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Abstract

A Study on Selecting Optimal Flattening Filter Free (FFF) Beam Quality for Intracranial Stereotactic Radiotherapy (SRT)

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Objectives: Use of FFF based VMAT for Hypo fractionated SRT (HSRT) is a well-established therapeutic modality for intracranial metastasis & benign lesions in the modern era. 6 MV-FFF and 10 MV-FFF beams available in Varian True beam STx linac offers high dose rate & increased dose per pulse which makes them an excellent choice for stereotactic treatments. As HSRT employs large dose per fraction, energy selection criteria should incorporate the impact of high and low dose gradients, integral dose and the effect of the increased Monitor Units (MU). Purpose: This study aims to critically analyse the selection of optimal beam quality for FFF-VMAT based intracranial SRT plans.

Methods: Fifteen intracranial SRT patients of different diagnose were studied retrospectively. Mean target volume was 10.46±6.73 cm3 (Range: 1.37-23.96 cm3) w/dose prescription of 18 Gy to 30 Gy in 3 to 5 fractions (mean±SD: 21.7±4.01). FFF based VMAT plans were created for both 6 MV-FFF (1400MU/min) and 10 MV-FFF (2400MU/min). An attempt was made to minimize the influence of other variables by forcing both plans w/identical target coverage. All plans were devised w/3 arcs (2 non coplanar partial arcs & 1 coplanar full arc w/same collimator & couch angles). For both the beam quality, optimizer was driven w/clinically accepted plan constraints & dose objectives w/single hold & synchronized time in each multi resolution (MR) levels w/a single intermediate calculation using Eclipse TPS (v13.6) & dose calculations were performed using Acuros XB algorithm w/calculation grid size of 1.25 mm. Statistical significance was assessed for all dosimetric parameters {GIHigh, GILow, CI, MU, HI, & Beam On Time (BOT)} & OAR doses using Wilcoxon signed rank test.

Results: 10 MV-FFF plans were found to have lesser MU compared to 6 MV-FFF ($p<0.002$) plans. This effect is more pronounced in deep seated tumors. 10 MV-FFF resulted in very short BOT ($p<0.0003$). No statistical significance were found in OAR doses (Brain stem ($p<0.054$), optic nerve ($p<0.779$), optic chiasm ($p<0.156$), lens ($p<0.234$) & cochlea ($p<0.28$)) between two energies. Mean Paddick CI was 1.262±0.13 and 1.257±0.12 for 6 MV-FFF and 10 MV-FFF respectively. HI was found to be 1.381±0.08 and 1.392±0.09 for 6 MV-FFF & 10 MV-FFF. Both the CI & HI were not statistically significant. We found GIHigh (V90%PI/V50%PI) was 2.9% higher ($p<0.0006$) for 10 MV-FFF and GILow (V25%PI/V50% PI) was -5.69% lower ($p<0.0006$) in 10 MV-FFF compared to 6 MV-FFF plans. Results showed that low dose volumes V2Gy & V5Gy were statistically not significant w/p values <0.0648 & <0.1902 respectively. High dose volumes (V10Gy & V12Gy) showed a significant increase in 10 MV-FFF w/p values <0.00064 & <0.0008.

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The high dose rate (2400MU/min) available w/10 MV-FFF allows the gantry to maintain maximum speed even for a large dose per fraction which in turn reduces the treatment time. Increased PDD attributed to the sparse gradient in high dose region. Reduction in number of MU's reduces the integral dose & the risk of secondary malignancy. Normal brain tissue doses were comparable between these two plans which make the 10 MV-FFF as preferable energy.

Conclusions: Adequate importance should be given for the high dose gradient region (GIHigh) when 10 MV-FFF energy is selected for intracranial SRT especially when critical organs are nearby. Results showed that increased mean energy & high dose rate of 10 MV-FFF makes it an ideal choice for VMAT based intracranial SRT.