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## *RESEARCH ARTICLE*

# HYBRID PLANNING A SIMPLE TECHNIQUE FOR CRANIOSPINAL IRRADIATION (CSI)

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## *Abstract*

**Purpose:** A simple planning technique for craniospinal irradiation using Eclipse treatment planning system.

**Material and methods:** In RT treatment planning, base plan optimization feature is used in sequential RT planning by anticipating the dose delivered to organ at risk (OAR) & planning target volume (PTV) in the base plan. In hybrid planning technique, the whole PTV is divided into two parts, Brain PTV & Spine PTV. Spine PTV is overlapped minimum 2-3 cm over the Brain PTV at their junction while creating structures for RT planning. Brain PTV is planned with conventional RT technique & the Spine PTV planned with rapid arc technique (VMAT). In the plan optimization process of spine PTV, first base plan is selected then the optimization parameter is set accordingly as per total prescribed dose of 36 Gy for both the PTVs. The base plan is the dose calculated plan which is incorporated in the rapid arc plan optimization hence the pre-existed doses of Brain PTV & OAR help to understand the plannerfor achieving desired planning objectives during Spine PTV, RT plan optimization. Finally for the dose calculation of Spine PTV RT plan, planner has to copy fields of Brain PTV & paste it in Spine PTV plan and need to calculate dose for these copied fields. The final plan contains a dose calculated of Brain PTV fields and Spine PTV fields termed as hybrid plan.

**Result:** Reduction in the total number of monitor units is observed for the hybrid plan compared to single VMAT plan, which is statistically significant ($p<0.05$).

**Conclusion:** Present study introduced the hybrid planning technique which can exploit benefits of conventional and modern techniques.



## Introduction

Craniospinal irradiation (CSI) is a very complex treatment method. The aim of craniospinal irradiation (CSI) is to irradiate the entire neuraxis. This treatment is used for medulloblastoma and high-risk germcell tumors.[1] The traditional conventional planning is commonly practice in most of the hospitals with two parallel opposed lateral fields with collimator rotation and one or two posterior-anterior (PA) fields depend on length of patient. Collimator

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rotation in brain fields helps to manage divergence of the cranial field so that hot spot can be avoided. Moving junction or feathering technique in conventional CSI technique is very crucial because any systematic or random error during patient set up can lead to junction overlap or gap. This junction overlap or gap result in overdose to spine or underdose hence moving junction after 5 to 7 fractions smoothes out the dose over a longer segment of the spinal cord. This junction shift can be either in cranial or caudal direction. This feathering technique presents great difficulty for both Physicist and Technologist in planning and patient set up.

Emerging radiotherapy techniques, such as Intensity Modulated Radiation Therapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT) have gradually replaced the traditional large field radiotherapy technique used in CSI planning and treatment. CSI involves number of anatomical structures and requires complex treatment planning, which often demands setting multiple isocenters and matching a large number of fields to obtain satisfactory plans. IMRT and VMATtechnique can offer better organ sparing, dose conformity and homogeneity than traditional multi-field 3DCRT plan.[2,3] Inverse treatment planning with IMRT or VMAT eases the planning complexity such as junction dose management but VMAT provides additional advantage of shorter treatment time.Therefore it is well accepted that conventional planning of CSI is challenging as compare to modern techniques (IMRT & VMAT) as theyhavesome distinct advantages.[4] In this study we have proposed “Hybrid planning technique” which can exploit benefits of both the conventional and modern techniques.

## Materials and Methods

A total 12 patients of craniospinal irradiation (Meduloblastoma) registered in the Department of Radiotherapy and Radiation Medicine, Institute of Medical Sciences, BHU, Varanasi from June 2022 to June 2024 were included in the study. The meduloblastoma cases are rare cancers hence there is no particular selection criteria followed in the study. Present study is a pilot study for verifying the feasibility of hybrid planning technique.

### A. Simulation and immobilization

All patients were immobilized in the prone position with a thermoplastic head mask and thoracic mask system that fixes on an “all in one universal base plate”. A head & chin rest is used for patients for additional control of head rotation and chin extension. A computed tomography (CT)three dimensional (3D) images acquired from head to mid-pelvis with 3 mm slice thickness. For patients those have boost dose (e.g., posterior fossa boost), same CT images will be used for the entire treatment course.

### B. Treatment planning

In this study, for twelve patient’s treatment plans were created by two different techniques first is simple VMAT plan and second is hybrid plan. Firstly, the contoured planning target volume(PTV) is divided into two PTVs named as Brain PTV & Spine PTV. While creating PTVs it is mandatory to overlap minimum 2.5-3.5 cm of Spine PTV over Brain PTV as shown in fig.1. In this “hybrid planning technique” the Brain PTV is planned by conventionalGerman helmet technique (two parallel opposed fieldswhich conforms the whole Brain PTV using multileaf collimator) and Spine PTV by VMAT technique as shown in fig.2. The first isocenter placed such that second and third isocenters have same lateral and vertical shift.Therefore, first isocenter serves as a reference for the rest of the treatment, and only a longitudinal shift needs to apply for second and third spine field isocenters. Because of different spine lengths, chin extensions and shoulder depressions, the longitudinal shifts will be patient-specific. The Spine PTV can be planned either by one isocenter or two isocenter depends on patient height.

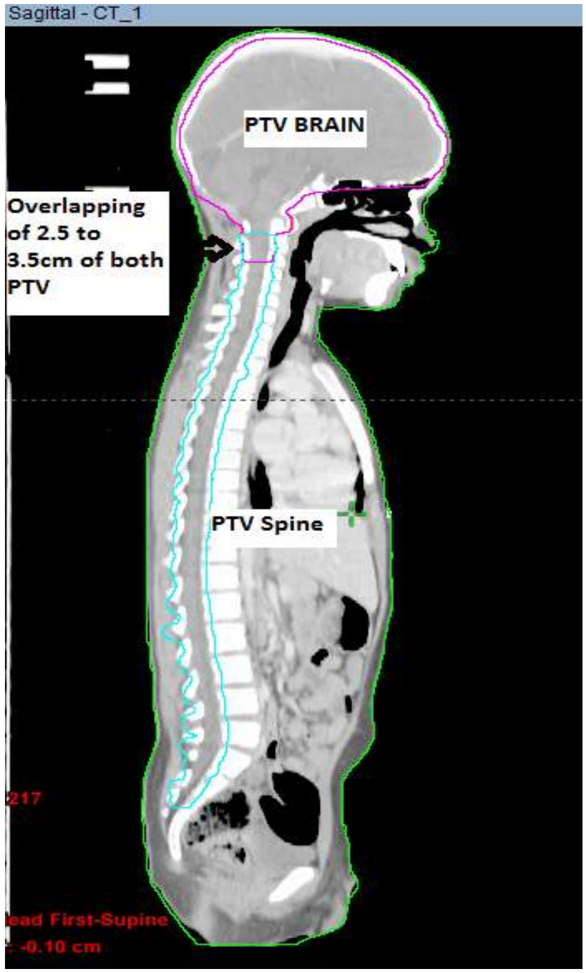


Fig. 1 Showing overlapping between Brain PTV & Spine PTV.

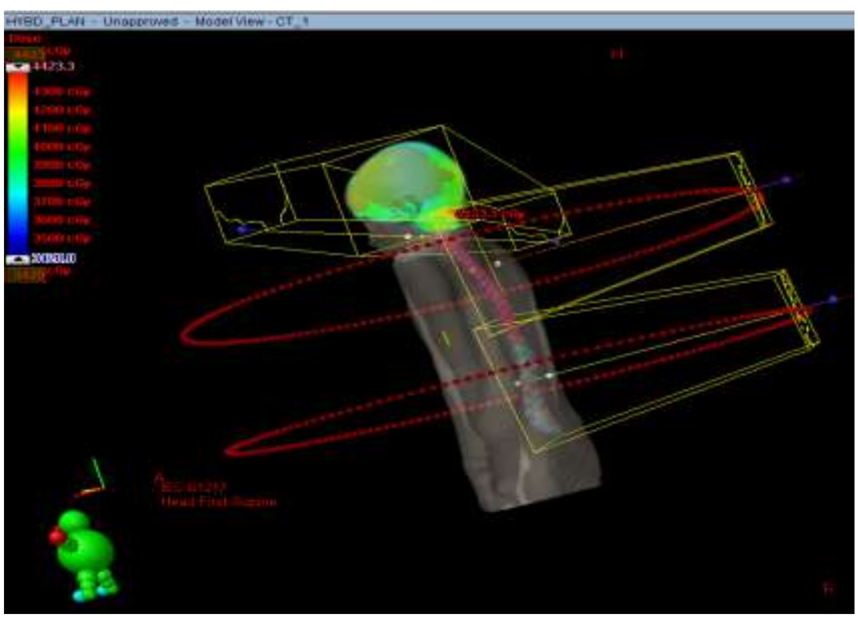

Fig. 2 Hybrid field arrangement for Brain PTV & Spine PTV.

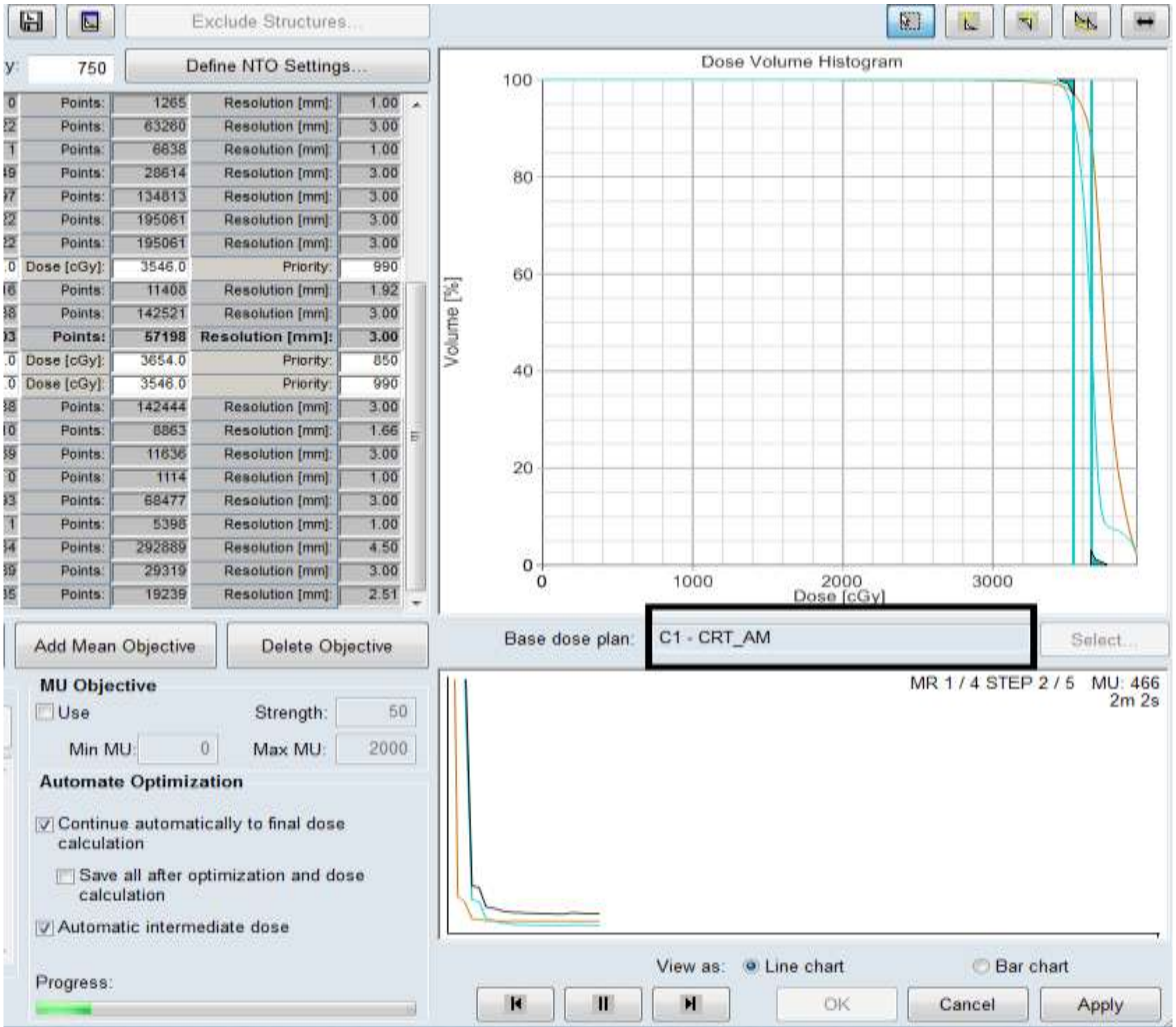


Fig. 3 Showing optimization process for both PTVs (Brain & Spine) highlighted with basedose plan option.After dose calculation of first independent plan named as "Brain PTV" which will be used as a base plan for creating "Spine PTV" plan for covering the entire PTV. In the Eclipse treatment planning system (Varian Medical Systems, Palo Alto, California, USA) there is a feature of a base plan which means the user can generate new plan with new prescription by taking into account the already planned prescribed dose available in dose optimization window (fig.3). This feature is generally usedby some users in sequential planning where planner can create new plan by anticipating the dose delivered to organ at risk (OAR) &planning target volume (PTV) in base plan. This said option is also available with other planning system e.g. Monaco. In the "Spine PTV" optimization window planner has to click on base plan tab then option will appear to select base plan. Next the planner has to set the optimization parameter accordingly as per total prescribed dose, in this study it is 36 Gy in 20 fractions. As the part of Spine PTV is overlapped with the Brain PTV, optimization allow planner to control maximum dose in the overlap region which means planner can able to manage junction dose and can avoid hot spotsor cold spots. For Spine PTV we have employed VMAT (Rapid Arc) technique with two full arcs. After achieving satisfactory objectives for various OARs (lung, kidney, heart etc.) final dose calculation is done. It is to be noted that the plan should be in "No plan normalization" mode.

After dose calculation, copy this plan and paste in the same course where conventional & VMAT plans created and name it hybrid plan.Next step is to copy conventional fields from the "Brain PTV" and paste it into the "Hybrid plan" as shown in fig.4.Again the dose calculation needs to be performed for the only conventional field in the hybrid plan, without calculating the intensity modulated arc fields.Theuniquefeature in this "Hybrid planning technique" is that, planning system allows planner to tune thefield weight of individual beams (bothconventional and intensity modulated arc fields). The advantage of this option allows the manipulation of the junction dose and target coverage.The final plan will contain Brain PTV fields and Spine PTV fields, this single hybrid plan have to be schedule for treatment delivery. An alternate complete VMAT plan has been generated for comparison of dose distribution against hybrid plan. The process of hybrid planning is shown in flowchart (fig.5) for quick reference and field arrangement in fig.5.

Fields | Dose Prescription | Field Alignments | Plan Objectives | Optimization Objectives | Dose Statistics | Calculation Models | Plan Sum

| Group | Field ID | Technique | Machine/Energy | MLC | Field Weight | Scale | Gantry Rtn [deg] | Coll Rtn [deg] | Couch Rtn [deg] | Wedge | Field X [cm] | X1 [cm] | X2 [cm] | Field Y [cm] | Y1 [cm] | Y2 [cm] | X [cm] | Y [cm] | Z [cm] | SSD [cm] | MU |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ✓ | ARC 1 | ARC-I | Eclipse CAP - 6X | VMAT | 1.300 | IEC61217 | 181.0 CW 179.0 | 10.0 | 0.0 | None | 13.1 | -5.8 | +7.3 | 24.2 | -11.9 | +12.3 | -0.01 | 18.56 | -8.26 | 96.0 | 239 |
| ✓ | ARC 2 | ARC-I | Eclipse CAP - 6X | VMAT | 1.450 | IEC61217 | 179.0 CCW 181.0 | 10.0 | 0.0 | None | 11.8 | -6.0 | +5.7 | 24.1 | -12.1 | +12.0 | -0.01 | -11.51 | -8.26 | 94.9 | 266 |
| ✓ | G90 | STATIC-I | Eclipse CAP - 6X | Static | 0.580 | IEC61217 | 90.0 | 0.0 | 0.0 | None | 20.9 | -11.3 | +9.6 | 18.8 | +0.0 | +18.8 | -0.01 | 19.22 | -2.62 | 94.7 | 96 |
| ✓ | G270 | STATIC-I | Eclipse CAP - 6X | Static | 0.580 | IEC61217 | 270.0 | 0.0 | 0.0 | None | 20.9 | 9.6 | +11.3 | 18.8 | +0.0 | +18.9 | -0.01 | 19.22 | -2.62 | 95.0 | 97 |

Fig. 4 Showing hybrid plan fields (conventional fields and Rapid arcs) with their beam weightages.

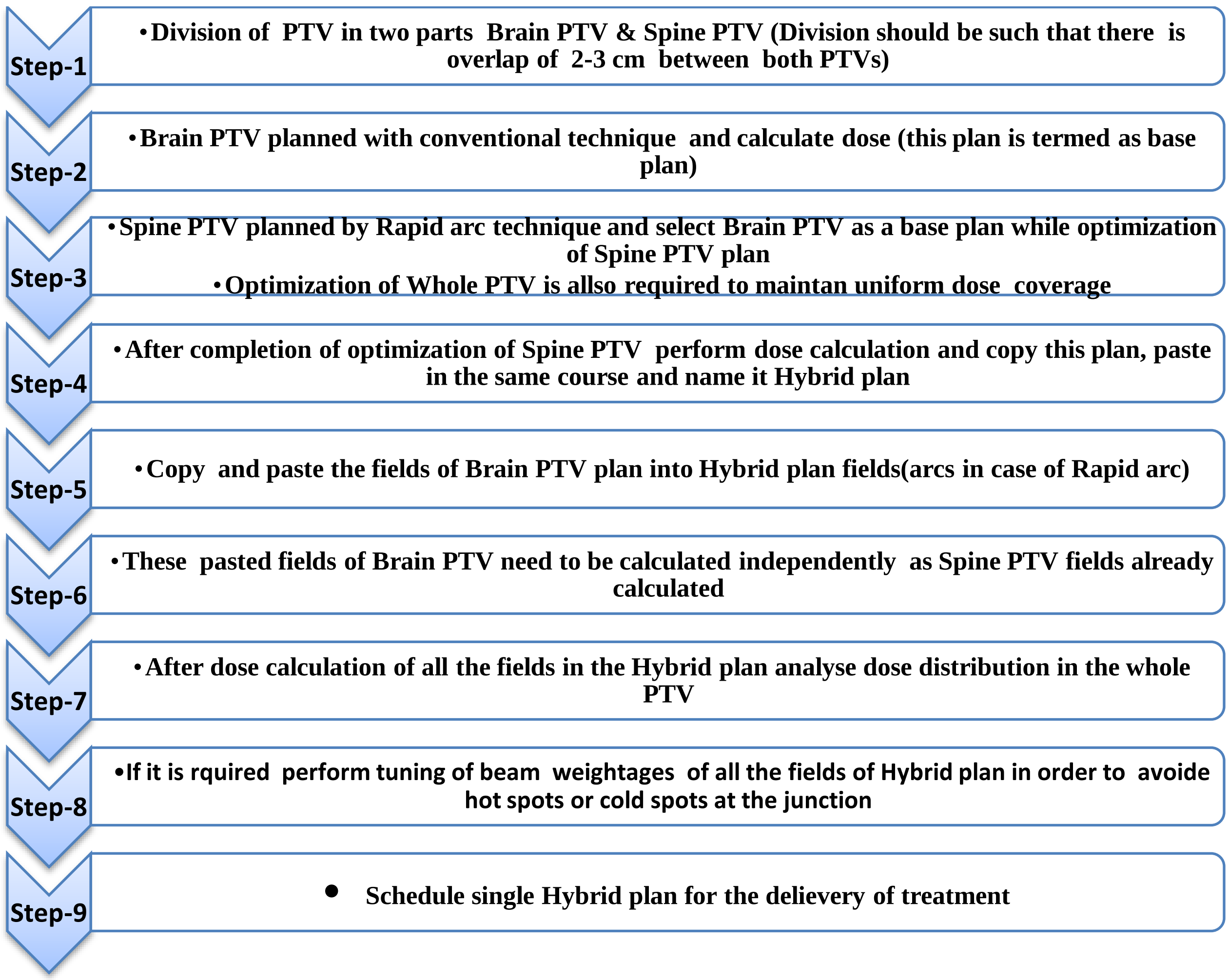


Fig. 5 Flow chart explaining step by step process of hybrid planning technique

**C. Treatment setup and field junction verification**

On first day of treatment, patient shifts are produced with the help of fiducial markers and laser alignmentbythe bilateral brain fields which is used as primary reference point for the subsequent isocenter shift. For set up verification, we usedmega voltage (MV) or portal imaging which allows verification based on bony landmarks. We compared the acquired images with the digitally reconstructed radiographs (DRR's) in orthogonal views (AP and RL) help to verify isocenter. LASER alignment is very helpful to identify that patient lie on couch in straight or deviated position. The remaining treatment fields are treated by applying longitudinal shift between consecutive isocenters with reference to brain fields as junction dose takes care by planning. As of now there is no tool available in imaging system that can merge two isocenter fields data and provide common image therefore physicians has to rely on his/her personnel experience to identify bony landmarks and soft tissue marks based on additional imaging of lower treatment fields. The benefit of MV imaging is that it records the actual treatment field shape, size and position. Since the therapists are used to do visual verification of prone setups where PA spine fields can be directly verified on skin as well as to verify source to skin distance (SSD).

**D. Statistical analysis**

Statistical analysis was carried out using the IBM SPSS for Windows, version 20.0 (IBM Corp., Armonk, NY). Descriptive analysis was used to determine the mean±SD for calculated monitor units and lens doses. A paired sample t test performed to assess the statistical significance between plans. p-value < 0.05 was considered significant for statistical interference

## Result

A total twelve patient treatment plans by two different techniques (complete VMAT & Hybrid) were anlysed in terms of monitor units as shown in table (1) and in terms of lens doses as shown in table (2). When the hybrid plan compared against complete Volumetric Modulated Arc Therapy (VMAT) plan it is was observed that there is significant reduction in the total number of monitor units. With student t-test the difference is statistically significant (p<0.05). In addition to this there is statistically significant (p<0.05) dose difference in both eyes lens doses between two techniques. It is found to achieve comparable dose distribution as obtained in complete VMAT plan as shown in fig.6 & 7.Dose volume histogram (DVH) of one patient plan comparing complete VMAT versus hybrid plan as shown in fig.8.

**Table (1)** Comparing doffernce between monitor units obtained in complete VMAT and Hybrid treatment plan

| **Patients** | **Monitor units** | |
|---|---|---|
| | **Complete VMAT plan** | **Hybrid plan** |
| **P-1** | **1023** | **772** |
| **P-2** | **970** | **775** |
| **P-3** | **967** | **751** |
| **P-4** | **962** | **723** |
| **P-5** | **959** | **684** |
| **P-6** | **950** | **710** |
| **P-7** | **941** | **690** |
| **P-8** | **933** | **692** |
| **P-9** | **926** | **697** |
| **P-10** | **908** | **686** |
| **P-11** | **827** | **593** |
| **P-12** | **842** | **604** |
| **Mean** | **934** | **698** |
| **Standard Deviation** | **54.5** | **56.6** |

***p value is significant (<0.05)**

**Table (2)** Comparing doffernce between doses received by left & right lens in complete VMAT versus Hybrid treatment plan

| **Patients** | **Right lens dose** | | | | **Left lens dose** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Complete VMAT** | | **Hybrid plan** | | **Complete VMAT** | | **Hybrid plan** | |
| | **mean** | **max** | **mean** | **max** | **mean** | **max** | **mean** | **max** |
| **P-1** | **12.53** | **22.08** | **5.4** | **8.6** | **11.98** | **21.24** | **5.3** | **8.5** |
| **P-2** | **12.09** | **13.94** | **5.2** | **8.1** | **6.54** | **7.75** | **4.97** | **7.41** |
| **P-3** | **11.25** | **12.77** | **5.7** | **9.1** | **11.12** | **12.14** | **4.8** | **8.9** |
| **P-4** | **11.30** | **13.02** | **6.1** | **9.5** | **9.62** | **10.87** | **5.9** | **9.4** |
| **P-5** | **10.72** | **11.90** | **6.54** | **9.2** | **11.03** | **13.84** | **6.42** | **8.3** |
| **P-6** | **10.22** | **11.67** | **6.6** | **9.7** | **10.68** | **12.86** | **6.5** | **9.2** |
| **P-7** | **9.45** | **10.68** | **5.67** | **7.22** | **8.98** | **10.70** | **5.57** | **7.39** |
| **P-8** | **9.65** | **11.23** | **6.3** | **8.1** | **9.26** | **11.55** | **6.4** | **8.4** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **P-9** | **9.21** | **11.05** | **6.5** | **8.2** | **9.08** | **11.24** | **6.1** | **8.2** |
| **P-10** | **8.97** | **10.86** | **5.0** | **7.3** | **8.32** | **10.25** | **4.92** | **7.08** |
| **P-11** | **8.82** | **9.89** | **4.6** | **7.1** | **8.76** | **10.31** | **4.5** | **6.8** |
| **P-12** | **8.59** | **10.86** | **4.5** | **6.9** | **8.54** | **10.82** | **4.4** | **6.6** |
| **Mean** | **10.23** | **12.49** | **5.67** | **8.25** | **9.49** | **11.96** | **5.48** | **8.02** |
| **Standard deviation** | **1.33** | **3.23** | **0.75** | **0.98** | **1.50** | **3.28** | **0.77** | **0.94** |

***p value is significant (<0.05)**

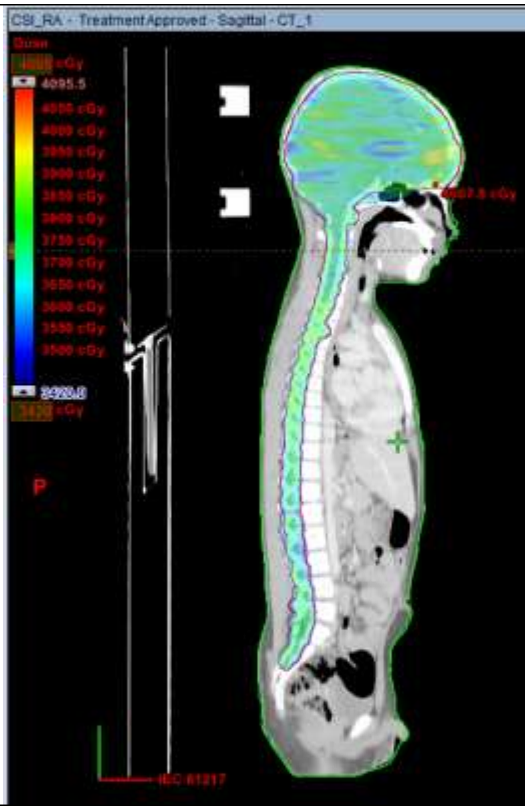


Fig. 6Dose distribution of a complete VMAT plan in dose colourwash with 95% of dose coverage

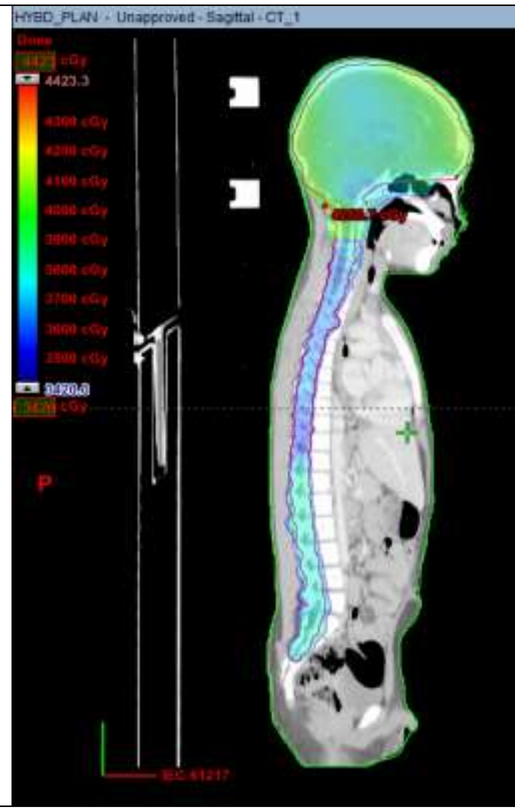


Fig. 7 Dose distribution of Hybrid plan in dose colourwashwith 95 % coverage

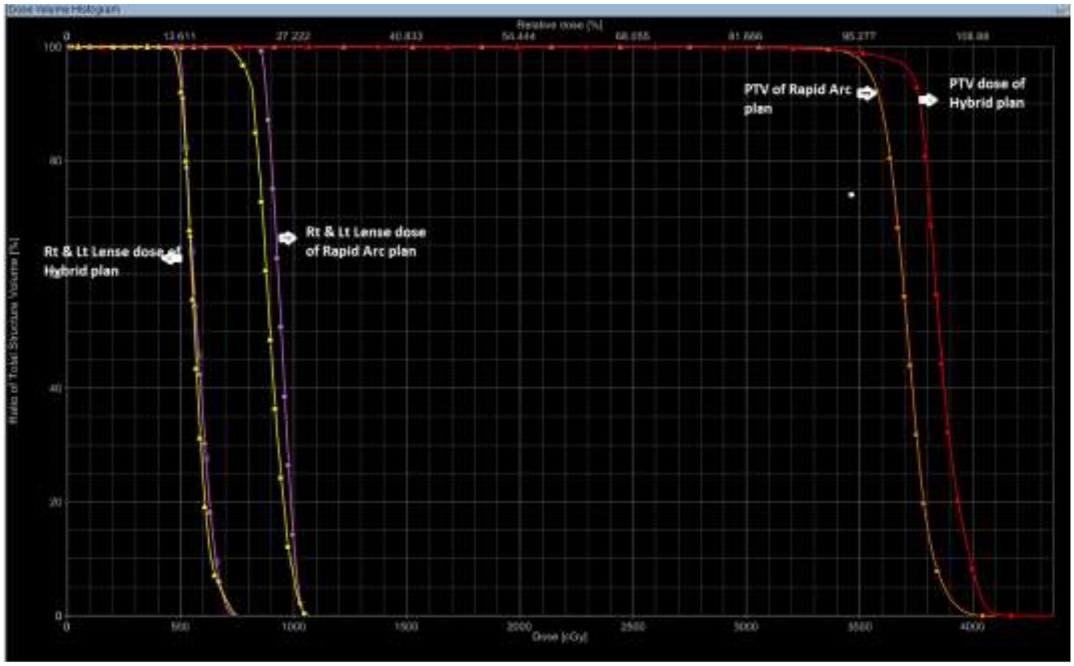

Fig. 8Comparison of dose volume histogram (DVH) between target & lens doses of two technique.

## Discussion

In conventional CSI technique matching the junction gap is challenging, any error in matching the field of cervical spine can cause adverse effects. Therefore, to prevent such a situation moving junction (feathering technique) is preferred. The limitation of moving junction technique is that small set up errors and inaccuracy in junction gap calculation may lead to high & low doses in the spinal cord. Because there is a high dose gradient region between matched fields. The field junction is a sensitive region where under-dosage may cause loss of tumor control and over-dosage may increase probability of radiation induced myelopathy. The moving junction technique introduces unwanted dose inhomogeneity along the planning target volume. To overcome shortcoming of moving junction technique extended source to skin distance (SSD) technique proposed butinthistechnique additional efforts required to achieve desired dose distribution, since dose rate decreases with SSD. Besides this dosimetry need to be performed for extended SSD.

The feasibility of CSI with Intensity Modulated Radiotherapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT)plan have been studied by many authors and mostof the studies showed improved dose homogeneity and target conformity.[2-4]These advanced techniques have a disadvantage of increase in monitor units (MU) which presents a higher risk of secondary cancer as compared to 3DCRT technique.[5]As per the European International society for pediatric oncology (SIOPE) contouring guidelines on craniospinal target delineation, it is suggested that there must be adequate coverage of the cribriform plate, the temporal lobes and the inferior aspect of the thecal sac otherwise there is increased risk of recurrence for medulloblastoma.[6] Modern techniques (IMRT & VMAT) have higher probability of missing these parts of CTV if not clearly delineated against the classical conventional technique.[6] The outstanding advantage of conventional technique in Brain PTV is that it adequately covered the whole of the subarachnoid space, including the cranial nerve roots and spinal nerve roots as they emerge from neural foramen. Hence the proposed hybrid planning technique can consider merits of both the planning techniques but simultaneously accepts shortcoming of modern technique which is a low dose volume. Low dose volume is a concern but can be minimized. It is our personal experience that achieving good homogeneity and saving critical organ especially lens (left & right) in Brain PTV by VMAT technique is quite difficult. It is observed that a minimum two arcs are required to achieve planning objectives which definitely increases number of monitor units (MU) and treatment delivery time against two bilateral conventional fields. It is also observed thataconventional (**German helmet)** technique very easily achieved lens tolerance dose criteria as compared to VMAT where additional efforts needs to exercise in optimization step of planning. It is found that (Table-1) there is mean MU difference of around 200-230 and better lens dose sparing between hybrid plan and complete VMAT plan for twelve patients study. The beauty of Hybrid planning is that it can achieve similar kind of dose distribution as compare to complete VMAT plan with acceptable higher dose in Hybrid plan. The limitation of study is the patient setup, it is desirable that plan should contain only longitudinal shift, means no shift in lateral and vertical between two or three isocenter plans. Hence planning Physicist must keep planning isocenters appropriately.

Orientation of patient (head first supine or head first prone) during simulation is an important decision in CSI technique.There are some advantages and disadvantages of prone or supine patient simulation over one another; we have preferred simulation in prone position because of accessibility of SSD verification at different fields.[7,8]Treatment setup reproducibility in CSI is difficult task for radiotherapy technologist therefore it is recommended to create only longitudinal shift in CSI planning.

## Conclusion

Considering both the pros and cons of conventional and modern technique we have introduced the hybrid planning technique which can exploit benefits of both the technique. "Hybrid planning technique" is a concept and application of this concept can be extended for planning of other treatment sites e.g. breast or chest wall irradiation also.

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