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Proton beam therapy image-guided radiotherapy training for RTTs – Experience from a single institution☆

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ABSTRACT

This study investigates whether an Image-Guided Radiation Therapy (IGRT) workbook and Cone Beam Computed Tomography (CBCT) case studies enhances Radiation Therapists' (RTTs) confidence analysing Proton Beam Therapy (PBT) CBCTs. An 11-participant questionnaire-based study was conducted to assess pre- and post-training confidence. Prior to training, RTTs exhibited higher confidence in photon CBCT decision-making over proton CBCT, highlighting the need for PBT-specific IGRT training, irrespective of prior photon experience. After completing the PBT IGRT workbook and case studies, RTTs experienced increased confidence in analysing PBT CBCTs. The workbook was particularly beneficial for junior RTTs, while experienced staff desired clearer guidance and real-life scenarios. The results show the IGRT workbook and CBCT case studies enhance RTTs' confidence in PBT CBCT analysis. PBT departments should consider these results for RTT led IGRT. Future work could involve adjusting training to account for participants' prior IGRT experience and conducting larger-scale studies to validate our results.

Introduction

Online daily volumetric image-guided radiotherapy (IGRT) has become standard practice for Therapeutic Radiographers/Radiation Therapists (RTTs) in photon beam therapy [1–5]. Numerous publications have addressed the training of RTTs in photon IGRT [6–11] and a limited number have explored RTTs' confidence in photon IGRT [12–14]. Advanced practice in IGRT, including complex decision-making and image approval, has been a natural progression for RTTs [9]. Nevertheless, there is a scarcity of evidence regarding the involvement of RTTs in IGRT for proton beam therapy (PBT). This aspect is significant considering the differing physical properties of photon beams and proton beams.

Photon radiotherapy plans are generally more robust to positional and anatomical variations than proton plans [15]. This robustness arises from the gradual dose fall-off of photon beams, which are relatively insensitive to tissue density changes along the beam path. In contrast, due to the sharp dose fall-off associated with the Bragg peak, proton plans can be more vulnerable to shifts in patient positioning and anatomical changes [15]. While this sharp dose fall-off allows for dose escalation to the clinical target volume (CTV) while minimising exposure to organs at risk (OAR) and normal tissue, density changes in the proton beam path can significantly alter the planned position of the Bragg peak, potentially compromising CTV coverage and increasing the dose to normal tissues and critical OAR [16,17]. These changes can be seen on cone beam computed tomography (CBCT)s, therefore, RTTs must comprehend the specific considerations and differences in CBCT analysis for PBT patients compared to photon patients. Furthermore, RTTs must recognise that action levels derived from CBCT analysis can vary between patients treated with photon radiotherapy and PBT, even for the same anatomical site. Therefore, training and assessments focused on PBT IGRT are essential for RTTs to develop the competence and confidence needed for analysing and making decisions on CBCTs for PBT patients.

There are currently only two National Health Service (NHS) PBT centres in the United Kingdom, and there is limited literature on RTT-led PBT IGRT practices. On Target 2 guidelines [1] and recent publications reporting advanced practice of RTTs leading in SABR, adaptive

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radiotherapy and MR-linear accelerators had to be reviewed [6–13]. The approaches used in these studies informed the development of IGRT training for a new service. Approaches utilised included: e-learning, presentations, workbooks, workshops, case studies and guidelines for practice. Pre and post questionnaires were commonly utilised [8,12,13]. Unlike photons, PBT presents unique challenges due to the distinct beam properties and the current gaps in RTT education and practical experience with PBT, making a direct adaptation from photon training not completely feasible.

This work introduces a tailored PBT IGRT workbook and CBCT case studies at one of the NHS PBT centres to assess RTT confidence in analysing and decision-making on PBT CBCTs. Confidence levels were measured before and after the completion of this specific PBT IGRT training.

Methodology

Development of the workbook and training cases

The PBT department commenced clinical service in December 2021. As it was a new service, resources were not available for evaluating RTT competence in reviewing PBT IGRT cases. In our established photon radiotherapy department, RTTs undergo verbal training with competent staff, combining offline review of existing patient 2D and 3D images and experiential online teaching.

To support PBT IGRT training, a tailored workbook was developed by experienced RTTs, including superintendents, team leads, and education/research RTTs. These RTTs were part of the core PBT team, who underwent intensive training which considered the Royal College of Radiologists' (RCR) On Target 2 guidelines [1]. Their training included observational days at PBT centres, PTCOG conferences, e-learning, and collaborative multidisciplinary sessions with the PBT physics team and consultant clinical oncologists. This enabled them to create and review the IGRT workbook, which was approved by a consultant clinical oncologist and physicist.

The PBT IGRT workbook covered the differing properties of photon and proton beams, and anatomical site-specific sections (brain, base of skull, head and neck, thorax, pelvis and craniospinal irradiation (CSI)). Each section included relevant anatomy, OAR volumes, imaging considerations, and changes observed on CBCT scans. It also addressed disease-related events affecting treatment suitability, decision-making, and dosimetric impacts in PBT. Screenshots from photon CBCTs were used for illustration. At the end of each section, a reference tool summarised key aspects for RTTs to assess when analysing PBT CBCTs. One-to-one training was provided for new or less experienced RTTs.

To complete the training package, a formative assessment was created using 9 CBCT cases (3 brain, 3 base of skull, 3 head and neck), selected from the photon department. These anatomical sites were chosen based on their anticipated use during the initial PBT clinical go-live phase. A PBT plan was created on the planning CT scans of the chosen photon patients by the PBT physics team to allow analysis of the CBCTs in the context of PBT. Gold-standard answers were created by the trained core PBT RTTs and approved by a physicist.

Upon completion of each anatomical section in the IGRT workbook, trainees analysed the 3 CBCTs for each anatomical site, documented their analysis, treatment decision following a traffic light protocol, justification for choosing this decision and a personal reflection in a standardised form (see Appendix A). Each case study was compared to the gold-standard answers, and feedback was provided to the trainee RTTs by the trained PBT superintendent RTTs.

Development of PBT IGRT pre- and post-questionnaires

Alongside the development of the PBT IGRT training workbook and case studies, two questionnaires were created (see Appendix B): one to be completed before receiving PBT IGRT training i.e. PBT IGRT workbook and PBT IGRT case studies, and a second to be completed after PBT IGRT training. These questionnaires were developed following CHERRIES guidance [18], on Target 2 [1] and previous photon IGRT publications [8,12–14]. The two questionnaires were developed collaboratively by a team of five senior RTTs, including a team leader RTT, three PBT superintendent RTTs (one of whom was an educational lead), and a research RTT. The team worked to ensure both grammatical accuracy and the elimination of potential bias in the content. The questionnaires contained questions that were unique to each questionnaire plus 7 that were identical to ensure analysis of comparative data. Eight RTTs piloted the questionnaires to test practicality, feasibility and to ensure the questions addressed the aim of this study. Open feedback allowed appropriate adjustments to be made before finalisation. The questionnaires were approved by the department governance group.

The questionnaires aimed to assess RTTs' confidence levels in analysing and making decisions on CBCTs using a Likert scale ranging from 1 (not very confident) to 5 (very confident). This approach has been previously utilised in photon IGRT training [12]. The pre-PBT IGRT questionnaire permitted the capturing of RTTs' confidence levels in analysing CBCTs in photon radiotherapy and establishing a baseline for their pre-training confidence in PBT IGRT. It was sent via email to trainee radiographers as soon as they joined the PBT department as part of their induction programme and it was ensured PBT IGRT training was not given until the questionnaire was completed.

The post-questionnaires were also sent via email and sought to gauge RTTs' confidence levels in analysing and making decisions on CBCTs after receiving PBT IGRT training. Respondents were encouraged to provide feedback on the usability and usefulness of the IGRT workbook, case studies, and overall training in the post-questionnaire.

Data collection and analysis

RTTs were provided a link to the pre-and post-questionnaires hosted on Google Forms. The data collected through the questionnaire was transferred to an Excel spreadsheet and stored in a secure location. During the training phase, the questionnaires were not anonymised for training purposes. Once the training was concluded, the questionnaires were anonymised specifically for the purpose of this analysis. The anonymised questionnaire results were stored and further analysed in Excel. It was ensured that all participants included in the study had no previous PBT or PBT IGRT experience or training. Descriptive statistics were employed to analyse the data and derive meaningful insights from the response. There were 11 respondents, with six questions related to their confidence in analysing and making decisions based on CBCTs for both photon and PBT patients. Thus, a total of 66 confidence scores were collected across six anatomical sites, including brain, base of skull, head and neck, thorax, pelvis, and CSI. Similar to Daly et al, percentage was derived from how many respondents scored their confidence as '4 = confident' or higher and this percentage was compared pre PBT IGRT training and post PBT IGRT training [12].

Results

Eleven participants completed the PBT IGRT workbook and CBCT case studies, as well as the pre- and post-IGRT training questionnaires.

The respondents had a range of radiotherapy experience, but none had any PBT IGRT experience. 46 % (5/11) were senior team leader RTTs (respondents 1 to 5), 36 % (4/11) were senior RTTs (respondents 6 to 9), and 18 % (2/11) were newly qualified junior RTTs (respondents 10 and 11). RTT responses regarding confidence in PBT are shown in Table 1.

Pre PBT IGRT training questionnaire

The survey results revealed that 82 % (9/11) of participants were aware of PBT-specific CBCT analysis considerations, and 82 % (9/11)

Table 1
RTT questionnaire responses for self-reported confidence in analysing and decision-making on PBT CBCTs pre and post PBT IGRT training.

Pre PBT IGRT training (n = 11)					
Anatomical site					
	1 – not very confident	2	3	4	5 – very confident
Brain	1	3	5	2	0
Base of skull	2	3	4	2	0
Head and neck	3	0	7	1	0
Thorax	2	1	7	1	0
Pelvis	2	1	5	3	0
CSI	4	4	3	0	0
Post PBT IGRT training (n = 11)					
Anatomical site					
	1 – not very confident	2	3	4	5 – very confident
Brain	0	0	0	1	10
Base of skull	0	0	2	5	4
Head and neck	0	0	0	4	7
Thorax	0	0	3	4	4
Pelvis	0	0	0	5	6
CSI	0	2	2	6	1

had prior experience with photon CBCTs. Confidence in analysing and decision-making on PBT CBCTs was generally lower compared to photon CBCTs (see Appendix C). Of the 66 confidence scoring responses in total (11 respondents scoring their confidence for brain, base of skull, head and neck, thorax, pelvis and CSI CBCTs), 72.7 % (48/66) of responses scored ‘4 = confident’ or higher in analysing and decision-making on photon CBCTs, whereas this was 13.6 % (9/66) for CBCTs for PBT patients.

Post PBT IGRT training questionnaire

All respondents (100 %) were aware of the specific considerations for analysing PBT CBCTs after training. Out of the 66 confidence scoring responses in total, responses scored ‘4 = confident’ or higher increased from 13.6 % (9/66) to 86.4 % (57/66) after the PBT IGRT training. Confidence improvements were observed across all anatomical sites (see Appendix D for comparison of confidence of individual respondents), with 100 % confidence increases for brain, head and neck, and pelvis cases. For base of skull, thorax, and CSI, most respondents showed heightened confidence, with some maintaining their pre-training confidence levels. One respondent (respondent 1) reported a decrease in confidence in analysing and decision making on PBT CSI CBCTs post PBT IGRT training.

Feedback on the PBT IGRT workbook

The post-questionnaire results revealed positive feedback regarding the PBT IGRT workbook and case studies. Five respondents rated the workbook as ’5 = extremely useful’, while five others rated it ’4 = useful’, and one rated it as ’3 = neutral’. Regarding the case studies, three respondents found them ’5 = extremely useful’, six rated them ’4 = useful’, one rated ’3 = neutral’, and one senior RTT rated ’2 = not useful’. As for the workbook’s positive impact on knowledge and confidence, three respondents strongly agreed, six agreed, and two were neutral. Suggested improvements (see Appendix E) included using real PBT patient cases.

Discussion

This study investigates the confidence and decision-making abilities of RTTs in PBT IGRT. To our knowledge, it is the first to specifically assess RTTs’ confidence in PBT. The findings show that prior to training, respondents were more confident in photon CBCT analysis, which is expected due to the novelty of PBT and the lack of specific IGRT training. Similar studies on photon IGRT training [8,12–14] have highlighted the development of confidence in image interpretation through structured training programs, with recent evidence showing that targeted training improves skills more effectively than experience alone [19,20].

Our study supports this by demonstrating that after completing the PBT IGRT workbook, RTTs showed increased confidence in PBT CBCT analysis across all anatomical sites. This improvement is consistent with findings in previous research, where training was linked to higher proficiency in decision-making and confidence [6–13]. These results suggest that the workbook is an effective resource for enhancing decision-making skills and image interpretation, similar to the benefits seen in photon IGRT training programs.

The reported reason for the decline in confidence for PBT CSI by one respondent was the absence of real PBT scenarios. It is possible our training may have highlighted the technique complexity of CSI and as a result they may have realised their initial confidence was misplaced. The need for tailored training resources has been emphasised in studies on photon IGRT, highlighting the critical role of practical, scenario-based training in improving RTTs’ ability to interpret images accurately and make decisions about treatment [8,11–13]. Our study contributes to this body of knowledge by showcasing how structured, offline case review training can boost RTT confidence even in the absence of real clinical cases, which aligns with recommendations from other training programs [8,11–13] Moreover, this study highlights the importance of providing adequate training early in the process when implementing a new clinical service, such as PBT, to ensure that RTTs are well-equipped to handle the complexities of PBT CBCT analysis when the service becomes fully operational.

Once our service is clinical, in addition to the training in this study, we envisage to add online analysis and decision-making on PBT CBCTs by RTTs under close supervision from the PBT superintendents to the PBT IGRT competency programme. As with the role out of any training programme, it is important to consider how we maintain confidence and competence of RTTs [11,20], especially as we are a rotational photon radiotherapy and PBT service.

However, certain limitations of the study must be acknowledged. First, not all respondents received the same in-person training, potentially introducing bias. Additionally, the sample size was small due to the nascent stage of the PBT service. While photon IGRT training publications were referenced, the use of validated tools to measure confidence was not incorporated into the evaluation. Future studies should use a larger sample size and consider integrating these tools for both photon and proton IGRT training programs to standardise evaluations and provide a clearer understanding of their impact on RTTs’ confidence in clinical practice.

This study underscores the need for tailored training resources that address the specific demands of PBT IGRT, especially given the rotational workforce of RTTs experienced in both photon radiotherapy and PBT. While the training package was beneficial for all participants, it is important to adapt it based on the individual’s IGRT experience level.

Conclusion

In conclusion, RTTs should be trained in analysing and decision-making on CBCTs for PBT patients, regardless of previous IGRT experience. In our experience, the introduction of the PBT IGRT workbook and CBCT case studies as a PBT IGRT training tool was successful in helping to increase the confidence of RTTs in analysing and decision-making on PBT CBCTs. These results suggest that future PBT departments seeking to train their staff in PBT IGRT before treating PBT patients can benefit from adopting a similar training approach. By utilising CBCTs of photon patients and contextualizing them within the PBT setting, teaching through an IGRT workbook, and assessing performance through offline review of photon CBCT cases in a PBT context, RTTs can acquire the necessary skills and knowledge for effective PBT IGRT. Future studies should include a larger sample size and should be adapted according to previous IGRT experience as a one-size-fits-all package may not be optimal for all individuals.

Declaration of competing interest

The authors 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.tipsro.2024.100299.

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