IMPLEMENTATION OF TIOJ-IMRT FOR CRANIOSPINAL IRRADIATION: A CASE REPORT AT ASI UKPO COMPREHENSIVE CANCER CENTRE

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Abstract— **Craniospinal Irradiation (CSI) is a technique used in radiation therapy to deliver a prescribed dose to the entire cranial-spinal axis. CSI was 50.4 Gy/28# was prescribed for the treatment of a 34-year-old male who presented with malignant hemangioblastoma. The treatment was in two phases - craniospinal irradiation (39.6 Gy/22#) and a posterior fossa boost (10.8 Gy/6#). The entire field length (cranium to lumbar spine) was 59.8 cm. An advanced technique using Intensity Modulated Radiation Therapy (IMRT) called Three-Isocentre Overlap Junction (TIOJ) was implemented for the treatment of the patient. The TIOJ-IMRT plan had three isocentres: one for the posterior fossa and two for spine. The isocentres were spaced equidistant to each other (18.6 cm) with an overlap. 11 IMRT photon beams were optimized simultaneously. This comprised of 5 cranial beams (gantry angles 0^0, 40^0, 95^0, 265^0, 320^0), 3 upper spine (145^0, 180^0, 215^0) and 3 lower spine beams (145^0, 180^0, 215^0). Collimator angle was set at 0^0 with no couch rotation. The isocentres were selected such that they were on the same anterior-posterior and lateral planes, requiring only longitudinal movement of couch between isocentres. From the result, the use of TIOJ-IMRT technique for Craniospinal Irradiation showed adequate coverage of PTVs ($V_{95\%} > 99\%$), minimal hotspot ($V_{105\%} < 2\%$) and sparing of critical OARs (lungs, heart, bowel, cochlea, lens, optic structures).**

Keywords— **Craniospinal Irradiation, Three-Isocenter Overlap Junction, IMRT.**

I. INTRODUCTION

Craniospinal Irradiation (CSI) is a technique used in radiation therapy to deliver a prescribed dose to the cranial-spinal axis. It is often implemented for treatment of childhood medulloblastoma [1]. CSI is a major treatment technique for primary tumors. Some of the tumors commonly treated are radio-sensitive malignant tumors of the meninges, medulloblastoma, high-risk germ cell tumors. CSI comprises of complex anatomical structures which demands complex treatment planning and often requires setting multiple isocentres and matching large number fields to obtain acceptable plans [2]. For adults, the use of CSI is more complicated because of the very long field length (> 54 cm). With the advent of Intensity-Modulated Radiotherapy (IMRT) techniques in radiation oncology, there has been an improvement on the conventional 3D treatment delivery by the combination of the inverse treatment planning with optimization and computer-controlled intensity modulation of the radiation beam [3]

Early discoveries for IMRT have been its application in the boost field in the treatment of medulloblastoma in children. Consequently, a major concern with the use of IMRT has been the probability of the resultant effect of local failures. This is so because the high-dose region surrounding the clinical target volume (CTV) is lower in comparison with the target volume in 3D radiotherapy [4, 5]. Studies have shown that as far back as 1996, IMRT has been used to treat the tumor bed (TB) and/or posterior fossa (PF) during a RT boost portion for medulloblastoma. However, recent innovations in neuroimaging have triggered various researchers to treat the tumor bed (TB) with the inclusion of margins to full doses during the boost portion of the RT course instead of the entire posterior fossa (PF).

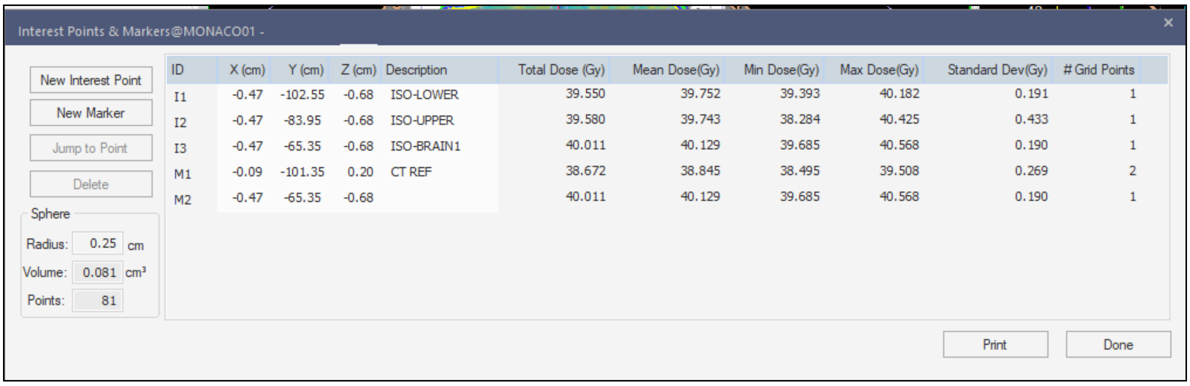
The uniqueness of IMRT techniques that makes it suitable for CSI treatment are:

a) For complex target volumes, IMRT offers better conformity index (CI) and homogeneity index (HI) than conventional 3D RT.
b) The use of IMRT in inverse treatment planning minimizes the complexities of planning and implementation. [2,6]

The implementation of the three-isocentre overlap junction (TIOJ) IMRT in the treatment of CSI has shown to simplify the implementation of the treatment plan, acceptable CI and HI, and hence reduce the time needed for planning and delivery. This is in comparison to other IMRT techniques: the three-isocentre jagged junction (TIJJ) earlier proposed by Cao et al [7,8,9,10]

II. MATERIALS AND METHODS

A 34-year-old male presented with a diagnosis of malignant hemangioblastoma. Patient is unable to walk, power lower limb (0/5), power upper limb (3/5), weakness in the right side, urinary and fecal incontinence. Patient has had paraparesis in April 2019 and has undergone two surgeries (2010 & 2019) for cerebellar hemangioblastoma-brain and spine. MRI and CT conducted prior to radiotherapy, shows thickening of the cervicothoracic segment of the spinal cord with metastatic infiltration 50.4 Gy/28# was prescribed for the patient to receive in two phases: 39.6 Gy/22# and 10.8 Gy/6# for the craniospinal irradiation and posterior fossa respectively. The three-isocentre overlap junction technique was employed for this plan. The entire field length of patient measuring from cranium to lumbar spine was 59.8 cm. Three isocenters were created – 1 for cranium and 2 for spine. The isocentres were spaced 18.6 cm equidistant from each other and overlap as shown in Figure 1. The isocentres were selected in the sagittal plane in order to be within the treatment fields i.e. on the same lateral and antero-posterior-position.



ID	X (cm)	Y (cm)	Z (cm)	Description	Total Dose (Gy)	Mean Dose(Gy)	Min Dose(Gy)	Max Dose(Gy)	Standard Dev(Gy)	# Grid Points
I1	-0.47	-102.55	-0.68	ISO-LOWER	39.550	39.752	39.393	40.182	0.191	1
I2	-0.47	-83.95	-0.68	ISO-UPPER	39.580	39.743	38.284	40.425	0.433	1
I3	-0.47	-65.35	-0.68	ISO-BRAIN1	40.011	40.129	39.685	40.568	0.190	1
M1	-0.09	-101.35	0.20	CT REF	38.672	38.845	38.495	39.508	0.269	2
M2	-0.47	-65.35	-0.68		40.011	40.129	39.685	40.568	0.190	1

Figure 1: Isocentre coordinates for the treatment plan.

A total of 11 beams were simultaneously optimized: 5 cranial beams – 0^0, 40^0, 95^0, 265^0, 320^0, 3 upper spine – 145^0, 180^0, 215^0 and 3 lower spine - 145^0, 180^0, 215^0. Collimator angle was set at 0^0 and there was no couch rotation. Patient-Specific Quality Assurance (PSQA) was performed with the PTW Octavius $D for each isocentre.

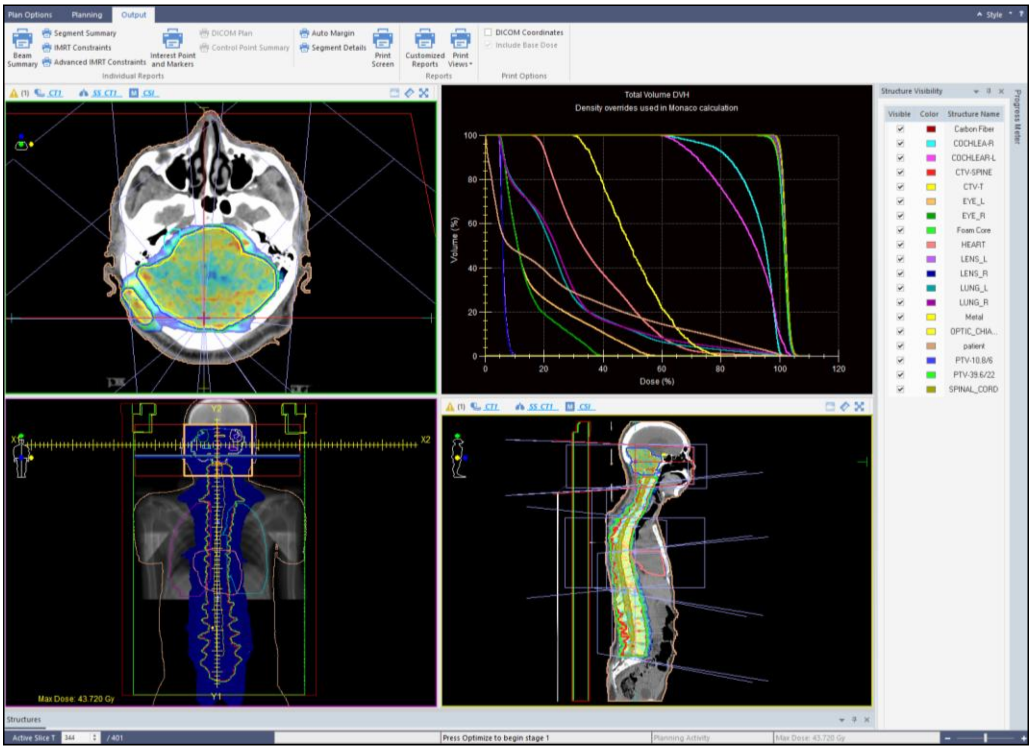


Figure 2: Isodose curves showing PTV and OAR coverage.

III. RESULTS AND DISCUSSION

From Figure 2, after optimization, the DVH curves showed that the CSI plan had 95% of the prescribed dose covering 99.26% volume of the PTV and the maximum dose 43.72Gy covering less than 5% of the remaining volume. The reference doses for the OARs were within tolerance limits. Dose to Spinal cord < 45Gy; dose to brainstem < 54Gy; mean dose to the cochlear < 45Gy and maximum dose to the lens < 7Gy while other Organs at Risk (OARs) were within tolerance limits. The treatment fields for the CSI was given simultaneously.

DVH Statistics Report

Elekta
Monaco 5.51.10

Hospital/Clinic:
Patient Name:
Patient ID:
Plan Name: CT1:SS_CT1:CSI
Description:
Comment: Width, length, wedge are MONACO values. XYZ positions are in MONACO coordinates.
Density overrides used in Monaco calculation

Doc Number:
Save Plan Date/Time: 29-Nov-22 1:56:58 PM
Print Date/Time: 30-Nov-22 8:29:01 AM
Workstation ID: MONACO01 192.168.1.10

Structure	Volume (cm³)	Plan Name	Min Dose Gy	Max Dose Gy	Mean Dose Gy	Ref. Vol. (cm³)	Ref. Vol. (%)	Ref. Dose Gy		Dosimetric Criterion	% Inside Calc Vol	Inside StudySet
PTV-39.6/22	1745.662	CSI	28.163	43.720	40.181	20.825	1.19	41.580	✓	V41.58Gy < 5 %	100.00	Yes
	1745.662	CSI	28.163	43.720	40.181	1732.668	99.26	38.000	✓	V38Gy > 95 %	100.00	Yes
LENS_L	0.252	CSI	1.840	4.024	2.465	0.000	0.00	4.024	✓	Dmax < 7 Gy	100.00	Yes
LENS_R	0.240	CSI	1.901	3.922	2.466	0.000	0.00	3.922	✓	Dmax < 7 Gy	100.00	Yes
patient(Unsp.Tiss.)	25508.006	CSI	0.024	43.224	9.373	0.000	0.00	43.224	✓	Dmax < 43.56 Gy	100.00	No
COCHLEA-R	1.384	CSI	24.282	40.516	36.618				✓	Dmean < 38 Gy	100.00	Yes
COCHLEAR-L	1.708	CSI	23.217	41.191	35.069				✓	Dmean < 38 Gy	100.00	Yes
EYE_L	9.288	CSI	1.740	23.037	6.725				✓	Dmean < 35 Gy	100.00	Yes
EYE_R	7.474	CSI	1.641	16.050	5.558				✓	Dmean < 35 Gy	100.00	Yes
HEART	403.586	CSI	5.509	40.597	14.742	24.894	6.17	25.000	✓	V25Gy < 10 %	100.00	Yes
LUNG_L	1033.900	CSI	1.612	41.962	10.239	57.894	5.60	25.000	✓	V25Gy < 10 %	100.00	Yes
LUNG_R	1044.420	CSI	1.651	42.673	10.691	75.373	7.22	25.000	✓	V25Gy < 10 %	100.00	Yes
OPTIC_CHIASM	0.696	CSI	11.644	32.076	19.974	0.000	0.00	32.076	✓	Dmax < 54 Gy	100.00	Yes
SPINAL_CORD	75.604	CSI	38.047	42.984	40.508	0.000	0.00	42.984	✓	Dmax < 45 Gy	100.00	Yes

Resolution: 0.10 cm **Bin Width:** 0.010 Gy

All DVH data is based on DVH resolution and bin width for ALL beams with calculated dose.

Approved by: Name:__________ Signature__________ Date:__________

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Figure 3: DVH statistics report showing doses to organs at risk (OAR)

In the sum plan of the CSI and posterior fossa as shown in Figure 3, the dosimetric criterion for all OARs was well below tolerance limits, while figure 4 showed both PTVs (CSI + Posterior Fossa) had 95% of the prescribed dose covering 99% of the volume. The maximum dose to the patient was 52.9Gy of the prescribed dose. This value is less than 7% of the prescribed dose and the criterion was set 53.9Gy. PSQA was implemented for each of the isocentres with the PTW Octavius 4D. The three-isocenter overlap junction (TIOJ) passed the PSQA test with 96.6% passing criteria.

Structure	Volume (cm³)	Plan Name	Min Dose Gy	Max Dose Gy	Mean Dose Gy	Ref. Vol. (cm³)	Ref. Vol. (%)	Ref. Dose Gy		Dosimetric Criterion
PTV-39.6/22	1744.512	CSI	27.986	43.612	40.181					
SPINAL_CORD	75.496	BRAIN+CSI	38.367	44.319	40.580	0.000	0.00	44.319	✓	Dmax < 45 Gy
	75.496	BRAIN	0.000	3.324	0.085	0.000	0.00	3.324	✓	Dmax < 45 Gy
	75.496	CSI	38.090	42.919	40.508	0.000	0.00	42.919	✓	Dmax < 45 Gy
patient(Unsp.Tiss.)	25515.160	BRAIN+CSI	0.030	52.981	9.812	0.000	0.00	52.981	✓	Dmax < 53.928 Gy
	25515.160	BRAIN	0.000	11.217	0.454	0.000	0.00	11.217	✓	Dmax < 53.928 Gy
	25515.160	CSI	0.025	43.155	9.374	0.000	0.00	43.155	✓	Dmax < 53.928 Gy

Resolution: 0.10 cm **Bin Width:** 0.010 Gy

All DVH data is based on DVH resolution and bin width for ALL beams with calculated dose.

Figure 4: PTV coverage for Brain and CSI

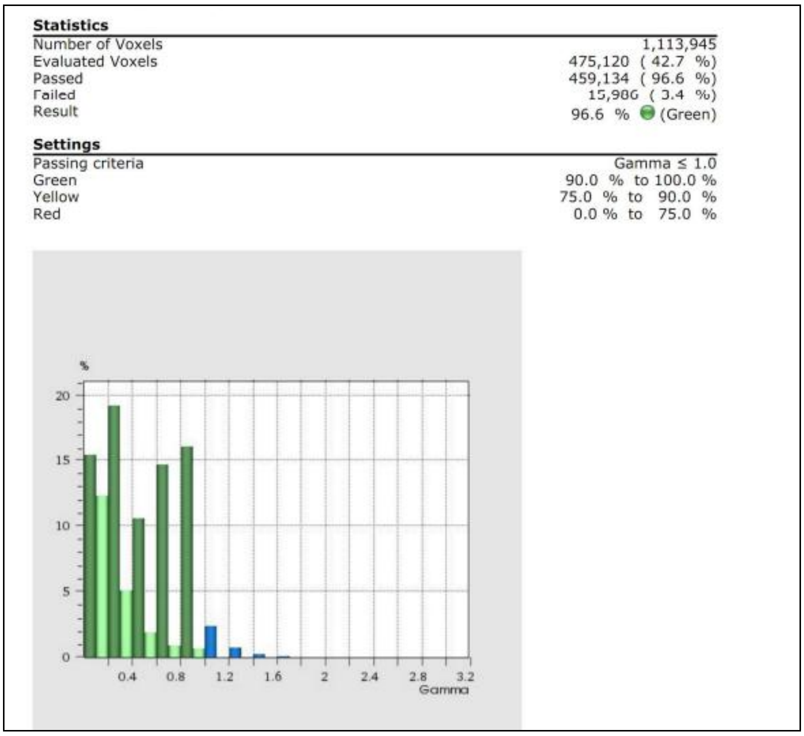

Figure 5: Gamma Index Analysis of PSQA

Patient Specific Quality Assurance (PSQA) was implemented with PTW Octavius 4D for each isocentre and the result of the Gamma Index Analysis shown in figure 5.

IV. CONCLUSION

The use of IMRT technique showed adequate coverage of PTVs ($V_{95\%}$Gy > 99% of volume) and minimal hotspot ($V_{105\%}$ Gy < 2%). Use of IMRT for CSI has been shown to improve local control of tumour. Special care must be taken to move couch between fields by measured distance when treating

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REFERENCES

1. 1 Mohammad Abu Ashour. Craniospinal Irradiation (CSI). Jordanian Royal Medical Services

2. 2 Wang Z, Jiang W, Feng Y. A simple approach of three-isocenter IMRT planning for Craniospinal Irradiation. Radiation Oncology 2013, 8: 217.
3. 3 Teh B.S., Woo S.Y., Butler E.B. Intensity Modulated Radiation Therapy (IMRT): a new promising technology in radiation oncology. Oncologist 1999; 4: 433 – 442
4. 4 Paulino A., Mazioom A., Teh B. Local Control After Cranospinal Irradiation, Intensity-Modulated Radiotherapy Boost and Chemotherapy in Childhood Medulloblastoma. Cancer 2011; 117: 635 – 41, VC 2010 American Cancer Society.
5. 5 Merchant T.E., Kun L.E., Krasim M.J. Multi-institution prospective trial reduced dose craniospinal irradiation (23.4Gy) followed by conformal posterior fossa (36Gy) and primary site irradiation (55.8Gy) and dose-intensive chemotherapy for average risk medulloblastoma. Int. J. Radiat Oncol Biol Phys. 2008: 70; 782 – 787
6. 6 Prabhu R.S., Dhakal R., Plantino M., Bahar N., Meaders K.S., Fasola C.E., Ward M.C., Heinzerling J.H., Sumrall A.L., Burri S.H. Volumetric Modulated Arc Therapy (VMAT) Craniospinal Irradiation (CSI) for Children and Adults: A practical guide for implementation. Pract. Radiat. Oncol 2022 Mar – Apr; 12(2)
7. 7 Cao F, Ramaseshan R., Corns R., Harrop S., Nuraney N., Steiner P., Aldridge S., Liu M., Carolan H., Agranovich A., Karavat A: A three-isocenter jagged junction IMRT approach for craniospinal irradiation without beam edge matching for field junctions. Int. J. Radiol Oncol Biol Phys 2012, 84: 648 – 654.
8. 8 Nanos C.A., Abatzoglou I., Koukourakis M.I. Volumetric Modulated Arc Therapy (VMAT) Craniospinal image guided radiotherapy and chemotherapy for high-risk medulloblastoma in adults: A case report with analysis of the technique. J case Rep Images Oncology 2021:7
9. Lee Y., Kim A.T., Zhao P., Karotki A. Practical Dose Delivery Verification of Craniospinal IMRT. J. Appl. Clin. Med. Phys. 2015 Nov 8; 16(6): 76-83
10. Paulino A.C., Skwarchuk M. Intensity-Modulated Radiation Therapy in the treatment of Children. Med Dosim. 2002; 27: 115 – 120

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