



Original Article

The National Referral Service for Proton Beam Therapy in England: A Journey Towards Equitable Access



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Abstract

Aim: Health care policies have frequently centred on ensuring equitable access within diverse populations. While new technologies have immense potential for improving health outcomes, they may not be necessarily available across varied geographical areas and socioeconomic backgrounds. The goal of this study is to analyse equity of access to Proton Beam Therapy (PBT) throughout England and how this has changed since the inception of a national PBT service in 2018.

Materials and methods: The Proton Utilisation Proportion (PUP) is the ratio between treated and newly diagnosed patients, which measures the proportion of eligible patients using the technology. These figures were provided for 7 of the most prevalent PBT cancer indications for the period 2013-2019. The first national NHS PBT centre began accepting referrals in October 2018, hence this time period was divided into pre-NHS PBT and post-NHS PBT.

Results: For the seven most common PBT cancer indications, the total number of newly diagnosed patients was 1686 before NHS PBT and 381 after NHS PBT. The number of treated patients was 479 in the pre-NHS PBT era and 180 afterwards. Overall, the PUP in England grew post-NHS PBT by 66%. More specifically, there is an increase in the PUP between the pre-NHS and post-NHS PBT for any diagnostic category and age group analysed. Among the diagnostic categories analysed, the greatest increase is seen in Medulloblastoma, which became a commissioned indication for PBT in 2016. By age group, post-NHS PBT the most noticeable increase is seen for the age group 16-24.

Conclusion: Promoting equal access to cutting-edge radiation technology is central to NHS England's core values. The PUP has expanded since the establishment of a National PBT service in England, which employs a central web-based Proton Referral Pathway overseen by a National Proton Office. Further investigation will be conducted to determine whether socioeconomic or geographic barriers exist between different areas.

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Keywords: Healthcare equity; national proton therapy service; proton beam therapy; proton utilisation proportion

Background

In 2007, the National Radiotherapy Advisory Group in the United Kingdom (UK) issued a report addressing the need to guarantee to all patients in the country access to state-of-the-art radiotherapy technologies, including proton beam therapy (PBT). The report detailed what needed to be done to grant equal access to patients from diverse geographical areas within the UK and from a range of socioeconomic backgrounds. Promoting equity has always been at the core

of NHS values as cited under the Equality Act 2010. In the UK, the National Health Service (NHS) is responsible for the commissioning and provision of PBT and is the statutory body which in 2008 started the National Proton Overseas Programme (POP). The POP granted access to cutting-edge PBT technologies to UK patients overseas whilst two national NHS facilities were being planned and built [1,2].

Routinely commissioned providers of PBT under the POP were the University of Florida Health Proton Therapy Institute (Jacksonville, USA), Oklahoma Proton Center (Oklahoma City, USA) and Westdeutsches Protontherapiezentrum (Essen, Germany). A small number of adult patients received treatment at the Paul Scherrer Institute (Villigen, Switzerland) and Institute Curie Proton

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Therapy Center (Paris, France). All these centres went through a full NHS England (NHSE) procurement process and were fully compliant with the NHSE service specification for overseas PBT providers [3]. The national NHS PBT service started in the UK only ten years later, with the opening of The Christie PBT Centre in Manchester in December 2018, followed by the University College London Hospitals (UCLH) PBT centre in 2021. Since the inception of the POP, there has been a single process for the operational management of referrals for PBT, including the allocation of a treatment centre. This process has been and is still managed by the National Proton Office [4]. The aim of this study is to evaluate how the national process for applying for PBT has served to guarantee equity of access to PBT and how this has changed since the national PBT service inception.

By definition, health equity means guaranteeing that each individual has the chance to attain optimal health by minimising geographic and socioeconomic barriers and granting everyone access to state-of-the-art healthcare. In this study, we assessed equity by calculating the proportion of patients eligible for PBT who actually received PBT. In addition, we report on the distances travelled for access to PBT and on the socioeconomic circumstances of the patients who received PBT.

Methods

Application process

Figure 1 represents the national referral pathway for PBT in the UK, in operation since 2008. A step-by-step description of the process is outlined below.

1. The referral pathway starts with the patient case discussion at the multidisciplinary (MDT) team

meeting of the referring specialised cancer centre. If potential eligibility for PBT is determined, a consultant clinical oncologist will see the patient for assessment and discussion and, if the patient agrees, will refer the patient to the national PBT panel through the dedicated referral portal.

2. All applications for PBT are submitted to the web-based PBT referral portal. The referral process includes the submission of the relevant demographics and clinical history in a dedicated form, together with the supporting radiological images which are uploaded separately on an "Image exchange portal". The referral will also contain any social or logistical considerations that might impact on patient care, safeguarding, or the ability of the patient or family to manage travel or treatment abroad.
3. Once the application has been submitted to the PBT referral portal, it is directed to one of the PBT national clinical panels, virtual panels made up mainly of leading oncologists, as well as some surgeons, from across the UK. There are 4 panels currently in place: paediatric (0–16 years old) and teenager & young adult (TYA, >16 and <25 years old) cancers, adult (≥ 25 years old) skull base and central nervous system, spinal and sacral tumours (adult and TYA), head and neck tumours (adult and TYA). The panel individually reviews the application and supporting documentation together with the imaging.
4. Panel members make the clinical judgement as to whether the case meets the criteria outlined by NHS commissioning policies for PBT and responds via the portal [3]. As a general rule, the higher cost of PBT is justified when the disease is considered curable, with a reasonable disease-specific survival at 5 years. The panel members also provide comments about the

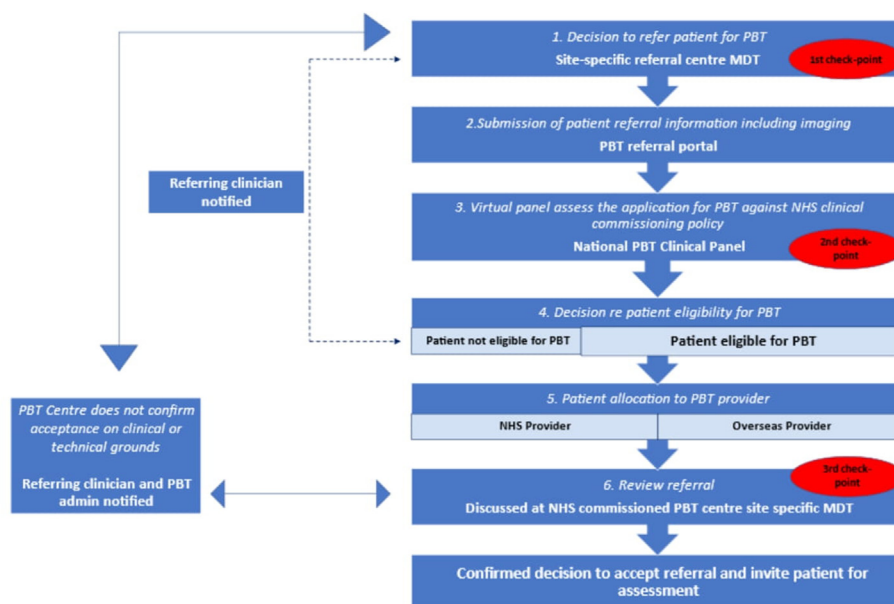


Fig 1. The national referral pathway for PBT in the UK, in operation since 2008.

logistics (especially on the safety of patient relocation) and the timing of treatment. The PBT National Clinical Panel Chair will review the responses from the panel and make the concluding recommendation/decision. The PBT National Clinical Panel Chair confirms in writing to the clinician making the application the panel decision with relevant feedback from the panel's members. It is the responsibility of the referring clinical team to communicate the commissioning decision and rationale to the patient and the family.

5. In the case of a positive response, the PBT National Clinical Panel chair will recommend which NHSE-commissioned PBT centre the patient should be referred to and the patient's clinical information and imaging data will be forwarded electronically to the treating centre.
6. Once the patient has been allocated to the treating PBT centre, the clinical case is rediscussed at the tumour site-specific MDT and the referring clinician is notified regarding the outcome of the discussion. In accordance with the NHS commissioning policies, patients who have been referred and accepted for PBT are required to attend an assessment and planning visit at the PBT centre to which they have been referred. Treatment commences approximately 2–3 weeks later [3].

Proton Utilisation Proportion in England

In order to establish the regional variation in the proportion of patients with eligible PBT indications [3] that were successfully referred through the national PBT portal and treated with PBT, the Proton Utilisation Proportion (PUP) was calculated for each region of England. It is important to emphasise that this analysis is restricted to England due to the limited availability of detailed cancer registries for the relevant indications for the other regions, despite the fact that the NHS referral service has been operational for the entire UK (as England, Wales, Scotland, and Northern Ireland) as described above.

The PUP is the ratio between the number of patients treated with PBT (observed) and the number of newly diagnosed (expected) patients and tracks the proportion of eligible patients using the technology.

$$a \text{ PUP} = \frac{\text{number of PBT treated patients}}{\text{number of expected patients}}$$

The denominator of equation *a* (number of expected patients) was provided by the National Disease Registration Service, by interrogating the cancer registries of the seven regions in England as defined by NHSE (London, North West, North East, East and West Midlands, South East, South West) for the PBT-commissioned diagnostic indications (Table 1). However, in view of the large number of very rare entities eligible for PBT and the potential General Data Protection Regulation implications, we decided to select the

eight most common PBT-commissioned indications. Incidence data were available for 7/8 of these, with incidence of low-grade gliomas not available due to the heterogeneous definition of this tumour entity (Table 1). These figures were provided for each of the seven diagnoses for the paediatric and TYA age groups. However, for the adult age group, only chordomas and chondrosarcomas were included in the analysis as these were the routinely commissioned indications above 25 years of age throughout the analysed time period.

Patient postcodes were extracted, as well as referring and treating centres' postcodes, in order to evaluate distances between patients and referring institutions and correlate these with the PUPs. The postcodes in England typically encompass approximately 15 addresses to provide quite precise localisation.

The incidence data, serving as the denominator in equation *a*, were supplied by the National Disease Registration Service, which oversees cancer registries in England; the availability of these data dictated the group selected for the study. Therefore, the analysis pertains to the period from 2013 to 2019, is limited to individuals aged 0–39 years, encompasses the seven NHS England areas (as opposed to the entire UK), and focuses on the seven most prevalent diagnoses. The analysis of this patient population can serve as a benchmark for the future, more comprehensive, analysis, which should ideally encompass the entire UK (including Scotland, Wales, and Northern Ireland), in addition to people over the age of 39.

The first national NHS PBT centre at the Christie in Manchester started accepting referrals in October 2018, therefore this period was split into pre-NHS PBT (1/13–30/9/18) and post-NHS PBT (1/10/18–31/12/19).

The numerator of equation *a* (“number of PBT-treated patients”), together with the demographics and clinical characteristics of patients referred and treated with PBT for matching clinical diagnoses and time periods was provided by the Proton Clinical Outcomes Unit, based at the Christie NHS PBT centre and responsible for the data curation and analysis of the patients referred through the national portal.

Once the PUP was calculated, the project methodology was defined as in Figure 2.

The index of deprivation was extracted from each patient's postcode, following the map of the Index of Multiple Deprivation (IMD) outlined by the government in 2019 [5]. The IMD serves for assessing relative deprivation in England. The definition of deprivation is broad and encompasses various aspects of an individual's living situation, following a well-established methodological framework. The IMD 2019 is calculated by combining and weighting seven unique domains of deprivation (income, employment, education, health, crime, barriers to housing and services, living environment). This metric provides a comprehensive assessment of the many forms of deprivation seen by individuals residing in a certain region. It is computed for each of the 32,844 Lower-layer Super Output Areas (LSOAs), or neighbourhoods, within England. LSOAs are small regions intentionally created to compare populations of similar size, often consisting of around 1500

Table 1
Breakdown of diagnostic categories included in this analysis, age groups, and NHS England regions

Diagnoses	Age groups (years)	NHSE regions
Ependymoma	<16 (paediatric patients)	London
Craniopharyngioma	16 ≤ TYA <25	North East
Medulloblastoma	Adults ≥25 and <39	North West
Ewing Sarcoma		East Midlands
Rhabdomyosarcoma		West Midlands
Chordoma ^a		South East
Chondrosarcoma ^a		South West

TYA, teenagers and young adults.

^a Of note, for the adult (≥25 year old) subgroup, only the Chordoma and Chondrosarcoma statistics were extracted as these were routinely funded for PBT.

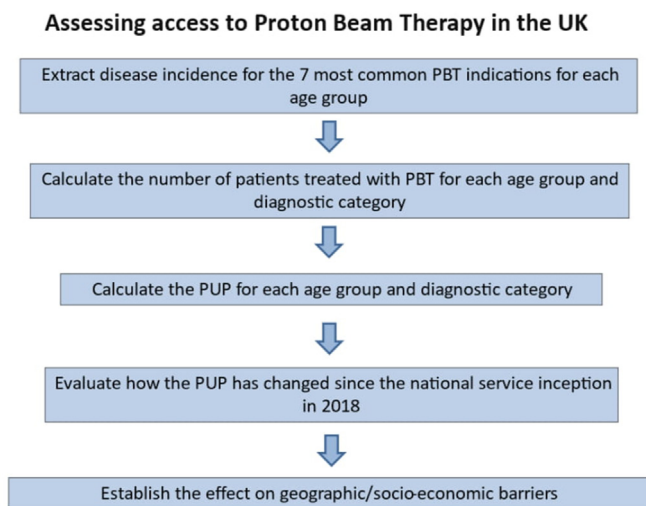


Fig 2. Project methodology to assess access to Proton Beam Therapy in England. PUP: Proton Utilisation Proportion.

individuals or 650 households. The ranking of all neighbourhoods in England, from the most deprived, ranked 1, to the least deprived, is based on their relative level of deprivation in comparison with other places.

Results

Figure 3 shows the number of UK patients treated with PBT since the inception of the POP in 2008, and later with the set-up of the National NHS PBT service at the Christie PBT (2018) and UCLH PBT centres (2021). In contrast to the PUP analysis, which was conducted on a specific patient population, these figures pertain to the entire PBT-treated patient population in the United Kingdom, regardless of age or diagnosis.

Of note, there has been a gradual increase in the number of patients treated annually with PBT since 2008. The establishment of the national NHS PBT service has coincided with a significant decrease in the number of patients needing to travel abroad for PBT treatment. The breakdown of the numbers of patients treated with PBT within the POP and within the National PBT service is given in Table 2. The detailed data are provided in Table 2 for the patients treated

at the Christie NHS PBT centre since 2018. Specifically, in the first months of service of the Christie NHS PBT centre up to April 2019, the vast majority of patients were represented by paediatric patients (73%), with only a minority of teenagers and young adults (13%), adults (13%), and patients enrolled in clinical trials (13%). Throughout the years, the proportions of TYA, adults, and trial patients have increased with the last complete financial year (2022/2023) reporting a proportion of TYA, adults, and trial patients of 21%, 38%, and 26%, respectively.

For the common PBT indications listed in Table 3 (all seven included in the paediatric/TYA subgroup, and two included in the adult subgroup), the number of newly diagnosed patients was 1686 in the pre-NHS PBT period and 381 in the post-NHS PBT period. The accepted referrals were 479 and 180 in the pre- and post-NHS PBT period, resulting in an increase in the PUP between pre- and post-NHS PBT of 66% overall (from 28% to 47%). The breakdown of incidence and referral statistics by age and diagnosis group is given in Table 3. An increase in the PUP between the pre-NHS PBT and the post-NHS PBT is noted for all diagnosis and age groups (Figure 4). By diagnosis, the most noticeable increase is for medulloblastoma. Standard risk medulloblastoma became a commissioned indication for PBT for paediatric and TYA patients only in February 2018.

The median IMD ranks have decreased between the period preceding and following the introduction of the national NHS PBT service at the Christie as illustrated in Figure 5. There is a trend towards lower IMD ranks following the introduction of the NHS PBT service, suggesting increased accessibility for more disadvantaged areas, though this difference does not reach statistical significance ($P = 0.081$), although this is not statistically significant.

The median distances travelled by patients to the referring institutions have increased in 6/7 regions (all but region 1), as shown in Figure 6, indicating that more distant areas of the country have been reached. Figure 6 displays boxplots that illustrate the distance to the referring centre for each NHS England region between the period preceding and following the opening of the first national NHS PBT facility at the Christie.

Lastly, the IMD percentiles between the pre- and post-NHS PBT opening demonstrate that the representation of the most disadvantaged groups (0-30th percentiles) has

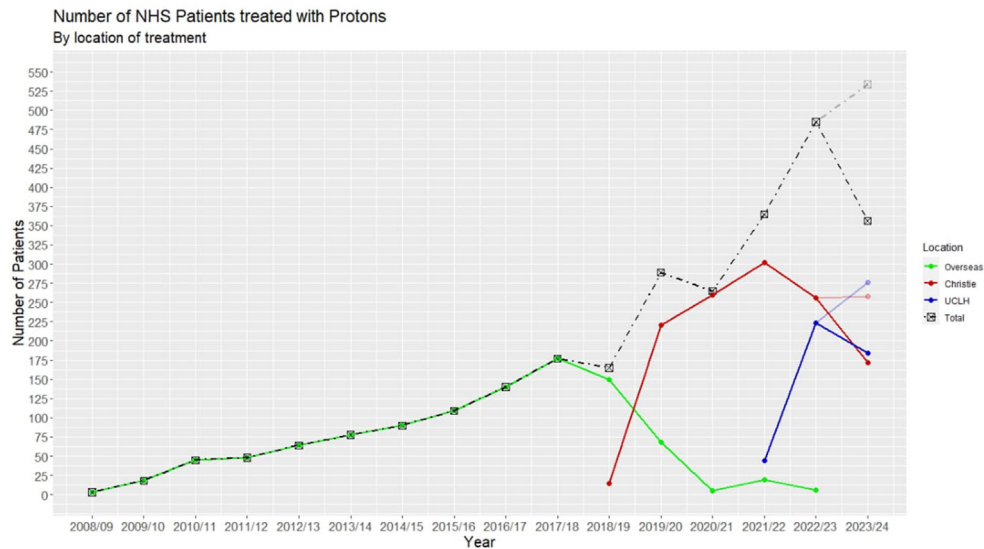


Fig 3. The green line represents the total number of patients (from the entire UK territory, of any age and any diagnostic indication) referred and treated overseas annually since the “Proton Overseas Programme” opening in 2008. The red line shows the number of patients treated at the Christie NHS Proton Beam Therapy centre since its opening in December 2018. The blue line is the number of patients treated at University College of London Hospital (UCLH) since its opening in 2021. The grey dotted line shows the total number of patients treated with Proton Beam Therapy (PBT). The figures for each year are calculated according to the financial year (April–March). The last financial year (2023–2024) is reported with the actual figure for April 2023–November 2023 together with the estimated figure for the whole financial year April 2023–April 2024.

increased since the national service was established (supplementary material Figure 1, Table S1). The data reveal a notable shift in access to PBT following the introduction of the NHS service. In the post-NHS PBT period, a higher proportion of patients came from more socioeconomically deprived backgrounds. Specifically, the 0–10th IMD percentile saw an increase from 10.65% to 12.88%, and the 20–30th percentile increased from 9.39% to 11.66%. The most pronounced change was observed in the 60–70th percentile, which rose from 9.19% to 14.11%. Conversely, there was a marked decrease in the proportion of patients from less deprived backgrounds, particularly in the 90–100th percentile, which dropped from 11.69% to 4.91%. These findings suggest that the introduction of the NHS PBT service has improved access for more deprived populations.

Discussion

Our previous work has revealed a significant increase in interest in the identification of factors that influence equity of access to PBT [6], the most common being socioeconomic status and geographical location. With the increase in demand and capacity for PBT worldwide, there has been a growing body of evidence on this topic over the past decade. Unsurprisingly, the United States, which has the highest number of PBT facilities and the most powerful global economy, has conducted the majority of the population-level studies to date as outlined in a literature review conducted by our group [6]. The most commonly reported indicators of disparities are geographic location, socioeconomic status, and insurance coverage. This suggests that efforts other than just increasing the number of

facilities that provide PBT will be needed to eliminate disparities in PBT access.

Regarding PBT, paediatric malignancies have the most compelling rationale and children are the age group that has been extensively investigated. The issue of unequal access is of great importance in this context also for its ethical implications, because of the long-lasting impact of oncological treatments in young patients with good life expectancy. The objective of this study was to examine the effectiveness of a national referral pathway for PBT in ensuring equitable access across England since the implementation of the POP in 2008. At a national level in the UK, there has been a consistent rise in the number of patients receiving treatment with PBT. This is likely attributable to multiple factors: increased knowledge among patients and physicians regarding PBT, the establishment of national NHS PBT facilities in Manchester and London, as well as the implementation of a user-friendly national portal, which became paperless since early 2019, which allows clinical oncologists from any location in the UK to refer patients with eligible indications. This facilitates the referring process from any location in the UK irrespective of the distance from the NHS PBT facilities as any patient who has access to a specialist cancer hospital and fulfils the requirements can be referred to PBT.

During the COVID pandemic in 2020, the national PBT program faced challenges due to the inaccessibility of overseas providers, while the Christie, as the sole provider, lacked the capacity to accommodate all UK PBT patients. A brief pause occurred at the start of the pandemic in March 2020 but, by early April, operations were resumed under a new COVID framework.

Table 2

a) Breakdown of the number of patients treated within the Proton Overseas Programme (POP) since 2008, and at the newly established NHS proton beam therapy (PBT) service at the Christie NHS PBT and the University College of London Hospitals (UCLH) PBT centres (b). The figures are by financial year (April–March). The last financial year (2023–2024) is partial as reported with the actual figure for April 2023–November 2023

a) Patients referred and treated within the POP annually since 2008							
Year	No.	Year	No.	Year	No.	Year	No.
2008/09	3	2014/15	90	2020/21	5		
2009/10	18	2015/16	109	2021/22	19		
2010/11	45	2016/17	140	2022/23	6		
2011/12	48	2017/18	177	2023/24	0		
2012/13	64	2018/19	150				
2013/14	78	2019/20	68				
b)							
Year of Christie PBT service operation		2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Total No. of patients treated at the Christie (PBT)		15 (100%)	221 (100%)	260 (100%)	302 (100%)	256 (100%)	172 (100%)
Adults		2 (13%)	52 (23%)	96 (37%)	102 (34%)	98 (38%)	62 (36%)
TYA		2 (13%)	63 (28%)	52 (20%)	79 (26%)	55 (21%)	30 (17%)
Paediatrics		11 (73%)	106 (48%)	112 (43%)	121 (40%)	103 (40%)	80 (46%)
PBT patients enrolled into clinical trials		2 (13%)	12 (5%)	44 (17%)	57 (19%)	67 (26%)	40 (23%)
Year of UCLH PBT service operation				2021/22	2022/23	2023/24	
Total No. of patients treated at UCLH (PBT)				44	223	184	

Abbreviations: TYA, teenagers and young adults. Of note, PBT patients enrolled in clinical trials are also included in the age categories and adults include any age >25 years old.

NHSE emphasised the necessity of preserving anaesthetic staff and equipment for paediatric radiotherapy services in general, and for PBT specifically. A series of measures were implemented to maintain operations as close to normal as feasible. These encompassed staff and patient testing, the absence of mandatory staff redeployment, dedicated paediatric anaesthetic support (both personnel and equipment), designated paediatric oncology support, middle-grade paediatric assistance, and evaluation of accommodation and shuttle bus provisions for patients staying at the Christie Hospital accommodation.

As of June 24, 2020, all activities were resumed including acceptance of patients previously placed under surveillance, such as those with craniopharyngioma, low-grade glioma, and pituitary adenoma. Additional categories,

primarily concomitant chemotherapy, low-dose radiotherapy, and craniospinal irradiation, were subsequently reopened.

According to the data from the Christie PBT centre, the largest category of patients comprised children, followed by adults, TYA (teenagers and young adults), and trial patients. This aligns with the paediatric indications that encompass the majority of the commissioned indications, while the routinely commissioned indications for adults above the TYA age range were limited to radioresistant cancers that necessitate dose escalation. Nevertheless, with the limitation of the analysis being restricted to the adult subgroup aged 25–39 years, the percentage of adult patients who have received PBT since the establishment of the national NHS service in 2018 has risen in conjunction with the

Table 3

Breakdown of incidence (N) and referral (R) statistics by age and diagnosis group pre- and post-the NHS proton beam therapy service inception in 2018. The percent increase for each category is also reported

		Pre-NHS PBT			Post-NHS PBT			Increase in %
		N	R	PUP _{pre}	N	R	PUP _{post}	
Total		1686	479	0.28	381	180	0.47	66%
Age groups	00-15	1050	382	0.36	225	131	0.58	60%
	16-24	430	67	0.16	103	39	0.38	143%
	25-39	206	30	0.15	53	10	0.19	30%
Diagnosis groups	Ependymoma	251	119	0.47	63	42	0.67	41%
	Rhabdomyosarcoma	419	125	0.3	87	39	0.45	50%
	Medulloblastoma	311	5	0.02	63	29	0.46	2763%
	Ewing sarcoma	257	116	0.45	64	30	0.47	4%
	Chondrosarcoma	242	15	0.06	59	5	0.08	37%
	Craniopharyngioma	155	84	0.54	31	30	0.97	79%
	Chordoma	51	15	0.29	14	5	0.36	21%

Abbreviations: PBT, proton beam therapy; PUP, proton utilisation proportion.

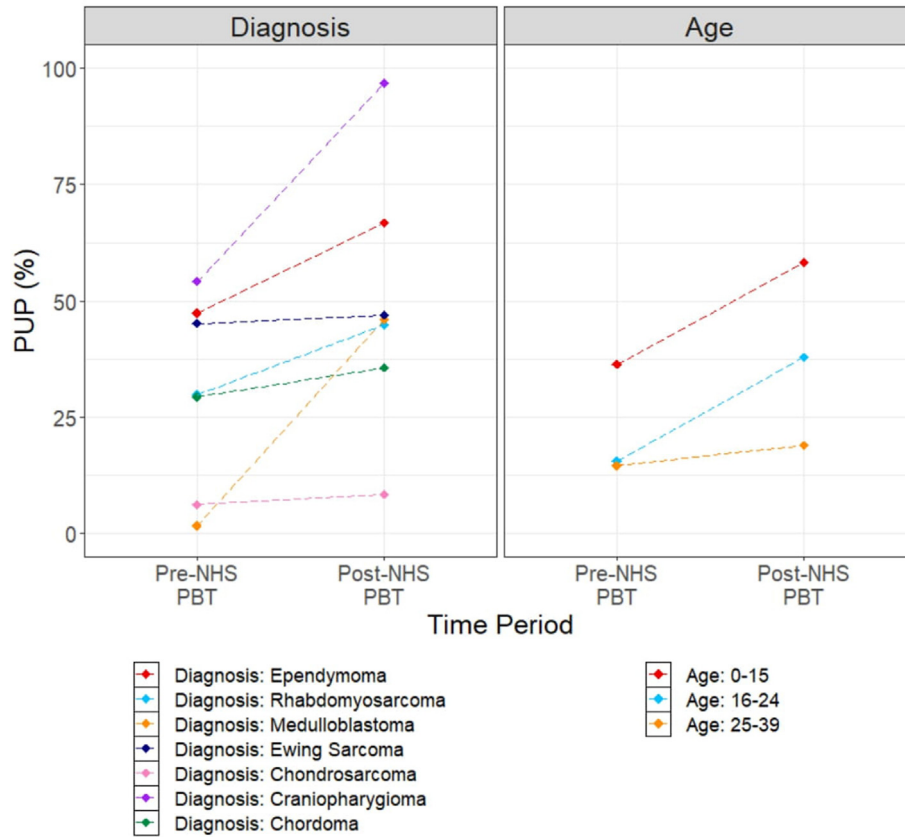


Fig 4. Visualisation of change in PUP pre- and post- the NHS Proton Beam Therapy service inception in 2018 by age group and diagnosis.

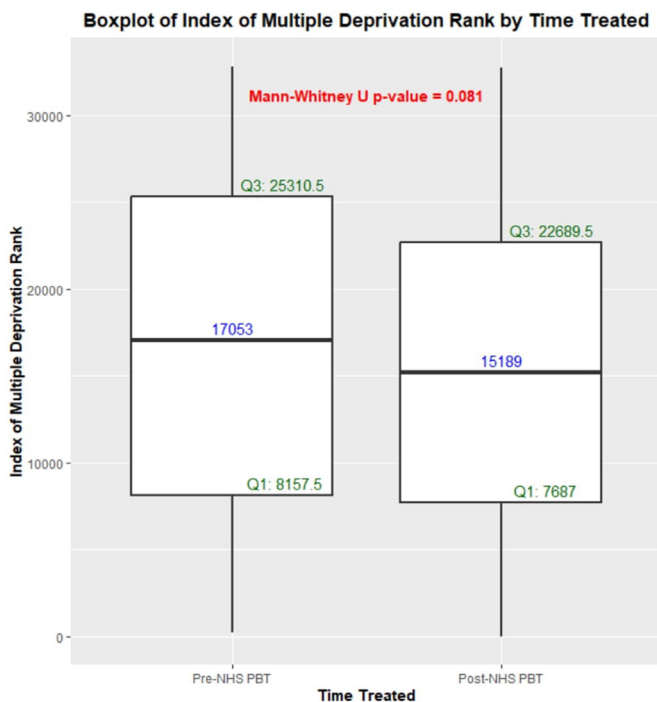


Fig 5. Boxplot indicating the index of multiple deprivation rank for the periods preceding and following the opening of the first National NHS PBT centre at the Christie in 2018 (median rank, interquartile range). The Mann-Whitney U test has shown no statistically significant IMD rank differences between the pre and post NHS PBT groups.

implementation of evaluative commissioning studies (CtE) and a national clinical trial portfolio [7]. According to current estimates, the NHS PBT service has the capacity to accommodate around 1300 patients per year. At present, 40% (approximately 500/1300) of the capacity is taken up by routine commissioning and registry cases (extremely unusual clinical situations that are approved for PBT if they meet the standards of anticipated clinical benefit that are consistent with regular commissioning criteria). The majority of the remaining capacity is expected to be utilised by randomised controlled trials (RCTs) and CtE studies in the near future, aligning with the establishment of an RCT portfolio and the advancement of CtE research. This will ensure that patients receive PBT and that their outcome data contribute to the expansion of the clinical evidence base, which is necessary to sustain the regular long-term funding of PBT. Ultimately, this will enable treatment for the patients who are most likely to derive clinical benefit from PBT.

The PUPs have been calculated based on the numbers of expected and treated patients for the given age groups and diagnostic categories. An increase in the PUP is noted for any diagnostic category and age group. With the exception of medulloblastoma, which was only commissioned starting in February 2018, the other six indication categories analysed in this study have not changed throughout the years.

Looking at the PUP in the different age groups, the most successful have been the paediatric and TYA, in which the

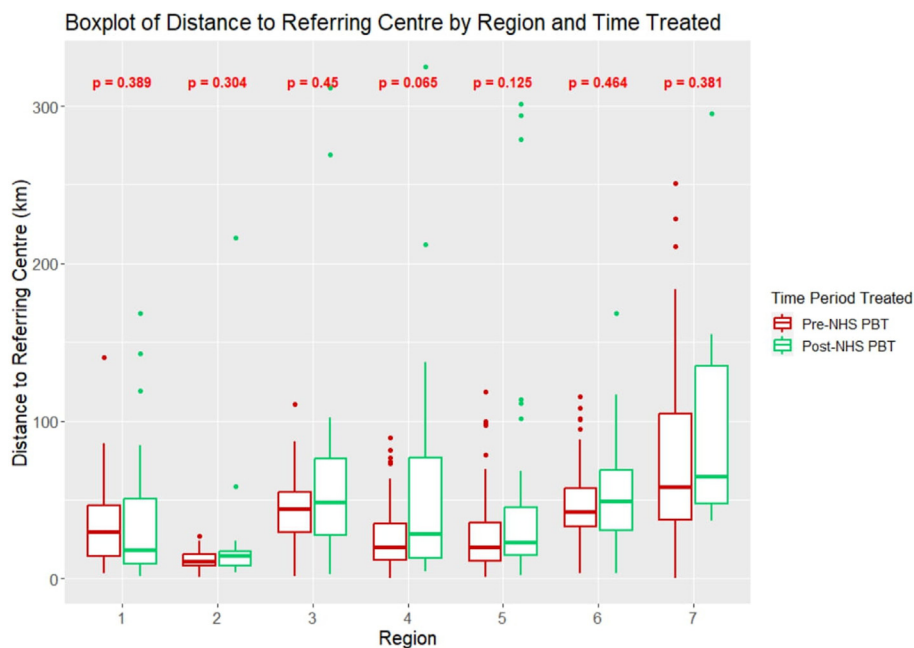


Fig 6. Boxplot indicating the distance to the referring centre for each NHS England commissioning region between the period preceding and following the opening of the first national NHS PBT facility at the Christie in 2018 (median, interquartile range). The Mann-Whitney U test has shown no statistically significant distance to referring centre differences between the pre and post NHS PBT groups for each NHS England region.

PUPs were already higher than in adults in the pre-NHS PBT period. However, with the inception of the NHS PBT service, the PUP increased by 60% and 143% in these two groups, respectively. This is backed up by a strong rationale for the use of PBT in these age groups, namely the reduction of late effects enabled by the physical properties of PBT, which allows a significant reduction of the integral dose [8]. For instance, the post-NHS PBT PUP for craniopharyngioma is 0.97, a remarkable indicator of the success rate of the programme for the paediatric patient population.

In the adult age group, the PUP in the post-NHS PBT period has increased by 30%.

The rise in the PUP between the pre-NHS PBT and the post-NHS PBT is a more significant measure compared with the PUP itself. This increase offers insights into how the establishment of a nationwide PBT programme has influenced the PUPs for different diagnostic categories and age groups. The PUP is not an entirely reliable measure of the usage of the national proton service as there can be a number of non-modifiable characteristics that may make patients ineligible for PBT despite falling into the commissioned indications (such as metastatic disease, site of disease, inadequate performance status to travel, inadequate surgery or other comorbidities that might affect the overall life expectancy). For chondrosarcoma the PUP was very low at 0.08, likely partly because chondrosarcomas can arise at multiple body sites, while only skull base, spinal, and paraspinal sites are commissioned for PBT. Therefore, the percentage increase has to be regarded with some caution. However, there might be other “modifiable” and potentially targetable factors such as cultural, geographic, and socio-economic barriers that, if addressed, can improve the PUP. [Figure 1](#) and [Table S1](#) show that the introduction of the NHS

PBT service has improved access for more deprived populations, thereby addressing the primary two obstacles to optimal access to the PBT service. However, we are of the opinion that the PUP can be further enhanced by identifying and addressing additional potential obstacles for the optimal implementation of the national PBT service.

For instance, in certain cases, clinicians may consider advanced photon radiotherapy technologies as a viable and equally effective alternative. Therefore, we strongly recommend engaging in conversations with the national proton panel in uncertain situations.

Additionally, the financial situation of the family and their caregiving obligations may also influence the decision to travel for treatment. Therefore, it is essential for patients and their relatives to have complete knowledge about the logistical support provided by the NHS for travel and accommodation, in order to make an informed choice.

Conclusions

Promoting equality of access to cutting-edge radiotherapy technologies is at the heart of NHS England’s values. Throughout the development of the policies and processes related to PBT access in the UK, the NHS has given regard to the need to reduce geographical and socioeconomic variation which may contribute to health inequalities. The number of patients receiving PBT in the UK has consistently grown each year since the introduction of the POP in 2008. The PUP has demonstrated a consistent rising trend across all age groups and diagnostic categories in England. In the period analysed, the proportion of English patients accessing the PBT service living in the 30% of the most deprived

areas increased in the period after the opening of the PBT service based in England. Future efforts will focus on identifying the specific subgroups that still have suboptimal access to PBT.

Author contributions

Simona Gaito contributed to conception and design of the study, acquisition of data, interpretation of data, drafting the article.

Anna France contributed to acquisition of data, interpretation of data, data analysis, Yuwei Wang: acquisition of data, interpretation of data, data analysis.

Neil Burnet contributed to article revision, final approval of the version submitted.

Adrian Crellin contributed to article revision, final approval of the version submitted.

Jason Kennedy contributed to acquisition of data, interpretation of data.

Gillian Whitfield contributed to article revision, critical revision for important intellectual content, final approval of the version submitted.

Peter Sitch contributed to acquisition of data, interpretation of data.

Marianne Aznar contributed to article revision, final approval of the version submitted.

Ed Smith contributed to article revision, final approval of the version submitted.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Simona Gaito reports a relationship with Parexel International that includes employment. The first and corresponding author, Dr Simona Gaito is still serving as a member of the editorial board for clinical oncology. Also, in October 2024, Dr Simona Gaito left her clinical role in the NHS and has been appointed by Parexel International as medical director, oncology. However, this work is related to her PhD project completed at the University of Manchester

in June 2024 and no conflicts of interests are to be disclosed in relation to the new role. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.clon.2025.103868>.

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