One year of experience and the transition to proton therapy in the UK

John Pettingell
Chief Physicist & Head of Radiotherapy
# Rutherford Cancer Centres

Rutherford Cancer Centres is owned by **Proton Partners International**

<table>
<thead>
<tr>
<th>Location</th>
<th>Centre open (linac, CT, MR, chemo)</th>
<th>Proton go-live</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newport</td>
<td>March 2017</td>
<td>April 2018</td>
</tr>
<tr>
<td>Newcastle</td>
<td>Aug 2018</td>
<td>Q2 2019</td>
</tr>
<tr>
<td>Reading</td>
<td>Oct 2018</td>
<td>Q3 2019</td>
</tr>
<tr>
<td>Liverpool</td>
<td>2020</td>
<td>2021</td>
</tr>
</tbody>
</table>

**Plus** more centres in UK
Our Centres

IBA Proteus One
- proton pencil beam scanning
- cone-beam CT
- oblique Xray
- 6D robotic table

Elekta Versa HD Linac
- VMAT, FFF
- cone-beam CT
- 6D ‘Hexapod’ table

Philips Big-Bore CT

Philips MR-RT

Elekta Mosaiq

Centralised

Philips Pinnacle
Our Network

**London Datacentre**
- Elekta **Mosaiq** Server(s) (backup systems)
- Philips **Pinnacle** Server(s) (backup / archive)
- EMR, imaging (secure data)
- Contouring, planning
- IBA QA database etc.

**Newport**
- IBA Proteus One PBT
- Elekta Versa HD
- Philips Big-Bore CT
- Philips MRI
- Chemotherapy

**Northumberland**
- IBA Proteus One PBT
- Elekta Versa HD
- Philips Big-Bore CT
- Philips MRI
- Chemotherapy

**Reading**
- IBA Proteus One PBT
- Elekta Versa HD
- Philips Big-Bore CT
- Philips MRI
- Chemotherapy

**Other UK centres**
- Liverpool,
- Derby,
- London,
- Dublin?

**Overseas centres**
- Abu Dhabi
- Dublin?

**Oncologist**
- PC, Mac
- iPad

**Physicist**
- Dosimetrist

**Dosimetrist**

**1Gbps leased line**

**100Mbps backbone**

**Overseas centres**
- Abu Dhabi
- Dublin?

**Newport**

**Northumberland**

**Reading**

**London Datacentre**

**www**
- Remote access to:
  - Pinnacle TPS
  - Mosaiq EMR

**www**
- One way link for training and support
Proteus®ONE: IBA’s single room proton therapy solution

- Synchrocyclotron with superconducting coil: “S2C2”
- 230MeV pulsed proton beam, high dose per pulse

- 220° gantry
- proton pencil beam scanning
- 20x24cm field size

- cone-beam CT & oblique Xray
- ‘open feel’ treatment room
- Philips ambient experience

Tried and tested radiation shielding vault design

Engineer support in Control Room with treatment staff
Our Timeline

2015  Feb  Proton Partners International began – raise funding, recruit team
2016  Apr  begin building in Newport
2017  Mar  open Newport centre, regulator approval to commence radiotherapy treatment
2017  Apr/May proton gantry/cyclotron delivered to Newport
2018  Feb  commence acceptance tests and clinical commissioning
2018  Mar  regulator approval to commence proton therapy treatment (including paediatrics)
2018  Apr 10th first proton therapy treatment (self-pay prostate)
2018  Jun  Newport proton commissioning completed for complex cases
2018  Aug/Oct open centres in Northumberland/Reading commencing with radiotherapy treatment
2019  Jan 7th first NHS Wales referral to RCC for proton therapy (craniopharyngioma)
2019  Sep  we will have three UK centres treating with proton therapy
Our Timeline

4 April 2017
https://www.youtube.com/watch?v=Xlak-lggej4

20 May 2017
https://youtu.be/jX6tlNd0AIU
## Acceptance & Commissioning – 9 weeks (simple cases)

<table>
<thead>
<tr>
<th>Machine time (double shifts, RCC, IBA, NPL physicists)</th>
<th>Additional (Philips, RCC physicists)</th>
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</thead>
<tbody>
<tr>
<td>Beam Acceptance Tests &amp; beam data for Treatment Planning System</td>
<td></td>
</tr>
<tr>
<td>Safety Acceptance Tests</td>
<td>Beam data modelling in TPS (no range-shifter), initial beam model used to create verification fields</td>
</tr>
<tr>
<td>Imaging Acceptance Tests &amp; clinical setup of CBCT</td>
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<tr>
<td>Calibrate QA devices</td>
<td></td>
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<tr>
<td>Verification fields delivered/measured</td>
<td></td>
</tr>
<tr>
<td>Absolute dose (TRS398) measurements (energy layers) for TPS</td>
<td>Refine beam data model in TPS</td>
</tr>
<tr>
<td>Measure WEP for immobilisation devices etc.</td>
<td>Recalculate verification fields and compare to measurements</td>
</tr>
<tr>
<td>Setup daily QA, patient QA</td>
<td></td>
</tr>
<tr>
<td>Absolute dose (TRS398) in dose cubes created in TPS using PPC05 &amp; Roos chambers</td>
<td>Range-shifter beam data modelling on TPS</td>
</tr>
<tr>
<td><strong>External dose audit (Essen)</strong></td>
<td></td>
</tr>
<tr>
<td>Clinical Applications training, workflows, end-to-end testing</td>
<td></td>
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<tr>
<td>First treatment (small volume, no range-shifter)</td>
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</tbody>
</table>
Commissioning measurements for Pinnacle TPS

Integral depth dose curves (Bragg peaks) (~65 curves)
- measured every 5 MeV from 70MeV to 230MeV
- with and without range-shifter

Measured with IBA Stingray chamber (12.5cm diameter)
Commissioning measurements for TPS

Pinnacle fit of 160MeV Bragg Peak
Commissioning measurements for Pinnacle TPS

- **In air fluence**
  - measured with *Lynx* scintillator (~160 measurements, 2,880 profiles)
  - x & y profiles of central spots, measured every 5 MeV from 70MeV to 230MeV at
  - +20, +10, 0, -10, -20cm from isocentre

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226 MeV  
100 MeV  
70 MeV
Commissioning measurements for Pinnacle TPS

- In air fluence
  - x & y profiles of central spots, measured every 5 MeV from 70MeV to 230MeV at +20, +10, 0, -10, -20cm
Calibrate the ‘Zoo’ (QA devices)

Zebra

- For fastest commissioning and fastest daily consistency checks
- Unique multi-layer ionization chamber design:
  - Instant uniform scanning of entire Percentage Depth Dose
  - High spatial resolution: 180 independent plane parallel chambers
  - Water equivalent material for equivalent scattering properties
  - Easy to use interface to OmniPro-Incline software

Lynx

- Optimized for pencil beam scanning
- High resolution scintillator-based sensor
- Active surface of 30 x 30 cm², effective resolution of 0.5 mm
- Single shot and movie mode measurements
- Compatible with OmniPro-1'mRT, Dicom RT export supported

DigiPhant PT

- Replaces time consuming manual solutions
- Dedicated MatriXX PT with 1020 ion chambers
- Measuring 2D and 3D dose distribution in water
- Analysis of relative and absorbed dose
- Data storage and evaluation in OmniPro-1’mRT
First patient treatment 10/04/18

• Prostate treatment
  • 60GyRBE in 20#
  • two lateral fields, ‘single-field uniform dose’
  • PBSTV = CTV + 5mm isotropic margin increased to 9mm in beam direction
• Rectal Spacer, “Bio-Protect” balloon,
  • push rectum away from prostate to reduce high doses
• Endo-rectal balloon
  • stabilise prostate and internal anatomy with respect to pelvic bones that beams pass through
• Bladder filling & immobilisation as for linac treatment
• Daily image guidance with 6D correction
  • CBCT and oblique X-ray
First patient – “Bio-Protect” rectal spacer

- Bio-Protect inserted (under GA) 7-10 days prior to planning scans
  - Bio-degrades within 6 months
- ERB inserted daily (at planning scans and daily treatments)
First patient – “Bio-Protect” rectal spacer

- Bio-Protect inserted (under GA) 7-10 days prior to planning scans
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- ERB inserted daily (at planning scans and daily treatments)
First patient – Single Field Uniform Dose (SFUD)
First patient – Single Field Uniform Dose (SFUD)
First patient – proton vs linac VMAT

Dose Volume Histogram

red = CTV + 5mm

proton = solid lines
linac = dotted lines
First patient – proton vs linac VMAT (with rectal spacer)

![Dose Volume Histogram](image)

- **Proton**: solid lines
- **Linac**: dotted lines

Rectum dose distribution graph showing differences in dose delivery between proton and linac VMAT techniques.
First patient treatment 10/04/18

Daily image guidance with 6D correction

- setup patient to lasers
- oblique images
- cone-beam CT & 6D correction
  - automatic bone match, then check soft tissue & adjust if necessary
  - be particularly careful about bone that the beams pass through
- repeat oblique images, verify position correction
- treat first field
- rotate table 180°
- oblique images, verify correction & 6D correction if necessary
- treat second field
First patient treatment 10/04/18

Looking for good match with respect to pelvic bones through which beams pass.
First UHF prostate patient treatment 14/01/19

- 42.7GyRBE in 7# (6.1Gy) - over 2.5 weeks, every other weekday
  - dose regime from HYPO-RT-PC
  - two lateral fields - single-field uniform dose
  - PBSTV = CTV + 5mm isotropic margin increased to 9mm in beam direction

- Rectal Spacer - “Bio-Protect” balloon
  - push rectum away from prostate to reduce high doses

- Endo-rectal balloon (semi-inflated and a few without)
  - stabilise prostate and internal anatomy with respect to pelvic bones that beams pass through

- Bladder filling & immobilisation as for linac treatment
  - Hand-held ultrasound bladder scanner “bio con 700” used to check prior to X-ray imaging

- Daily image guidance with 6D correction
  - CBCT and oblique X-ray
Ependymoma

- **proton**
- **VMAT**

Green = CTV
Red = PTV_59.4
Blue = PTV_54
Dark Green = PTV_50.4
(To come off cord)
Training, Mentorship, Peer Review

• Training, purchased from IBA, provided by University Pennsylvania
  • comprehensive on-line training package prior to on-site visit
  • one to three weeks hands-on training at Roberts Proton Therapy centre, Pennsylvania
  • 13 clinical oncologists, 7 radiographers, 3 physicists, 1 dosimetrist

• Other training/visits:
  • PSI Winterschool
  • Shreveport, Louisiana – first Proteus One gantry (plus CBCT)
  • Essen, Germany; Skandion, Sweden; Nice, France; William Beaumont, Detroit

• Proton specific MDT:
  • local oncologist team
  • collaborating with remote referring oncologists
  • radiologist, and other specialties if necessary
  • RCC clinical team

• Penn clinical support (proton experience)
  • treatment plan review
  • Advice at MDT stage and throughout process if required
Indications, NHS and Insurance Companies

NHS indications = paediatric & young adult (upto 25 years) & adult base of skull
17 insurance companies, but the largest one has 50% of private patients

<table>
<thead>
<tr>
<th>Companies</th>
<th>Time (months) to agree proton</th>
<th>Indications funded</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Case by case need to justify</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>NHS indications only</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
<td>NHS indications only</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>Case by case need to justify / NHS indications only</td>
</tr>
<tr>
<td>2 (biggest)</td>
<td>18</td>
<td>NHS indications plus some adult H&amp;N</td>
</tr>
<tr>
<td>2</td>
<td>24</td>
<td>Case by case need to justify</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>Paying photon prices and patients can top-up to proton /case by case if justified</td>
</tr>
<tr>
<td>1</td>
<td>ongoing</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>not covered</td>
<td></td>
</tr>
</tbody>
</table>
Indications treated so far, numbers increasing

- Brain: Ependymoma, Craniopharyngioma (NHS), Oligodendroglioma
- H&N: Ethmoid sinus, Retromolar trigone
- Sacral ependymoma
- Sarcoma
- Breast
- Bladder
- Rectum (including recurrence/re-treatment)
- Prostate
- Prostate & Nodes
- Hip retreatment (palliative)
Relationship with IBA

- Very good support during planning, installation, acceptance, commissioning
  - Arranging multiple site visits – large number of IBA centres
  - Penn training, commissioning support
- Great on-site IBA teams
  - 4 full-time engineers employed on each site
  - One engineer in control room throughout treatment day
  - Daily hand-over of proton machine
    - 7am to 11pm Monday to Friday = clinical
    - 11pm to 7am Mon to Fri and all weekend = IBA
- Uptime guarantee 94% year1, 96% year2, 97% year3
  - Newport currently 95%
  - IBA on-site team have supported us treating patients at weekends and public holidays to make up for down-time – no patients had overall treatment time extended
Thank you for listening!

therutherford.co.uk