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# Evaluation of Dosimetric Parameter Differences between HyperArc and Non-Coplanar VMAT Treatment Planning for Intracranial FSRT

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## ABSTRACT

**Purpose:** This study evaluates the dosimetric impact and treatment delivery parameter differences between HyperArc (HA) volumetric modulated arc therapy (VMAT) and non-coplanar VMAT treatment planning for intracranial fractionated stereotactic radiotherapy (FSRT).

**Methods:** HA planning integrates an SRS Normal Tissue Objective (SRS NTO) with Automatic-Lower Dose Objective (ALDO) to promote higher prescription isodose levels to the target, consistent coverage, steeper dose gradients, and more rapid dose fall-off during optimization. To assess its performance, paired HA VMAT and non-coplanar VMAT plans were generated using the Varian Eclipse treatment planning system (TPS). Select organ-at-risk (OAR) structures were manually contoured to ensure anatomical consistency between phantom and patient geometries. Gross tumor volume (GTV) and planning target volume (PTV) coverage, OAR sparing, and treatment delivery parameters were compared between plans.

**Results:** HA planning enabled dose escalation to the GTV and PTV while maintaining OAR doses comparable to those of the non-coplanar VMAT plan. Percentage differences in PTV coverage between HA and non-coplanar plans were 8.22% at V105% and 1.01% at V100%, with minimal differences observed at V95% and V90%. A 3.2cGy difference was observed at D95%. At D1%, dose differences for the optic nerves, optic chiasm, spinal cord, and healthy brain were 35.3cGy, 12.1cGy, 0.4cGy, and 43.8cGy, respectively. Both plans utilized four half arcs; however, collimator angles differed substantially. The HA plan employed collimator angles of 78.0°, 117.0°, 21.0°, and 15.0°, compared with 335.0°, 355.0°, 40.0°, and 25.0° for the non-coplanar plan. Couch kick angles were similar between plans. The HA plan required fewer monitor units (2381 vs. 2595).

**Conclusion:** HA VMAT treatment planning, incorporating ALDO and the SRS NTO, provides improved dose conformity, higher target dose, and reduced treatment delivery requirements while maintaining OAR sparing comparable to conventional non-coplanar VMAT planning for intracranial FSRT.

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## INTRODUCTION

Treatment of brain metastases using Stereotactic radiosurgery (SRS) or fractionated stereotactic radiotherapy (FSRT) has demonstrated sub-millimeter accuracy ensuring the effective tumor control while sparing surrounding normal tissue. Traditionally, beam arrangements and collimator/couch rotations were dictated by the planner. Depending on the complexity of patient anatomy and planner experience, obtaining the best plan possible may take time. HyperArc (HA, Varian Medical System, Palo Alto, CA, USA) an automated treatment planning process for SRS and intracranial FSRT has been developed to efficiently treat brain metastases.

## METHODS AND MATERIALS

To assess its performance, paired HA VMAT and non-coplanar VMAT plans were generated using the Varian Eclipse treatment planning system (TPS). Select organ-at-risk (OAR) structures were manually contoured to ensure anatomical consistency between phantom and patient geometries. Gross tumor volume (GTV) and planning target volume (PTV) coverage, OAR sparing, and treatment delivery parameters were compared between plans.

## RESULTS

- Percentage Difference in PTV coverage between HA and conventional (Con.) FSRT treatment planning
  - **8.22% at V105%**
  - **1.01% at V100%**
  - **Minimal differences observed at V95%**
  - **3.2cGy difference at D95%**
- Dose statistics for OARs
  - **At D1% dose differences of 35.3cGy, 12.1cGy, 0.4cGy, and 43.8cGy were recorded for the optic nerves, optic chiasm, spinal cord, and healthy brain**
- Both plans consisted of 4 Arcs with four distinct collimator rotations.
  - **78, 117, 21, and 15 degrees for the HA plan**
  - **335, 355, 40, and 25 degrees for the conventional plan**
  - **Both plans applied the same couch rotations**
- Using HyperArc the total MU computed for treatment was lower, indicating less table time for the patient
- These metrics can be seen quantitatively in Tables 1 and 2 and qualitatively in the cumulative dose-volume histogram (DVH) shown in Figure 1

## DISCUSSION

HA plans incorporate a different immobilization system as well (e.g., Encompass couch top and open-faced masks). These new devices coupled with IGRT/SGRT motion management equipment allow for improved accuracy in patient setup and intrafraction motion monitoring during treatment.

This study show that for intracranial FSRT, HyperArc escalates the dose to the target lesion(s) while sparing much of the surrounding normal tissue to a similar extent as conventional planning. This can become critical, especially in the case in which OARs are close in proximity to the target lesion(s).

During the contouring stage a portion of the brainstem (~ 0.36cc) and right cochlea (~0.001cc) were drawn to intersect the PTV. Little variation in dose statistics were seen in the brainstem. Table 1 shows a 4.04% reduction in the mean dose to the cochlea for the conventional plan compared to the HA plan. This potentially comes at the expense of roughly 9.26% and 8.22% of high dose (105% of Rx) to the GTV and PTV, respectively.

"Beam on" time is also reduced with the use of HA. As shown in Table 2 there is a difference of 214 monitor units (MUs) between the plans. Given the nominal dose rate of a typical 6FFF MV beam, this would result in an approximate 9 second difference.

**Table 1.** HyperArc (HA) and conventional non-coplanar (Con.) treatment plan DVH values for GTV, PTV, and specified OARs

| | V105% (%) | | V100% (%) | | V95% (%) | | V90% (%) | | D98% (cGy) | | D95% (cGy) | | D50% (cGy) | | D2% (cGy) | | D1% (cGy) | | Min (cGy) | | Max (cGy) | | Mean (cGy) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Structure** | HA | Con. | HA | Con. | HA | Con. | HA | Con. | HA | Con. | HA | Con. | HA | Con. | HA | Con. | HA | Con. | HA | Con. | HA | Con. | HA | Con. |
| GTV | 90.4 | 82.4 | 99.2 | 100.0 | 100.0 | 99.7 | 100.0 | 99.9 | 2182.2 | 2178.9 | 2192.8 | 2186.8 | 2310.9 | 2284.5 | 2610.5 | 2541.1 | 2841.8 | 2559.8 | 2154.9 | 2150.8 | 2697.3 | 2591.1 | 2337.3 | 2310.3 |
| PTV | 74.7 | 68.8 | 99.0 | 98.0 | 100.0 | 100.0 | 100.0 | 100.0 | 2114.7 | 2117.9 | 2140.2 | 2143.5 | 2261.5 | 2234.5 | 2592.5 | 2529.6 | 2623.6 | 2551.8 | 1998.6 | 1979.8 | 2697.3 | 2591.1 | 2292.4 | 2274.2 |
| Brain | 0.3 | 0.2 | 0.4 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 | 6.7 | 6.3 | 8.4 | 7.9 | 81.9 | 76.1 | 653.1 | 684.6 | 1070.0 | 1113.8 | 4.8 | 4.5 | 2697.3 | 2591.1 | 127.6 | 127.6 |
| Brainstem | 0.0 | 0.3 | 1.6 | 1.8 | 2.6 | 2.7 | 3.3 | 3.6 | 99.0 | 104.5 | 122.2 | 125.8 | 331.4 | 318.2 | 2052.5 | 2078.6 | 2142.7 | 2167.3 | 72.5 | 77.3 | 2221.1 | 2261.2 | 502.0 | 505.6 |
| Pituitary | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 141.2 | 190.7 | 146.9 | 195.5 | 190.1 | 239.4 | 252.4 | 312.4 | 253.9 | 321.6 | 136.3 | 176.6 | 256.8 | 337.6 | 191.2 | 243.8 |
| Optic Chiasm | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 124.0 | 118.9 | 136.7 | 129.7 | 210.3 | 199.7 | 261.2 | 273.5 | 265.8 | 277.9 | 100.1 | 93.6 | 280.8 | 291.7 | 204.2 | 196.2 |
| Optic Nerves | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 16.7 | 22.9 | 19.5 | 26.3 | 89.9 | 114 | 217.5 | 256.9 | 228.3 | 263.6 | 12.6 | 16.0 | 255.5 | 283.3 | 84.9 | 120.7 |
| Lt Cochlea | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 65.9 | 62.4 | 67.3 | 64.1 | 77.0 | 74.5 | 91.7 | 85.3 | 92.7 | 85.3 | 64.2 | 59.8 | 96.1 | 86.3 | 77.6 | 74.2 |
| Rt Cochlea | 0.0 | 0.0 | 5.8 | 3.1 | 18.3 | 11.8 | 32.7 | 22.8 | 1282.7 | 1201.2 | 1331.2 | 1250.3 | 1745.7 | 1668.8 | 2138.2 | 2118.6 | 2160.6 | 2130.4 | 1191.0 | 1101.4 | 2195.6 | 2183.3 | 1736.6 | 1666.4 |
| Spinal Cord | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.9 | 2.6 | 4.7 | 2.6 | 11.9 | 10.1 | 64.2 | 62.0 | 71.4 | 71.8 | 3.1 | 2.2 | 100.5 | 92.2 | 16.4 | 13.6 |

**Table 2.** Plan parameters and total monitor units (MUs) for HyperArc (HA) and conventional non-coplanar (Con.) plans

| Plan | Arcs | Collimator Rotation | Couch Rotation | Total MU |
|---|---|---|---|---|
| HyperArc (HA) | 4 | 78.0°, 117.0°, 21.0°, 15.0° | 0.0°, 315.0°, 270.0°, 45.0° | 2381 |
| Conventional (Con.) | 4 | 335.0°, 355.0°, 40.0°, 25.0° | 0.0°, 45.0°, 90.0°, 315.0° | 2595 |

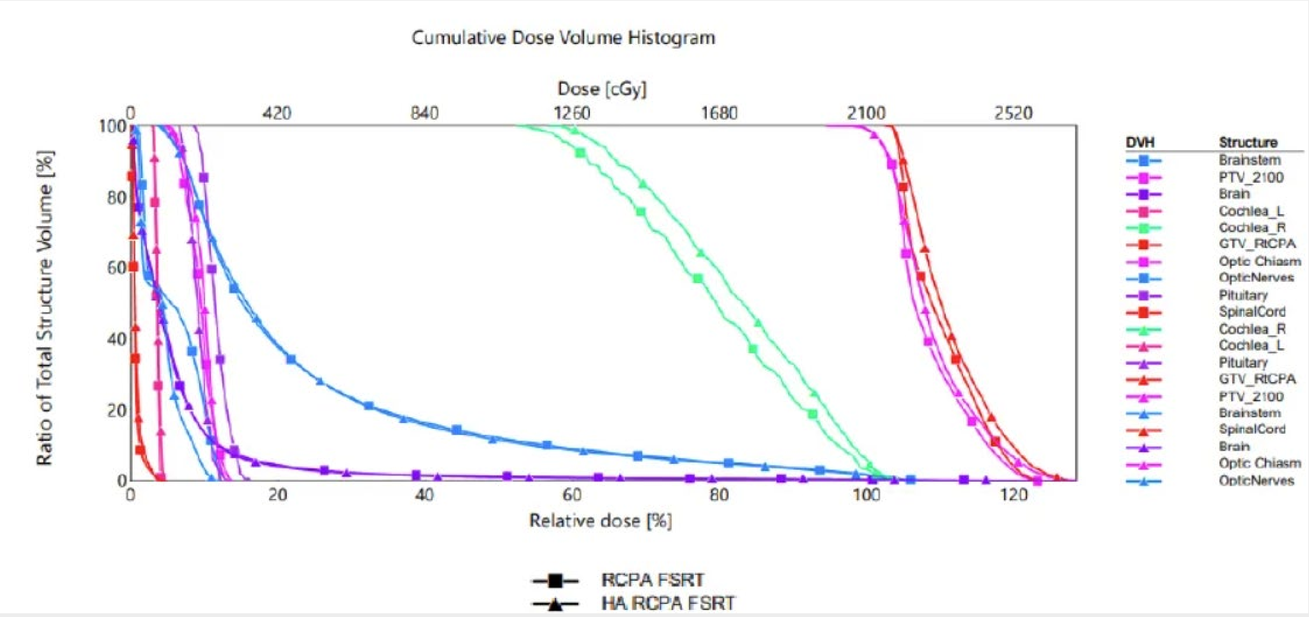


**Chart 1.** Dose-volume histogram (DVH) of structures of interest in both the HyperArc (HA) treatment plan and conventional non-coplanar treatment plan

## CONCLUSIONS

HA VMAT treatment planning, incorporating ALDO and the SRS NTO, provides improved dose conformity, higher target dose, and reduced treatment delivery requirements while maintaining OAR sparing comparable to conventional non-coplanar VMAT planning for intracranial FSRT.

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