A Service Evaluation of the Immobilisation used for Craniospinal Irradiation at the Proton Beam Therapy Centre at The Christie NHS Foundation Trust

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Introduction

Craniospinal Irradiation (CSI) is the delivery of radiation therapy for the treatment of specific primary brain and spinal tumours[1]. A multi-isocentre technique is adopted to deliver radiation to the whole brain and spinal cord. Numerous modalities have been utilised for CSI delivery including photons, electrons, and protons. However, protons offer a superior dose distribution with highly conformal plans compared to other modalities (Figure 1), favourably reducing dose to the adjacent organs at risk (OARs)[2,3]. The consequent advantage is to decrease the long-term side effects to the patient associated with this technique, with the young patient demographic particularly benefiting as the types of cancers treated with CSI are more prevalent in the younger population[4].

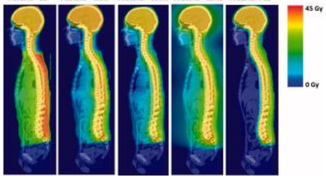

Figure 1. Observed dose distributions for different CSI modalities including; 3D conformal radiotherapy, intensity modulated radiotherapy, volumetric modulated arc therapy, tomotherapy, and pencil beam scanning delivered with protons (figure taken from Seravelli *et al.*[3]). It illustrates that the proton plan offers the most conformal plan with the least dose to OARs.

Following a period of cyclotron downtime patients were re-scanned due to unsatisfactory mandible position and subsequent exit dose through the oral cavity on the photon back-up plan. In response, the Proton Beam Therapy (PBT) service updated the immobilisation used for the CSI technique to satisfy both treatment modalities (Figure 2 and Figure 3). Updating the immobilisation had two intended benefits;

- Improving patient position in the PBT department where frequent on-treatment set-up issues at the superior isocentre due to c-spine flexion were observed.
- Improving the head position in case the need for photon contingency arose.

Figure 2. Original immobilisation

Figure 3. Updated immobilisation

Aims

A retrospective service evaluation was conducted with the aim of assessing both the original and updated immobilisation focussing on three key areas; the residual error, the use of 2DkV gross error check (GEC) images and total patient treatment time.

Methods

A sample of 21 patients were identified over a 12-month period, 9 on the original immobilisation and 12 on the updated immobilisation. To assess the residual error, all post-correction verification images for the superior and inferior isocentre were retrospectively analysed offline. The region of interest was placed over stipulated aspects of the volume and the images were re-registered using a bony match. Using methods detailed in On Target[5], the overall mean residual error and the population random error were calculated for the verification images in the treated position and the retrospectively re-registered images for both isocentres. The Mann Whitney U test was used to determine if there was any statistically significant difference in the residual errors for both isocentres. The number of GEC images required on cone beam computed tomography (CBCT) days were recorded for both immobilisation types and the average calculated per isocentre. Furthermore, a time-in-motion audit was completed for all treatment fractions available for each patient and the average calculated.

References

1. NHS (2020). Clinical Commissioning Policy Statement Proton Beam Therapy for Craniospinal Irradiation in Adults (201003P) [URN:1841]. [online] Available at: https://www.england.nhs.uk/wp-content/uploads/2020/10/1841-Proton-Beam-Therapy-for-Craniospinal-Irradiation-in-Adults-Policy.pdf [accessed on 9th November 2020)] 2. Cox, M, Kusters J, Gidding C, Schieving J, van Lindert E, Kaanders J and Janssens G. (2015). Acute Toxicity Profile of Craniospinal Irradiation with Intensity-Modulated Radiation Therapy in Children with Medulloblastoma: A Prospective Analysis. ***Radiation Oncology.*** 10 (241) pp1-9 DOI:10.1186/s13014-015-0547-9 3. 3. Seravali E, Bosman M, Lassen-Ramshad Y, Vestergaard A, Oldenburger F, Visser I, Koutsouveli E, Paraskevopolou C, Horal G, Ajithkumar T, Timmermann B, Fuentes C, Whitfield G, Marchant T, Padovani L, Garnier E, Gandola L, Meroni S, Hoeben B, Kusters M, Alpetite C, Losa S, Goudijl F, Magelssen, Egeberg Evensen M, Saran F, Smyth G, Rombi B, Righetto R, Kortmann R and Janssens G. (2018). Dosimetric Comparison of Five Different Techniques for Craniospinal Irradiation Across 15 European Centers: Analysis on Behalf of the SIOP-E-BTG (Radiotherapy Working Group). Acta Oncologica, 57(9), 1240-1249. Doi:10.1080/0284186x.2018.14655884. The Royal Marsden NHS Foundation Trust, (2021). Medulloblastoma/PNET. [online] Available at: https://www.royalmarsden.nhs.uk/your-care/cancer-types/paediatric-cancers/medulloblastomapnet [Accessed on 30th January 2021]. 5. The Royal College of Radiologists. (2008). *On Target: Ensuring Geometric Accuracy in Radiotherapy*. 1st ed. [pdf] London:Royal College of Radiologists Available at: https:// www.rcr.ac.uk/system/files/publication/field_publication_files/BFCO%2808%295_On_target.pdf [Accessed on November 19th 2020].

Results

Residual error has decreased for the SUP isocentre with the use of the new immobilisation with minimal changes in residual error for the INF isocentre. However, the main issues with the original immobilisation were in relation to the SUP isocentre. The Mann-Whitney U test showed that there was a statistically significant difference in residual error for SUP A/P, INF L/R and INF rotation, seen in table 1. All show a p-value closer to zero for the updated immobilisation, a decrease in residual error implies an improved treatment position, suggesting the dose is being delivered where it was planned.

Table 1. Results from the Mann Whitney U test

Variable	Test Statistic	Effect Size, r (95% CI)	P-value
SUP A/P	9486	0.152 (0.034,0.262)	0.009
SUP S/I	9913	0.110 (-0.004,0.222)	0.060
SUP L/R	10290	0.063 (-0.054,0.188)	0.283
SUP Pitch	11188	-0.028 (-0.147,0.081)	0.630
SUP Roll	9782	0.090 (-0.033,0.209)	0.125
SUP Rotation	11166	-0.026 (-0.146,0.088)	0.652
INF A/P	10875	-0.011 (-0.122,0.103)	0.857
INF S/I	10730	0.007 (-0.101,0.120)	0.904
INF L/R	8889	0.197 (0.082,0.300)	<0.001
INF Pitch	10830	-0.004 (-0.115,0.112)	0.950
INF Roll	11670	-0.074 (-0.188,0.042)	0.209
INF Rotation	8332	0.210 (0.090,0.327)	<0.001

The average time taken to treat CSI patients has decreased from 72 minutes to 65 minutes. Figures 4 and 5 display the average time for the two immobilisation. Averages have decreased for treatment times for all patient groups.

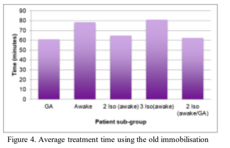

Figure 4. Average treatment time using the old immobilisation

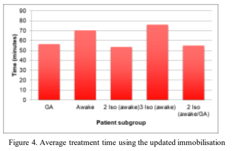

Figure 4. Average treatment time using the updated immobilisation

The number of GEC images used for CSI patients prior to CBCT has decreased with the updated immobilisation, with no more than 1 GEC image being used for both the MID and the INF isocentre for the updated immobilisation.

Table 2. Descriptive statistics for GEC usage on the original immobilisation

	SUP	MID	INF
Average	1.5926	1.2	1.0278
Standard Deviation	1.1669	0.4104	0.1667

Figure 4. Descriptive statistics for GEC usage on the original immobilisation, patient A was a medical anomaly so results were calculated with and without patient A

	SUP	MID	INF
Average	1.6087	1	1
Standard deviation	1.4138	0	0
Average excluding Patient A	1.4138	1	1
Standard Deviation excluding Patient A	0.6763	0	0

Discussion

Numerous improvements in residual error have been seen with the updated immobilisation and on average residual error is closer to zero. This gives increased confidence that the dose delivery is closer to the planned nominal case. There has been a decrease in the incidence of GEC images and with updated immobilisation, the treatment time on average has decreased. As a result of the findings from this service evaluation, the GEC image has been removed from the standard treatment pathway for CSI patients, only to be re-introduced when required. The concomitant dose for CSI patients as a result of imaging is therefore reduced. The treatment appointment slot for CSI patients has decreased from 90 minutes to 60 minutes and 75 minutes for 2 isocentre and 3 isocentre treatments respectively. Future service evaluations assessing treatment times may allow for further decrease in appointment length following the removal of the GEC image. Limitations of this service evaluation include both the time constraints associated and the implications of the COVID-19 pandemic resulting in a small patient population. Future studies may allow for a larger population, with the continual ramp up of the proton department in addition to the expansion of the indications list following the pandemic, thus, further increasing the validity of results drawn.

Conclusions

Patient set-up has been improved with the updated immobilisation, with a decrease in residual error noted for certain translations and rotations. Re-set-ups from GEC images have decreased using the updated immobilisation, improving patient experience due to decreased time on the bed whilst also decreasing concomitant dose to the patient. The appointment slot for CSI patients has decreased, allowing more capacity for other patients to be scheduled, and fitting closer to the PBT business case model for appointment slots.

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