaling
  – Occurs for each shift
  – Magnitude: e.g. 3% (chosen by institute)

• Total nr. scenarios
  – Photons: 14 (setup)
  – Protons: \( 14 \times 2 = 28 \) (setup & range)
PTV nominal-dose  CTV voxel-min-dose

No dose invariance!

E.W. Korevaar
Treatment monitoring

• Daily
  – Logfiles
  – Motion information (AlignRT, ABC, RPM)
  – Anatomical information (CBCT)

• Verification CT
CBCT vs. CT surveillance: quality?

Pre-treatment CT

CBCT
Automated dose accumulation (2)

- All information available to calculate the daily dose including intrafraction motion
- Triggers for plan adaptation can be objectively defined
- NTCP, LET - work in progress
Automated plan adaptation (LET)

- RBE is known to increase in high LET area’s
- Automating LET map generation and plan adaptation triggers

Single beam LET\(_d\) calculation

D. Wagenaar
Automated: Patient QA automation

- Independent Monte Carlo dose calculation with MCsquare
- Development of an automated process with a web interface for result viewing

A. Meijers / A.C. Knopf
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Radiation: Superior Physics

- PBS: Lowest Integral dose (2 to 3 times vs XRT).

- PBS 3D HIGH DOSE Conformality (1-4Fs) ~ IMXT (4-9Fs).

- PBS can treat larger fields, large depths comparable with XRT.

- PBS reduces scattered dose than IMRT
Vision: A SMART Proton PBS Clinic

- Seamless: Patient centered technology for dynamic care
- Model-based: Patient specific biomarkers for selection
- Automated: Patient Treatment Planning, Delivery & QA
- Radiation: Superior Physics of the Patient Treatment Beam
- Therapy: Biologically guided personalized Patient Treatment
Stem Cell Sparing RT

IMRT

Dept of Radiation Oncology, UMCG
Pre-treatment imaging

- Including PET imaging also for NTCP

A: Low SUV, high xerostomia risk
B: high SUV, low xerostomia risk

N.S. Sijtsema / L.V. van Dijk
Conclusions of a SMART Proton Clinic

• **S**eamless: the right choice and integration of technology
• **M**odel-based: high quality big data and iterative process
• **A**utomated: site specific and technology driven
• **R**adiation: protons are the present and future
• **T**herapy: biology and protons maximize the therapeutic window
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• Jeffrey Free
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High precision, Innovation and Healthy Ageing of Cancer Patients