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Working in a UK national proton radiotherapy facility: the therapeutic radiographer perspective

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Editorial

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Abstract

The first national UK proton beam therapy centre opened at The Christie NHS Foundation Trust in 2018, which alongside University College London Hospitals NHS Foundation Trust (UCLH) proton beam therapy centre, is expected to treat approximately seven-hundred and fifty patients per year at service ramp up.

The aim of this editorial is to share with a wider audience the role of a Band 6 proton senior treatment radiographer working in a national NHS service and future developments of the service. Prior to the service being clinical, a range of processes were followed, including the creation of quality documents, departmental training and end-to-end testing, with the first patient receiving treatment in December 2018.

Proton senior radiographers are responsible for the delivery of safe and accurate radiotherapy and ensuring a smooth patient pathway, through a multi-collaborative team approach. Although there are key differences between proton and photon radiotherapy, the fundamental aspects, including radiation principles, governance and patient advice are the same. The training package for proton senior radiographers includes an individual local induction as part of the proton education and competency framework, which incorporates practical learning, including clinical supervision and workshops, plus audio-visual presentations and workbooks to complete.

Future developments of proton beam therapy include proton arc therapy and flash therapy, alongside educational developments, such as training the future workforce and advanced practice consultant radiographer roles. Shared learning through multi-collaboration of international proton beam therapy centres is crucial to improve care for future service users.

Introduction

Proton beam therapy (PBT) is a type of radiotherapy which involves accelerating heavily charged proton particles in a cyclotron to almost the speed of light.[1] When the heavy mass is accelerated, protons travel determined distances prior to interacting with the target volume, depositing a steep dose drop off, known as the Bragg peak.[2] As a result, less scatter is produced in comparison to photon radiotherapy,[2] potentially reducing dose to organs at risk (OAR) and decreasing acute and long-term side effects for patients, thus increasing quality of life.[3] This is particularly beneficial for paediatric patients, to enable preservation of developing tissue and reduce dose to critical structures.[2] Reduced toxicities to OAR through more conformal high dose volumes, due to the physical properties of protons, is also exploited to enable dose escalation.[1] In turn, this has the potential to increase disease control, whilst reducing the risk of secondary malignancies.[2]

In 2013, The Christie NHS Foundation Trust and University College London Hospitals NHS Foundation Trust (UCLH) won a two-hundred and fifty million pound tender from the UK Government to develop two PBT centres in England,[4] comprising three clinical Varian Medical System ProBeam pencil beam scanning gantries at each site. This was in response to a strategic outline case by the Department of Health,[5] demonstrating the impracticalities and costs of facilitating PBT for patients overseas. Building and commissioning at both sites commenced in 2014, with The Christie NHS Foundation Trust PBT Centre opening in 2018 and UCLH Proton Beam Therapy Centre opening in 2022. Each site is expected to treat approximately seven-hundred and fifty patients per year at full ramp-up of service.[3]

NHS England provide a proton indications list[6] for a range of disease sites. Patients are referred for treatment by their clinical oncologist at their local centre via the PBT referral portal, which is then reviewed by a panel of experts, such as radiologists, surgeons and clinical and medical oncologists prior to acceptance.[7]

The aim of this editorial is to discuss the role of a proton senior treatment radiographer working in a national proton service and future developments of the service.

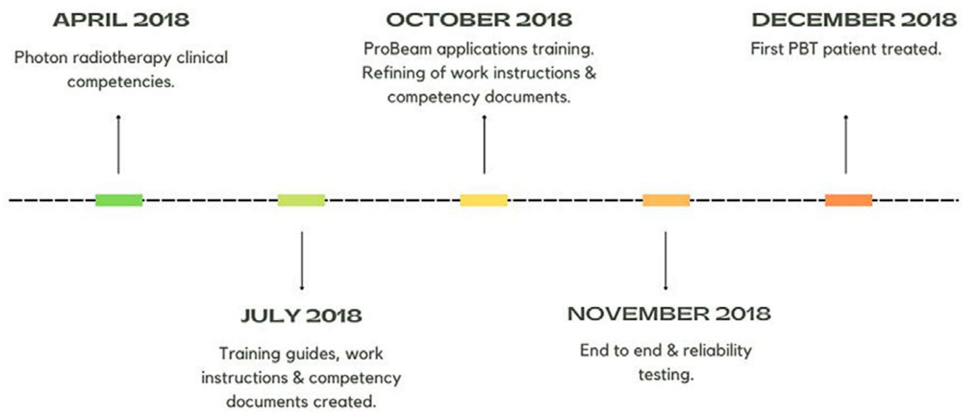

Figure 1. A timeline demonstrating pre-clinical PBT processes.

Proton Radiotherapy in Practice

Pre-clinical PBT

Figure 1 demonstrates the steps taken by the fifteen proton treatment radiographers hired in the lead up to the service becoming clinical. Staff employed externally underwent a six-week local induction to ensure that radiographers received standard Christie photon department training, which would be utilised for photon contingency in the event of cyclotron breakdown to reduce gaps in treatment, in line with RCR guidance.[8]

Training guides for ARIA oncology management system, ProBeam hardware and verification were initially created from manufacturer documentation prior to ProBeam applications training by superintendent radiographers, who had visited international proton centres. Work instructions, such as end of treatment summaries, were created by senior radiographers, utilising photon department protocols as guidance. Competency documents were designed by the radiotherapy education team and superintendent radiographers.

ProBeam applications training was delivered by one of three proton physicists worldwide, through theory and practical demonstrations with radiographers.

To promote collaborative working and solidify learning, on completion of applications training, two groups consisting of Band 6, 7 and 8 radiographers further consolidated their practical skills using phantoms. This was done at different time points each day, due to one Gantry being clinically available. Post applications training, training guides, work instructions and competency documents were refined by superintendent and senior radiographers.

End to end testing of processes from the start to the end of a patients' proton pathway was completed by AHP teams in the department prior to the service becoming clinical. This included continuous reliability testing of the beam across each gantry by radiographers, to ensure safety and quality in procedures.[9]

The first PBT patient was treated in December 2018, with 883 patients treated up to the end of September 2022. Over the past four years, numerous service evaluations and audits have been conducted by AHP groups across the service to enhance the safety and care received by patients. This includes time in motion audits and verification training projects conducted by Radiographers,[10] in line with good clinical governance and legal and professional standards.

Comparing proton and photon radiotherapy

Proton senior radiographers are responsible for the safe, accurate and efficient running of ProBeam gantries. The role involves managing a workload of paediatric, teenage and young adult and adult patients, taking into consideration individual requirements, such as treating paediatric patients—who require general anaesthetic in the mornings as they have fasted.

To ensure a smooth patient pathway from referral to post radiotherapy,[10] radiographers work directly with a range of AHPs, such as physicists and clinicians, who would review any set up and clinical changes noted by radiographers on treatment verification images.

There are some key differences between proton and photon radiotherapy, which are demonstrated in Figure 2.

In comparison to a linear accelerator, which weighs around 3 tonne, each ProBeam gantry weighs 200 tonne and is built over three stories, therefore due to the mechanics and safety, the ProBeam gantry moves six degrees per second.[11] The treatment couch enables for six degrees of freedom, to which corrections can be applied up to three degrees in pitch, roll and yaw.[11] Treatment times vary depending on complexity of a treatment site. For example, whole craniospinal irradiation takes considerably longer to treat in comparison to craniopharyngioma, due to set up, verification and treatment of multiple isocentres. Radiographers perform a practical 'Day 0' simulation, checking couch yaw, gantry, snout and imaging angles to improve efficiency prior to patients starting PBT.

As the beamline from the cyclotron feeds into three gantries, a beam etiquette approach is applied across all machines. Two-way radios are utilised to communicate any beam issues or to request beam priority, for example, for a patient with compromised airways. Varian engineers provide twenty-four hour on-site cover and trouble-shooting advice in the department. Radiographers work closely with engineers to reduce the risk of beam interruption and to communicate any delays to patients.

Imaging in the control area is actioned for treatments with multiple couch rotations to enhance efficiency; however, most imaging takes place in the treatment room imaging bay, which is demonstrated in Figure 3. Benefits of this include reducing patient anxieties by being closer to patients until treatment delivery and increased safety by enabling anaesthetic teams to closely monitor paediatrics under general anaesthetic.

Radiographers are required to have an excellent understanding of activation during PBT, following guidance from 'Establishing the Best Available Techniques for the UK (BAT)'.[12] Clinical devices, including range shifters, which are inserted in the nozzle of the machine snout to bring dose more superficially and individual thermoplastic shells become radioactive during PBT. They must not be removed from the gantries until dose is at a safe level.[12] Radiation is monitored using a Geiger counter by treatment

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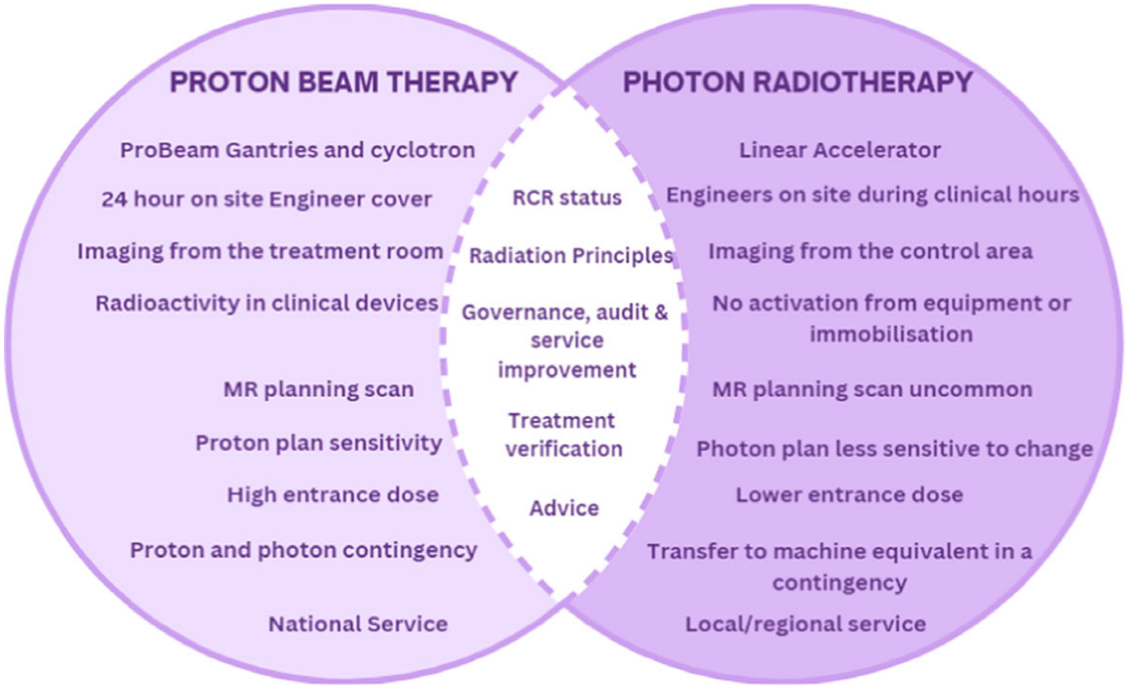

Figure 2. A Venn diagram demonstrating the differences and similarities between proton and photon radiotherapy.

Figure 3. ProBeam treatment room, with the imaging bay noted to the right-hand side (photograph courtesy of The Christie NHS Foundation Trust).

radiographers. Patients wanting to keep their thermoplastic after completion of PBT may wait up to a couple of hours until activation has depleted to room level.

PBT patients require an MR scan as part of pre-treatment planning, which are fused with CT planning scans to optimise visualisation of tumour volume and soft tissue. It is imperative that all staff required to work in MR controlled access areas receive annual safety training and complete a screening form, which is reviewed by an MR authorised person. Patients have custom MR-safe immobilisation created in line with local anatomical site instructions and are informed at pre-treatment to maintain weight and avoid making any dramatic changes to their appearance, such as shaving a large beard off, until after completion of PBT. Protons are extremely sensitive to changes in patient contour and anatomy in comparison to photon radiotherapy, therefore radiographers remind patients of this information throughout treatment, to avoid dosimetric uncertainties, which often lead to treatment requiring replans and new immobilisation.[10]

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Photon plans are created as a contingency in the event of cyclotron breakdown, as a service-level agreement stands between the proton and photon department, to enable proton patients to be treated by a combination of proton and photon radiographers. Depending on the length of cyclotron breakdown delay, clinician discretion is applied as to whether patients may continue treatment with photons, pause treatment, receive bi-daily treatment or be treated at the UCLH proton centre. Radiographers partake in monthly contingency treatments, which are carried out at weekends for patients who miss a fraction, to ensure that radiotherapy is completed as per RCR guidelines.[8]

NHS England provide temporary accommodation, located in the city centre, at no cost to the patient. Patients are allocated a keyworker (specialist radiographer or nurse) once accepted for PBT and a wide range of professionals, including occupational therapists, physiotherapists and psycho-oncologists work collaboratively to ensure that needs are met.[13] As PBT may last up to seven weeks, radiographers develop rapports with patients and ensure that their physical, social and emotional needs are addressed, such as through referring patients for appropriate support.[13]

Although there are differences between proton and photon radiotherapy, the fundamental aspects of radiotherapy are the same—such as following procedures in line with IRMER (2017),[14] working in line with good governance through promoting service development and understanding the importance of treatment verification.[15] The fundamental care and advice provided to patients, including managing radiotherapy reactions and demonstrating respect through personalised communications with patients, is elemental across all types of radiotherapy.

Training implications

PBT treatment therapeutic radiographers receive a six-week local induction as part of the proton education framework. It is tailored to each individual by the Radiotherapy Education Team, to ensure that Trust essential training, ProBeam hardware, verification and ARIA oncology management system training and competencies are achieved. A range of training styles, including audio-visual presentations, workshops and clinically supervised training are utilised, taught and mentored by proton superintendent and senior radiographers. This optimises different learning styles to suit individuals and reduce pressure on clinical staff and for trainees on induction.[16]

Qualified therapeutic radiographers are not required to have worked clinically in a photon radiotherapy department prior to employment in PBT; however, problem-solving and plan review skills are often complex,[10] therefore experience in a photon department post-qualification may prove beneficial.

Radiographers rotate amongst the three clinical gantries and Band 5 therapeutic radiographers rotate into PBT from the photon department, which enhances the individual's radiotherapy knowledge, in line with continuing professional development[17] and ensures that when staff return to their substantive photon post, they are able to assist in PBT photon contingency, such as treatment preparation.

PBT therapeutic radiographers are also provided the opportunity to rotate through proton pre-treatment, which involves a six-week induction where clinical skills, mould room, CT and MR basics are taught through the proton pre-treatment education framework. MR safety, hardware, screening and scanning is taught over a longer period of time, with therapeutic radiographers working collaboratively with diagnostic radiographers on the MR-Sim, to enhance MR safety and education of MR in radiotherapy.[18]

Proton senior therapeutic radiographers' scope of practice in PBT includes authorisation of an additional 2DkV image for patients on a 2DkV pathway, acceptance of verification images out of protocol tolerance if there is appropriate reasoning, dosimetric machine changes and signing off beam position errors. Role development opportunities for senior radiographers include becoming link workers in areas such as moving and handling, altered airways, infection control and basic life support. They also take an active role in recruitment and working groups involving superintendent and principal radiographers, such as DATIX, patient information, immobilisation and technical groups, to aid in service development, in turn improving quality and patient care.[15]

Adapting to COVID-19 in a national service

During the COVID-19 pandemic, the PBT department experienced changes to 'normal' practice.[19] This included ensuring that anaesthetic and radiographer staff completed fit mask testing to treat patients under general anaesthetic, as it is an aerosol generating procedure.[20]

Radiographers became accustomed to wearing PPE and cleaning times were scheduled on the gantries between patients as per local infection control advice (see Figure 4). COVID-19 positive or contacts of positive individuals are isolated from other patients travelling to the department, alongside waiting in designated isolated areas within the department to reduce the risk of COVID-19 transmission.[19]

During the pandemic, the UK government expressed the requirement for all to 'stay at home' where possible to reduce COVID-19 transmission,[21] which may have reduced PBT patients' quality of life during their treatment, as alongside being away from home and local support, social face-to-face activities were no longer available. Radiographers worked collaboratively with teams within the department, such as complementary therapy and play specialists, to help support patients holistically.[13]

Future Developments

PBT clinical outcomes literature is limited internationally; therefore, evaluating PBT toxicities, long-term tumour control and techniques are imperative to enhance understanding and improve outcomes for patients (See Figure 5).[10]

Clinical trials comparing photon radiotherapy with PBT are currently underway, including TORPEdO (16424014). TORPEdO compares whether intensity-modulated proton radiotherapy toxicities are reduced compared to intensity-modulated photon radiotherapy, for patients with oropharyngeal cancer, with a specific interest in skin toxicity.[10] The PARABLE trial (ISRCTN14220944) has also commenced, which compares whether PBT can reduce heart dose in comparison to photon radiotherapy, in patients with breast cancer who have an enhanced risk of long-term cardiac events post irradiation.[22]

The PBT centre has a dedicated research gantry (Gantry 4), which belongs to The PRECISE Group.[23] A range of proton developments, including proton arc therapy, FLASH therapy and proton computed tomography (pCT), are being explored.[23]

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Figure 4. PBT radiographers treating a patient during the COVID-19 pandemic (photograph courtesy of The Christie NHS Foundation Trust).

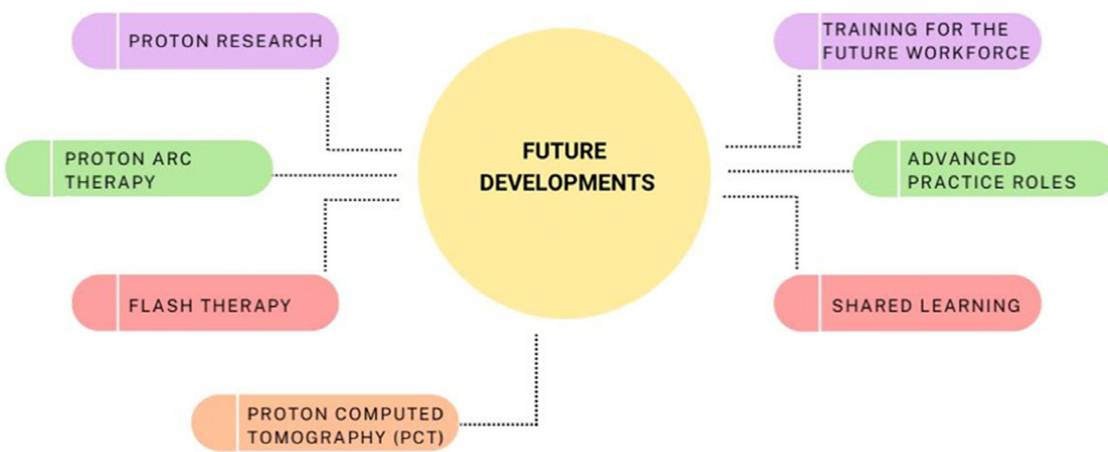

Figure 5. A concept map diagram demonstrating future developments in PBT.

Proton arc therapy benefits include a reduced integral dose and improved robustness of target coverage in comparison to photon arc radiotherapy; however, challenges of this technique include changing energies during treatment delivery with gantry motion.[24] FLASH therapy is a developing radiotherapy technique in electron and photon radiotherapy, which involves utilising high dose rates in order to deliver high dose per fraction (over forty gray per fraction).[25] Pre-clinical FLASH studies have demonstrated significantly reduced radiation side effects whilst achieving disease control, therefore exploiting the physical properties of protons may prove advantageous due to more conformal high dose to target volumes achieved in comparison to photons.[25] Utilising protons as a low dose verification tool (pCT) is also currently being explored by the PRECISE Group; however, such technical developments are in the very early stages of testing prior to clinical implementation.[10]

Educating the radiography workforce from pre-registration level is important, such as the national Proton Clinical Placement Expansion Programme, which alongside proton clinical placement experience involves interactive online teaching sessions and workshops, to enhance and promote PBT knowledge.

Future developments of senior therapeutic radiographer roles within PBT include superintendentr, advanced clinical practitioner and consultant radiographer roles, such as site-specific specialisms and keyworkers. This enables a wider network of care for service users, further develops the skillset of radiographers and reduces department pressures.[26]

Moving forward, shared learning of technical and educational developments through collaborative working is integral to enable a seamless national delivery of PBT. It is crucial that proton centres work collaboratively towards common goals, including PBT techniques, standardised treatment in the event of proton contingency and educating the future workforce.[10]

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Conflicts of Interest. There are no conflicts of interest.

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