DEVELOPMENT AND EVALUATION OF IMRT TECHNIQUE FOR CRANIOSPINAL AXIS RADIOTHERAPY PLANNING

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Abstract- **This study aimed to evaluate and compare the dose distribution of the CSI technique using Helical IMRT with conventional LINAC_IMRT and VMAT. Five patients diagnosed with Medulloblastoma (High and Medium Risk) were treated with Craniospinal Irradiation at our institute by Helical Tomotherapy (V3.3.1.3). The plans were replanned for conventional techniques, IMRT, and VMAT using Eclipse V15.6. The prescribed dose was 36 Gy in 20 fractions for high risk and 23.4 Gy in 13 fractions for medium risk. For planning, PTV was split into two parts, one in PTV-Brain (cranial contents) and the second in PTV-Spine (inferiorly from C1) to improve dosimetry. As per our studies, for *Spine*- the mean values of D_{max}, $V_{107\%}$, $V_{95\%}$, CI, HI in case of IMRT were 37.985 cGy, 0%, 97.625%, 0.765, 0.0725; for VMAT were 38.135 cGy, 0%, 97.325, 0.967, 0.0725; and for IMRT_HELICAL were 38.72cGy, 0.025%, 96.35%,0.96, 0.0975. Similarly, for *Brain* - the mean values of D_{max}, $V_{107\%}$, $V_{95\%}$, CI, HI in case of IMRT were 38.4025 cGy, 0%, 98.225%, 0.977, 0.0625; for VMAT were 38.375 cGy, 0%, 96.575%, 0.965, 0.1125; for IMRT_ HELICAL 39.34, 0, 98.275, 36.55, 0.98, 0.077. For *Brainboost* - the mean values of D_{max}, $V_{107\%}$, $V_{95\%}$, CI, HI in case of IMRT were 18.875 cGy ,0%, 97.875%, 0.975; for VMAT were 19.1075 cGy ,0%, 98.075%, 0.9725, 0.0775; for IMRT_HELICAL 19.24 cGy, 0%, 98.7%, 1.0125, 0.3275 respectively. The D_{max} for serial OARs for *IMRT* technique ranges from 25 - 40 Gy for Eyes, 6.5 - 8.2 Gy for Lens, 25 - 40 Gy for Optic Nerve, 54-56 Gy for Brainstem, 43-56 Gy for Chiasm and D_{mean} for parallel OARs ranges from 13-22 Gy for Parotids, 4-8 Gy for Lungs, 5-30 Gy for Esophagus, 4-13 Gy for Heart. For *VMAT*, D_{max} ranges from 22- 40 Gy for Eyes, 7.2-10 Gy for Lens, 27-41 Gy for Optic Nerve, 54-56 Gy for Brainstem, 30-50 Gy for Chiasm and D_{mean} ranges from 10-20 Gy for Parotids, 5-13 Gy for Lungs, 11-22 Gy for Esophagus, 4-14 Gy for Heart. For *IMRT_HELICAL*, D_{max} ranges from 16-32 Gy for Eyes, 4-6 Gy for Lens, 26-40 Gy for Optic Nerve 37-54 Gy for Brainstem, and 28-50 Gy for Chiasm and D_{mean} ranges 9- 19 Gy for Parotids, 4-8 Gy for Lungs, 5-22 Gy for Esophagus, 4-14 for Heart. Helical tomotherapy offers clear dosimetric advantages, good target coverage with high homogeneity and conformity, and OAR sparing. However, higher MU and longer beam-on time mean a potentially higher risk of secondary malignancy.**

Keywords- **Craniospinal Axis Irradiation, HELICAL IMRT**

I. INTRODUCTION

Craniospinal irradiation encompasses radiation therapy aimed at the entire craniospinal axis to eliminate tumor cells found in the cerebrospinal fluid. Craniospinal irradiation (CSI) is indicated in patients with malignant central nervous system (CNS) tumors that tend to develop cerebrospinal fluid (CSF) dissemination [1-3].

This advanced radiotherapy (RT) technique targets the cranium and spinal cord, involving the movement of junctions along the lateral brain and spinal fields. It is highly complex technically because it requires encompassing a challenging clinical target volume that includes the entire brain, the full length of the spinal axis, and the surrounding meninges.

Under current practice, when combined with chemotherapy, the radiotherapy dose is 23.4 Gy for the craniospinal axis standard-risk medulloblastoma and 36 Gy for those with high-risk disease. In both cases, it is followed by a conformal boost to the posterior fossa, up to a total dose of 54 Gy. Conventionally, the brain is treated with lateral opposed fields, and a direct posterior field is used for the spine.

Currently, CSI is the main treatment option for patients with *medulloblastoma*, a particular type of CNS tumor that can spread into the craniospinal fluid of the neural axis. Long-term side effects associated with the treatment of the brain include neurocognitive deficits, hearing impairment, growth hormone deficiency, and cataracts [4-9]. CSI plays a very important role in the treatment of medulloblastoma and is often required for cases involving germ cell tumors, non-Hodgkin lymphoma, or anaplastic ependymoma with spinal metastasis.

A. Patient positioning and Immobilization for treatment:

Mostly, CSI is delivered to patients in the prone position using lateral opposed fields covering the whole brain and upper cervical spine matched to a direct posterior field that extends inferiorly to cover the caudal extent of the thecal sac and to confirm the isocenter position and field junction on the skin. However, the prone position is often discomforting for the patient and can cause significant patient movement at times during prolonged treatment. Supine position allows easy access to the oral cavity and airway when general anesthesia (GA) is required and is more comfortable for most

patients, making the position easier to hold throughout treatment, which reduces the risk of intra-fraction motion [10,11]. Weekly junction displacements, known as feathering, by moving the treatment field junction weekly, have been adopted to reduce the larger over- or underdose in the junction areas.

B. Treatment Planning:

Defining a volume is a prerequisite for meaningful 3D treatment planning and accurate dose reporting (dose uniformity within 7% and 5% of the dose delivered to a well-defined prescription point). Treatment plan acceptance is largely based on dosimetric data such as dose-volume histogram (DVH) statistics for targets, normal tissues, and isodose line distributions.

The basic Fundamental treatment planning of CSI includes the use of lateral parallel opposed fields for the cranium and upper cervical spinal cord, and the use of a matching posterior spinal field to the cranial field, including the full spinal subarachnoid space. The treatment volume for CSI includes the entire CNS subarachnoid space, and the inferior border is extended below S2 to include the thecal sac. As there is a large percentage of the patient's anatomy that is exposed to some level of radiation dose, it can only produce good effects if it is delivered in an appropriate clinical context.

Feathering after 5 to 7 fractions smoothies out any overdose or underdose over a longer segment of the cord. It is relatively simple and easy to verify the delivery of CSI in the prone position due to direct visualization of the field light on the patient's surface. Over the last decade, many techniques for CSI have evolved to decrease the dose to the organs outside the target volume, in particular, the thyroid, heart, and intestines.

C. Various types of Treatment Modality:

To achieve the basic fundamental treatment planning, the 2D technique is most commonly used in centers that lack advanced linear accelerators for conformal treatment planning. The 2D approach results in dose inhomogeneity, especially at the beam junction(s), and a significant dose anterior to the spinal target volume. Traditionally, the 3D conformal radiotherapy (CRT) technique is applied for CSI by using two lateral opposed photon beams for the brain and matching one or more posterior photon beams for the spine. However, this method has a few drawbacks; the large dose gradient between each treatment field, even small errors in positioning, can result in unintended high or low doses to the spinal cord. Also, 3DCRT usually sets up the patient in the prone position to confirm the isocenter position and field junction on the skin, which is discomforting for the patient that causing significant patient movement at times during prolonged treatment. Manual shifting of field junctions between fractions is complex and increases set-up errors and the entire treatment time.

It has been demonstrated that IMRT can produce better results than conventional and simple conformal radiation therapy techniques, due to a significant reduction of radiation dose and toxicity delivered to the critical organs. It is different from the conventional techniques that lean on a single plane matched junction in the neck region with a "gapped" junction in the spine, in which very high- and low-dose regions are produced in the treatment volume. Apart from IMRT benefits, the segmented and overlapping fields created by IMRT and the resulting dose distribution are complex. Increase the prescription dose to the target and achieve a better sparing of the surrounding critical tissues than traditional 3D CRT, but the dosimetric information alone does not always point out the radiobiologically superior treatment for the patient.

RapidArc is a type of volumetric modulated arc therapy (VMAT) that provides intensity-modulated radiation therapy (IMRT) with multi-leaf collimator (MLC), dose rate, and gantry speed modulation. For Complex techniques like CSI, with the innovative VMAT technique, a homogeneous and conformal dose to the brain and spinal canal could be achieved, while limiting the dose to the relevant OARs. By using RA, the field junction matching difficulties were alleviated with the use of overlapping fields/arcs, where the dose contribution from each arc was automatically calculated during the optimization process.

The tomotherapy unit delivers a continuous, helical-shaped beam, using a single isocenter, no field junctions, and no gaps or overlaps within the entire irradiated volume, which leads to highly homogenous dose distribution, thus increasing the chances of disease control and lowering the toxicity risk. Daily patient position can be verified using megavoltage computed tomography (MVCT) at every treatment fraction.

Moreover, HT also involves setup uncertainty due to the relatively short range of MVCT compared to the long range of the treatment field in the craniocaudal direction required for CSI using HT. The main disadvantage is that the part of the abdomen containing the small intestine might be irradiated due to the anterior fields in our technique, although no distinct toxicity of gastrointestinal organs, such as enteritis, has been observed during treatment or on follow-up.

II. MATERIAL AND METHODS

A. Patient selection

For this study, five patients diagnosed with medulloblastoma (High and Medium Risk) were previously treated with CSI at our institute by helical tomotherapy were retrospectively replanned with conventional techniques; Intensity Modulated Radiation Therapy (IMRT), Volumetric Modulated Arc Therapy (VMAT) using Eclipse V15.6 (3DCRT), Intensity Modulated Radiation Therapy (IMRT), Volumetric Modulated Arc Therapy (VMAT) using Eclipse

V15.6. For planning, PTV is split into two parts, one in PTV-Brain (cranial contents) and the second in PTV-Spine (inferiorly from C1) to improve dosimetry.

B. IMRT Planning

Craniospinal irradiation (CSI) using the conventional linear accelerator (IMRT_LA) technique involves the combination of two separate treatment plans - one for the brain and another for the spine and a separate booster dose for the brain (if required) - delivered using 6 MV photons on the Eclipse Treatment Planning System (TPS).

The spinal planning target volume (PTV_spine) was planned and treated, including five fields like 40º,130º,180º, 235º,320º, using inverse planning technique. If the length of the patient is tall and if the spine is not covered by a single isocentre, then two isocentres in the spine are used with the same beam angles. The isocentre was positioned at the geometric centre of the PTV_spine along the cranio–caudal (Y) axis and midplane at the level of the C2–C3 vertebral body. A total dose of 36Gy was prescribed and normalized to the spinal isocentre. Optimization using Anisotropic Analytical Algorithm was carried out to reduce doses to organs at risk (OARs) without compromising target coverage or creating excessive hot spots.

A separate plan was created for the cranial PTV (PTV_brain). The isocentre for the cranial fields was set at the most inferior slice of the PTV_brain, while maintaining the same lateral (X) and depth (Z) coordinates used in the spinal plan. The beam orientation consists of 7 beams: 220º, 260º, 300º, 350º, 30º, 70º, 110º. Appropriate collimator angles were chosen to align the cranial dose gradient with that of the IMRT spinal plan.

This plan used lateral opposed, half-beam blocked fields, each conformally shaped to the target using MLCs based on the beam's-eye-view. A uniform 1 cm margin was applied around the PTV_brain in all directions except caudally, where the margin was reduced to account for the penumbra effect and enhance target coverage. The dose distribution was calculated and normalized to a reference point at the geometric centre of the PTV_brain. Finally, the spinal and cranial plans were combined dosimetrically to generate the composite IMRT_LA plan for the entire craniospinal axis.

Generally, in medulloblastoma, the most common site of origin is the Posterior Fossa. So, to reduce the recurrence, a booster dose is given to the posterior fossa. The beam orientation for booster dose includes bilateral field and a posterior field along with angles like 135º and 225º.

C.VMAT Planning

Volumetric Modulated Arc Therapy (VMAT) plans were created with three isocenters—two for Phase 1 (covering the brain and spine) and one for Phase 2 (brain boost). To treat the upper part of the planning target volume (PTV), which includes the brain and upper spinal cord, two coplanar arcs were used with opposing rotation directions (clockwise and counterclockwise). A single partial arc was used to treat the lower spinal regions. For lower region of spine, two full arcs with opposite rotation directions were used to cover the lower spine regions.

For Brainbooster, two full arcs with opposite directions were used for the Posterior fossa to reduce the recurrence. Several Beam-blocks were applied to prevent beam entry through sensitive structures such as the eyes, optic nerves, arms, and lungs. Collimator angles were alternated to reduce the tongue-and-groove effect of the MLC leaves.

Upper and lower arcs were optimized simultaneously using dose–volume constraints for the PTV, organs at risk (OARs), and the ring structure. The optimization process continued until the plan met the defined criteria, ensuring that at least 95% of the PTV received the prescribed dose, while keeping doses to surrounding normal tissues within acceptable tolerance limits.

D. Tomo Planning

Helical TomoTherapy-based IMRT employed a fan beam thickness (FBT) of 2.5 cm, a pitch value of 0.3 or 0.43, and a modulation factor of 2.5-3.00. The prescribed total dose was 36 Gy to both the PTV_brain and PTV_spine.

The optimization algorithm Convolution Superposition used in the TomoTherapy system and Eclipse TPS is different, so identical dose–volume constraints could not be directly transferred. Nonetheless, similar constraint parameters were adopted to the extent possible. Optimization proceeded until further reduction in organ-at-risk (OAR) doses could no longer be achieved without compromising target coverage or inducing unacceptable dose inhomogeneity (i.e., hot spots).

Given TomoTherapy's capacity for continuous delivery over extended lengths, the spinal component (PTV_spine) was planned as a single uninterrupted volume. The directional blocking feature was employed to selectively limit beam entry through critical OARs, including the eyes and kidneys, thereby enhancing normal tissue sparing while maintaining adequate dose conformity to the target volumes.

E. Plan Evaluation:

The dosimetric outcomes of VMAT, IMRT_LA, and IMRT_Tomo were compared qualitatively and quantitatively using PTV dosimetry and dose to OARs. PTV dosimetry includes maximum dose (D_{max}), minimum dose (D_{min}), mean dose(D_{mean}) to the PTV target, volume of PTV receiving atlleast 95% of the dose($V_{95\%}$), volume receiving 107% of the dose($V_{107\%}$), Homogeneity Index(HI) that characterizes the uniformity of the absorbed dose distribution within the target,

$$HI = \frac{D_{2\%} - D_{98\%}}{D_{50\%}}$$

Where $D_{2\%}$ is the dose received by 2% of the volume, $D_{98\%}$ is the dose received by 98% of the volume, which is

used to assess minimum dose to the target and D50% is the dose received by 50% of the volume (Median Dose).

Conformity Index, which defines the degree of dose conformity of the Target Volume to the PTV volume, can be evaluated and defined as

$$CI = \frac{\text{Dose to 95\% of volume}}{\text{Prescribed Dose}}$$

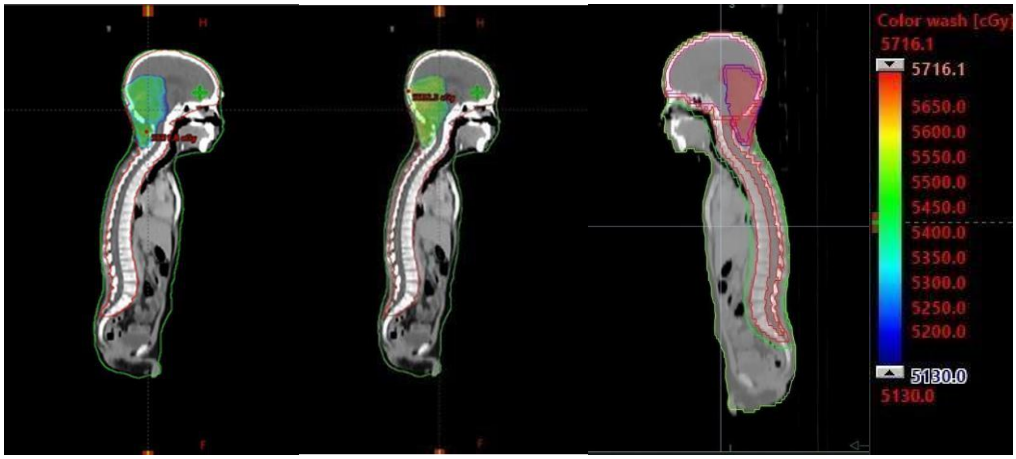

Figure 1: Colourwash representation of the dose fluence distribution across the entire PTV for different treatment techniques: IMRT_LA, VMAT, IMRT_HT

III. RESULT

A.PTV Dosimetry, Homogeneity & Conformity Index:

The figure shows the colourwash representation of the dose fluence distribution across the entire PTV of one patient for each treatment technique. Dosimetric parameters related to coverage, homogeneity, and conformity for all the three different techniques are shown in the table below. For all three dosimetric data, they are described as the mean for all datasets along with the standard deviation (SD). The target volume coverage, which is described by $V_{95\%}$, was >95% for all the plans. The best target coverage was seen in the TOMO plan with the mean dose of 98.275% for PTV_Brain,98.35% for PTV-Spine, and 98.7% for PTV_Brainboost. The high dose volume within the target, V107%, was almost 0 for PTV_Brain, PTV_Spine, and PTV_Brainboost for all the techniques. All plans had comparable mean dose (Dmean) for PTV_Brain (36.04 cGy), PTV_Spine (36.03 cGy), and PTV_Brainboost (18.5 cGy). The intermediate dose; D50% for PTV_Brain (35.7), PTV_Spine (35.9) and PTV_Brainboost (36.01) were also almost same.

Table 1: Dose-Volume relation for the 3 different treatment techniques. All values represent the mean of five patients (SD-Std. Deviation)

	PTV_Brain			PTV_Spine			PTV_Brainboost		
	IMRT_LA	VMAT	TOMO	IMRT_LA	VMAT	TOMO	IMRT_LA	VMAT	TOMO
D_{max}(cGy)(SD)	38.40(0.41)	38.37(0.40)	39.34(1.11)	35.985(0.7)	37.135(0.37)	39.73(0.69)	16.87 (0.27)	17.1 (0.34)	19.24(0.69)
D_{min}(cGy)(SD)	13.17(2.42)	12.01(0.69)	11.64(6.7)	24.37(0.32)	26.23(2.05)	24.79(4.2)	5.34(0.29)	6.3(3.55)	9.83)(2.3)
D_{mean}(cGy)(SD)	35.99(0.33)	35.87(0.15)	34.40(0.28)	35.75(0.33)	35.93(0.17)	36.4(0.087)	18.01(0.24)	19.08(0.82)	17.4(0.17)
$V_{95\%}$(%)(SD)	95.225(1.96)	96.575(1.16)	98.275(1.3)	97.625(1.35)	97.325(1.82)	98.35(1.7)	95.875(0.85)	97.075(1.33)	98.7(1.25)
$V_{107\%}$(%)(SD)	0(0)	0(0)	0(0)	0(0)	0(0)	0.025(0)	0(0)	0(0)	0(0)
$D_{50\%}$(cGy)(SD)	35.6(0.31)	35.090(0.09)	32.55(0.28)	35.83(1.04)	36.01(1.99)	36.5(0.12)	16.09(0.14)	16.23(0.16)	18.26(0.13)
$D_{98\%}$(cGy)(SD)	34.34(0.68)	34.21(0.49)	33.75(0.53)	31.77(1.25)	32.08(2.33)	33.74(0.09)	16.87(0.24)	16.08(0.36)	17.26(0.8)
$D_{2\%}$(cGy)(SD)	36.45(0.41)	36.96(0.46)	36.91(0.42)	36.46(0.75)	36.19(0.53)	37.32(0.28)	18.07(0.61)	18.57(0.18)	18.15(0.31)
$D_{95\%}$(cGy)(SD)	35.21(0.86)	34.64(0.41)	35.50(0.93)	34.81(1.4)	34.61(1.3)	34.92(0.55)	17.52(0.42)	17.48(0.59)	17.92(0.42)
HI(SD)	0.0625(0.012)	0.1125(0.015)	0.047(0.012)	0.065(0.017)	0.0725(0.025)	0.0975(0.03)	0.0635(0.78)	0.0775(0.12)	0.3275(0.56)
CI(SD)	0.977(0.017)	0.965(0.01)	0.98(0.012)	0.765(0.01)	0.94(0.04)	0.96(0.01)	0.975(0.97)	0.9725(0.33)	1.0125(0.88)

Table 2: The dose statistics in terms of maximum (D_{max}) and mean (D_{mean}) dose for all treatment techniques

	D_{max}(cGy)			D_{mean}(cGy)		
	IMRT_LA	VMAT	TOMO	IMRT_LA	VMAT	TOMO
Esophagus	3338	3362.45	3290.6	2168.9	1956.8	2368.7
Heart	2401.6	2298.8	1863.3	797.8	748.125	406.78
Lung_L	3531.975	3439.05	3152.5	1097.52	1063	651.25
Lung_R	3597.6	3469.75	3294	1138.7	1091	661.25
Brainstem	5489	5479.9	4506	5145.5	5230.12	4130.8
Chiasm	4515.05	4727.8	4167.25	4206	4418.9	3952.75
Eye_R	3551.9	3675.675	2300	1382	1802	1041.75
Eye_L	3691.75	3634.8	3328	1698.5	1731.3	1005.75
Lens_R	692.8	915.15	505	632	776.725	540
Lens_L	740.9	912.75	611.25	618	793.5	583.7
Larynx	3040.1	3157.5	2972.5	1549.7	1510.65	1632
OpticNerve_L	3810.5	3342	3731.5	2944.5	2789.6	3214
OpticNerve_R	3972.5	3806.8	3779	2802	2770	3305
Parotid_L	3697	4251.8	3142	1078.47	2400	1496.5
Parotid_R	4008.1	3918.05	3059	1811	2259.7	1439

In case of homogeneity index, PTV_brain, PTV_Spine and PTV_Brainboost shows highest Homogeneity for TOMO plans. The conformity index for Tomo Plan. in PTV_Brain (0.98), PTV_Spine (0.96), PTV_ Brainboost (1.01), shows better conformity than IMRT_LA (PTV_Brain-0.97, PTV_Spine-0.765 and PTV_Brainboost-0.97) and VMAT (PTV_Brain-0.965, PTV_spine-0.94 and PTV_Brainboost-0.97)

B. Dose to OARs:

The dose statistics in terms of the maximum (D_{max}) and mean (D_{mean}) dose for each OAR from the three planning techniques of IMRT_LA, VMAT, and IMRT_Tomo are shown in Table 2. The IMRT_Tomo plan was better for the reduction of doses (both D_{max} and D_{mean}) to all OARs. For OAR-like lens D_{max} for Tomo plan is 2-4% less(5cGy) than modern techniques like IMRT_LA(7Gy) and VMAT (9Gy). Similarly, for parotid, D_{mean} is 3-4% less than IMRT_LA (40Gy) and VMAT (40Gy). Also for Heart, which is 4-5% less than IMRT_LA(8Gy) and VMAT(7Gy). So, Tomotherapy has better OAR sparing capacity, followed by VMAT and IMRT.

IV. DISCUSSION

Homogeneous dose distribution in CSI is one of the most complicated techniques with excessively long fields and complex shapes of the target volume. With rapid development in the technique from classic 2D planar imaging to modern Helical IMRT technique, the radiotherapy technique evolves in terms of normal tissue sparing, target coverage, homogeneity, as well as conformity. (12,13). As per our studies, for both IMRT (D2% = 36.45 Gy, D98% = 34.34 Gy) and VMAT (D2% = 36.19 Gy, D98% = 32.08 Gy), the near minimum (D98%) and near maximum dose (D2%) fell within the recommended PTV dose constraints of 95% and 107% for all the five patients from our case study. This analysis showed that the only the difference between the IMRT and VMAT D2% data was significant. In clinical practice, the reason for using more conformal techniques is better sparing of healthy tissue outside the planning target volume. However, it should be mentioned that knowledge of the uncertainties related to possible motion of the target and correct target volume delineation is prerequisite for highly conformal techniques. Initially, CSI was planned with two collimated lateral cranial fields modified with MLCs or conformal blocks, which are connected geometrically onto the beam divergence of the direct posterior spinal field. The junction of the cranial and spinal fields, which is at the C2–C3 level, is generally junctioned to minimise over- or underdose across the junction field. For 2D, field shaping and matching are done on the bony landmarks seen on the real-time fluoroscopic images on a conventional simulator. The pros of CT simulators and virtual simulation allow better field definition for improved coverage and sparing of OARs. This procedure Although the patients were treated for several years, refrained from giving data for dose–volume relationships of targets and OARs, as long-term side effects become a growing concern for the paediatric population, that are necessary to be evaluated by dose-volume data. According to our modern technique study, regarding the dose to OARs (Heart lungs, kidney, Optic Nerve, etc.), almost all of them were in favour of Helical IMRT and VMAT (For

example, Lens). The recommended dose constraints of 20 Gy for the eyes, 6Gy for the lenses were exceeded for all techniques. Although the dose to OAR was least in the VMAT technique, even than that of the developed technique like Helical Tomotherapy. The finding that VMAT and IMRT_HT spared the OARs better than IMRT_LA is attributed to the number of subfields or partial arcs and their geometric setup, as well as the TPS optimization algorithm (For Helical IMRT). In case of Homogeneity and Conformity, better conformity among the modern techniques is observed in VMAT AND HT, whereas helical shows more accuracy. The HI was somewhat similar (not exactly) for all the techniques when considering the range of data per technique. However, better HI values for PTV_spine were observed with modern radiotherapy techniques.

For techniques like CSI, approximately 4-5 hours were needed to complete the procedure from contouring, planning, evaluation, quality assurance, to perform fraction treatment delivery for CSI patients, with the VMAT duration being the shortest by approximately an hour or two. Generating the treatment plans was faster for IMRT (4 hours) and VMAT (3 hours) because plan templates were created for these techniques and loaded as a planning starting point. For Tomotherapy, lying in supine position is the most convenient position for simulation and treatment delivery, without the need to move them during the treatment (single isocentre) and facilitating a smoother process for anaesthesia and/or sedation when needed, as opposed to standard techniques which require prone positioning and several field junctions.

Patient positioning is simple and reproducible, further supported by daily IGRT using the built-in MVCT increases treatment precision. However, despite the convenient treatment planning and dosimetric benefits, Tomotherapy comes with a significantly longer beam-on-time, and this might be limiting for patients with poor compliance, low performance status, or experiencing pain, or those who need anaesthesia or sedation during radiotherapy. However, this could be mitigated by employing several strategies, such as projecting movies on the tube ceiling, thus increasing compliance, especially in children.

V. CONCLUSION:

Due to the development and the evolution of various techniques, there is constant growth in the field of radiotherapy treatment, especially in specialized techniques like CSI owing to patient comfort and homogeneity. The increasing development in radiotherapy techniques, Helical Tomotherapy plans provided a better dose conformity, homogeneity, and OARs sparing at the expense of exposing larger volumes of tissue to lower dose and longer beam-on time compared with the other techniques.

If considering only LINAC-based technique, then RapidArc-based plans seem to be ideally suitable to plan such long and complex target volumes, owing to lower integral dose to normal healthy tissues, followed by IMRT_LA. All the modern techniques are better in terms of tissue sparing, but Helical Tomotherapy is better in terms of accuracy and Homogeneity. Thus, helical tomotherapy offers clear dosimetric advantages, good target coverage with high homogeneity and conformity, and OAR sparing. Although combined with the higher MU and longer beam-on time, this means a potentially higher risk of secondary malignancy in specific patients, such as patients at a very young age and with a genetic predisposition to certain cancers.

The preference to use this technique should be made case to case, taking into consideration both technical and clinical feasibility and relevance.

VI. REFERENCES:

1. Butturini, A. M., Jacob, M., Aguajo, J., Vander-Walde, N. A., Villablanca, J., Jubran, R., Erdreich-Epstein, A., Marachelian, A., Dhall, G., Finlay, J. L. High-dose chemotherapy and autologous hematopoietic progenitor cell rescue in children with recurrent medulloblastoma and supratentorial primitive neuroectodermal tumors: the impact of prior radiotherapy on outcome. *Cancer 115,* 2956-2963 (2009).
2. Gardner, S. L., Asgharzadeh, S., Green, A., Horn, B., McCowage, G., Finlay, J. Intensive induction chemotherapy followed by high dose chemotherapy with autologous hematopoietic progenitor cell rescue in young children newly diagnosed with central nervous system atypical teratoid rhabdoid tumors—Pediatr *Blood Cancer 51,* 235-240 (2008).
3. Shibamoto, Y. Management of central nervous system germinoma: proposal for a modern strategy. *Prog Neurol Surg 23,* 119-129 (2009).
4. Cox, M.C.; Kusters, J.M.; Gidding, C.E.; *et al.* Acute toxicity profile of cranial-spinal irradiation with intensity-modulated radiation therapy in children with medulloblastoma: A prospective analysis. *Radiat. Oncol.* **10** (1):1–9; 2015 PMID: 26597178; PMCID: PMC4657242. doi: 10.1186/s13014-015-0547- 9.
5. Ostrom, Q.T.; Gittleman, H.; Farah, P.; *et al.* CBTRUS statistical report: Primary brain and central nervous system tumors diagnosed in the United States in 2006–2010. *Neuro. Oncol* **15** :646–7; 2013 Erratum in: Neuro Oncol. 2014 May;16(5):760. PMID: 24137015; PMCID: PMC3798196. doi: 10.1093/neuonc/ not151.
6. Skowro´nska-Gardas, A.; Chojnacka, M.; Morawska-Kaczy´nska, M.; *et al.* Patterns of failure in children with medulloblastoma treated with 3D conformal radiotherapy. *Radiother. Oncol.* **84** (1):26–33; 2007 PMID: 17560676. doi: 10.1016/ j.radonc.2007.05.018 .
7. Sharma, D.S.; Gupta, T.; Jalali, R.; *et al.* High-precision radiotherapy for cranial-spinal irradiation: Evaluation of three-dimensional conformal radiotherapy, intensity-modulated radiation therapy, and helical TomoTherapy. *Br. J. Radiol* **82** :10 0 0–9; 2009 Epub 2009Jul 6. PMID: 19581313;PMCID: PMC3473394.doi: 10.1259/bjr/13776022.
8. Kiltie, A.E.; Lashford, L.S.; Gattamaneni, H.R. Survival and late effects in medulloblastoma patients treated with craniospinal irradiation under three years old.*Med. Pediatr. Oncol* **28** (5):348–54; 1997 PMID: 9121399. doi: 10.1002/(sici) 1096- 911x(199705)28:5 _ 348:aid- mpo4 3.0.co;2-h .
9. Hatten, M.E.; Roussel, M.F. Development and cancer of the cerebellum. *Trends Neurosci* **34** (3):134–42; 2011 PMID: 21315459; PMCID: PMC3051031. Doi: 10. 1016/j.tins.2011.01.002.

10. Sarkar B, Munshi A, Manikandan A, Roy S, Ganesh T, Mohanti BK, Pradhan A: A low gradient junction technique of craniospinal irradiation using volumetric-modulated arc therapy and its advantages over the conventional therapy. Cancer Radiother. 2018, 22:62-72. 10.1016/j.canrad.2017.07.047.
11. Michalski JM, Klein EE, Gerber R: Method to plan, administer, and verify supine craniospinal irradiation. J Appl Clin Med Phys. 2002,3:10.1120/1.1508013.
12. St Clair, W. H. *et al.* Advantages of protons compared to conventional X-ray or IMRT in treating a pediatric patient with medulloblastoma. *Int. J. Radiat. Oncol. Biol. Phys.* 58, 727–734. https ://doi.org/10.1016/s03603016(03)01574 -8 (2004).
13. Yoon, M. *et al.* Craniospinal irradiation techniques: A dosimetric comparison of proton beams with standard and advanced photon radiotherapy. *Int. J. Radiat. Oncol. Biol. Phys.* 81, 637–646. https ://doi.org/10.1016/j.ijrobp.2010.06.039 (2011).

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