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Dosimetric impact of FFF over FF beam using VMAT for brain neoplasms treated with radiotherapy

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Abstract

Background: This study was conducted to assess the dosimetric impact of FFF beam plans on high-grade brain neoplasms using the VMAT technique when compared with FF beam plans.

Material and Methods: Thirty patients with high-grade brain neoplasms, who had received radiotherapy using VMAT technique retrospectively were selected for this study. All the patients were planned for VMAT using 6MV_FF beam and the same plan was re-optimized using 6MV_FFF beam keeping the same dose constraint. Radiotherapy dose distribution on planning target volume (PTV) and organs at risk (OAR), target conformity index (CI), Homogeneity Index (HI), Low dose volume in the patient (V_5 , V_{10} , V_{20} , and V_{30}), and Integral dose to the whole body in both plans were compared.

Results: The PTV coverage and OAR's showed no significant differences in dose distribution between the FFF and FF beam VMAT planning. There was a reduction of the average maximum dose in the right eye, left eye, right optic nerve, and left optic nerve using FFF beams. The reduction in average low dose volume was observed in V_5 , V_{10} , V_{20} , V_{30} , and Mean Dose. Also, a significant reduction was observed in the integral dose to the whole body using the FFF beam.

Conclusions: Using FFF beams with VMAT is doable for the treatment of high-grade brain neoplasms, and the delivery mode of the FFF beam in VMAT may yield similar results to FF beam which should be confirmed in a large scale prospective clinical trial.

Key words: dosimetric evaluation; FFF; FF; VMAT; brain neoplasms.

Background

Radiotherapy with concurrent chemotherapy or alone has widely been inculcated into the treatment schema of brain tumours.^{1,2} With the advent of a multimodality treatment regimen and a better understanding of the disease process, the survival of brain tumour patients (benign and malignant) has been improving over the past decade as noted from the CONCORD 3 analysis.³ With the improvement in prognosis, long-term toxicities are gaining significance in the treatment of these kinds of tumours, which can be improved by using high precision conformal arc radiation therapy.

Volumetric modulated arc therapy (VMAT) allows accurate and efficient radiation delivery to the patient varying the multi-leaf collimator (MLC), dose rate, gantry speed in addition to the inverse planning could able to generate intensity modulation, which can decrease the dose to proximal structures and decreases normal tissue toxicity rates. Previous studies have demonstrated that VMAT plans offered superior target-dose conformity and homogeneity along with decreased doses to normal tissue benefits over 3DCRT plans.⁴

To generate homogeneous dose distribution at a specified depth in a treatment field the medical linear accelerator generally uses a flattening filter in the gantry head. Linear accelerators that operate without flattening of the photon beams, so-called Flattening Filter Free accelerators (FFF) have been introduced to increase the delivery efficiency of the primary photon beam. Now all vendors are offering beams without flattening filters and have gradually become the focus of attraction. The FFF beams are characterized by a cone-like fluence profile, softened beam spectrum, increased surface dose, and sharper penumbra in small field sizes. FFF beams have higher dose rates that reduce overall treatment time. Reduction in head leakage and the peripheral dose of FFF beam gave an extra advantage of lower outfield dose to the patient which is more dominant with smaller fields and deeper depths. However, the removal of the flattening filter increases the scatter dose to the patient.⁵⁻⁷ The clinical use of FFF beam for different sites like the brain⁸, head and neck⁹, breast cancer¹⁰, prostate¹¹ and cervix cancer¹² has been investigated by several authors and they found a reduction in mean dose to normal tissue, reduced the risk of secondary malignancy to out-of-field organs, sparing of normal tissue and OAR's without compromising the target coverage.

FFF beam is being mostly used in stereotactic radiosurgery (SRS) or fractionated stereotactic radiotherapy (FSRT) due to the advantage of the high dose rate available for such precise treatments. Other than that FFF beam is still not widely used in conventional planning.

This study aims to see the dosimetric impact of FFF beam plans on high-grade brain neoplasms using the VMAT technique when compared with the Flattening Filter (FF) beam in terms of PTV coverage, plan quality, OAR doses, beam delivery, dose fall-off outside the target volume and integral dose.

Materials and Methods

Patient Selection

The data of thirty patients with high-grade brain tumors, who had received radiotherapy using the VMAT technique under the Versa HD unit (Elekta Oncology Systems, Crawley, UK) were retrospectively selected from our database for this study. The patients diagnosed with glioma were graded according to the WHO grading system.

This study was approved by the Ethical review committee of the institute. This study was not treatment-based but a retrospective dosimetric planning study, our institutional review board waived the need for written informed consent from the participants. All patient's information was confidentially maintained.

Simulation and Contouring

Planning computed tomography (CT) images were taken using CT-Simulator (16 slices, GE Optima 580) in the supine position with a 3-point L-TM mask (Macro Medics®, Netherlands). Contrast-Enhanced Computed Tomography (CECT) slices of 2.5 mm were acquired. The CT images were then transferred to the Monaco Sim (v 5.11.02), images were co-registered with MRIs to facilitate normal tissue and target volume delineation.

The target volumes and OARs were contoured according to the respective standard guidelines. The target volumes like Gross Tumor Volume (GTV), Clinical Target Volume (CTV), and PTV were defined as per their definitions in International Commission on Radiation Units and Measurements (ICRU) Reports.^{13,14} The target volume for gliomas was done following ESTRO-ACROP contouring guidelines.¹⁵ Meningioma target delineation was according to London cancer neuro-oncology radiotherapy guidelines.¹⁶ The planning target volume (PTV) was derived from the clinical target volume plus a uniform 3-mm margin and was then cropped 2 mm away from the surface of the body to compensate for the dose build-up effect. The OAR contouring adhered to the EPTN consensus guidelines.¹⁷

Treatment planning

All VMAT plans were created in Monaco® (V5.11.02) treatment planning system and dose computed using the X-ray Voxel Monte Carlo (XVMC) (MC v1.6) algorithm, with a grid size of 0.3 cm and 2% calculation uncertainty per plan and delivered by Elekta Versa HD Linear Accelerator (Elekta Oncology Systems, Crawley, UK) equipped with 160 leaves Agility MLC of 5mm leaf width at isocentre, in un-flattened mode, a 2 mm stainless steel was introduced as filtration in the carousel. All the patients were planned for VMAT using 6MV_FF beam and the same plan was recalculated using 6MV_FFF beam keeping the same constraint. The characteristics of both beams were described in **Table 1**.

The method of generation of FFF beam depends on the vendors and its characteristics are also different as described by Xiao et al.¹⁸ In this study, we used Elekta linear accelerator which uses its own independent set of parameter values referred to as the 'Energy Set' by using energy tuning of the beam, alteration of the gun current to increase the mean electron energy incident on the target, and changing the bending magnet currents to adjust the electron energy selection window. There were three variables Elekta that were manifold to accomplish by adjusting bending coarse current, bending fine, and gun current.¹⁹

Dose Prescription

Both FF and FFF beam VMAT plans were created using a 6 MV photon beam. All the patients were suffering from high-grade brain malignancies so treated to a uniform dose of 60 Gy in 30 fractions.

Plan evaluation

Cumulative dose-volume histogram (DVH), Isodose distribution, and Dose-volume statistics were evaluated to assimilate the plan. The PTV coverage was evaluated for volume received by 95% of the prescribed dose ($V_{95\%}$). Maximum dose, near max ($D_{2\%}$) dose, near min ($D_{98\%}$) dose and mean dose to PTV were also evaluated. Homogeneity Index (HI) and Conformation Number (CN) of the PTV were evaluated according to the definition. Also, Monitor Units of both plans were evaluated.²⁰

To find the dose to the organ at risk maximum and near max ($D_{2\%}$) doses were taken into account and to see the dose fall-off outside the PTV, low dose volumes like V_5 , V_{10} , V_{20} , and V_{30} were evaluated, also integral dose was calculated to account for the whole-body dose to the patient.

Table 1. Characteristics of 6MV_FF and 6MV_FFF Beam in Our Linear Accelerator

Nominal Energy	$d_{\max}$ (cm)	Dose at 10cm depth (%)	Maximum dose rate on beam axis at $d_{\max}$ (cGy/min)	Beam quality factor ($TPR_{20,10}$)
6MV_FF	1.5	0.6751	600	0.6783
6MV_FFF	1.7	0.6764	1800	0.6783

The Homogeneity Index (HI) shows the variation of the dose received by the PTV and it is an evaluation of dose homogeneity within the PTV volume. The Homogeneity Index (HI) was calculated in this study using formula:

$$HI = \frac{D_5 - D_{95}}{D_p} \times 100 \quad \text{Eq. 1}$$

where D_5 and D_{95} are the minimum doses in 5% and 95% of the target volume and D_p is the prescribed dose. The ideal value is zero. This formula is a modification of the formula by Wu *et al.*²¹

The Conformation Number (CN) was calculated in this study using the formula given below. It simultaneously takes into account irradiation of the target volume and irradiation of healthy tissues, which was earlier studied by van't Riet *et al.*²² Conformation number:

$$CN = (TV_{RI} \div TV) \times (TV_{RI} \div V_{RI}) \quad \text{Eq. 2}$$

where TV is the target volume, TV_{RI} is the target volume covered by the reference isodose, and V_{RI} is the volume of the reference isodose.

The integral dose (ID) of radiation is delivered to the PTV and the whole patient body. The integral dose computed in this study is defined as

$$ID [Gy \cdot L] = D [Gy] \cdot V [L] \quad \text{Eq. 3}$$

where $D [Gy]$ is the mean dose delivered to volume $V [L]$ (where L is liter). This ID formula earlier was used by the Aoyama *et al.*²³ to find the integral dose to normal tissue and to compare the various irradiation situations.

Statistical analysis

Each pair of plans (FF and FFF for the same patient) were compared and then the statistical analysis was made. The data was compiled and mean, median values of different parameters were calculated using statistical methods. A two-tailed paired t-test was performed to find the significant difference in the two techniques and $P < 0.05$ was considered as statistically significant.

Results

Thirty patients with brain neoplasms treated with volumetric modulated arc therapy (VMAT) were analyzed. The patients included 20 males and 10 females, with a median age of 45 years (ranged from 19 to 75 years). The clinical information of the patients was tabulated in **Table 2**. Isodose distribution of axial view of two patients generated from VMAT planning using FF and FFF beams were represented in **Figure 1** including the low dose volume distribution.

Table 2. Patient Characteristics

Variables		N (%)
Age		45 years (range, 19–75)
Histopathology	Glioblastoma	14 (46.7%)
	Anaplastic Astrocytoma	8 (26.7%)
	Anaplastic Oligodendroglioma	4 (13.3%)
	Anaplastic Meningioma	3 (10%)
	High grade glioma	1 (3.3%)
WHO Grading	IV	14 (46.7%)
	III	14 (46.7%)
	IV/III	1 (3.3%)
	II	1 (3.3%)
Gender	Male	20 (66.7%)
	Female	10 (33.3%)

Figure 1. Treatment plans using VMAT for high-grade brain neoplasm of two patients in the axial view shown in the above figures with isodose distribution, both plans were created using FF and FFF beam.

Figure 2. A typical cumulative dose-volume histogram (DVH) produced by Monaco TPS of PTV and OAR's for 6MV_FF (in continuous line) and 6MV_FFF (in dotted line) using VMAT planning of a patient.

PTV, HI, CN, and monitor units

A comparative cumulative dose-volume histogram of VMAT plans of a patient for PTV and OARs was shown for both types of beams in **Figure 2**.

The averaged PTV volumes of these retrospectively selected thirty patients were 322.55 cc (ranged from 27.42 cc to 656.83 cc, SD = 152.62 cc).

The results showed that the maximum dose of PTV in FFF VMAT planning was higher by 0.21% and the mean dose was lower by 0.06% as compared to FF VMAT planning. There were no statistically significant differences observed in the maximum ($P = 0.30$) and mean ($P = 0.57$) dose of PTV between the two planning modalities.

Near max ($D_{2\%}$) and near min ($D_{98\%}$) dose to the PTV in FFF VMAT planning was increased by 0.14% and decreased by 0.17% as compared to FF VMAT planning.

The PTV covered by reference isodose line (95% isodose) was slightly higher with FF beam ($95.99 \pm 0.68\%$) plan as compared to FFF beam ($95.74 \pm 1.46\%$), no significant difference was observed in dose coverage for PTV ($P = 0.28$) in both plans.

It was observed that planning with both beams gave homogeneous dose distribution within PTV. There was no such difference observed in the homogeneity index which is also not statistically significant ($P = 0.07$).

There were significant differences in Conformation number (CN) between the two beam techniques. The Conformation Number (CN) in the FFF mode (0.92 ± 0.01) was higher as compared with the FF mode (0.89 ± 0.05) and differences were 3.37% ($P = 0.02$).

A significant increase in total monitor units was observed in FFF VMAT planning (614.74 ± 118.99 MU) compared to FF VMAT planning (594.74 ± 110.91 MU) and the difference was 3.36% ($P = 0.01$).

Low dose volumes (V_5 , V_{10} , V_{20} , V_{30}), Mean dose, and Integral dose

As shown in **Figure 3**, no significant change was observed in very low dose volume like V_5 ($P = 0.11$). But significant low dose volume reduction was observed in V_{10} , V_{20} , and Mean Dose ($P = 0.03$, 0.04 , and 0.03) with FFF beam. An average dose reduction was observed in V_{30} in FFF beam planning which was not statistically significant ($P = 0.33$). Concerning the low dose volume, improvements with FFF beams were observed in terms of V_5 , V_{10} , V_{20} and mean dose by 1.22%, 1.32%, 0.7%, and 0.87% respectively along with minor change observed in V_{30} . There was a significant reduction in integral dose observed with FFF beam planning as compared to FF beam 0.91% ($P = 0.03$).

Organs at risk (OARs)

There were no significant changes observed in OAR's doses between the FFF VMAT and FF VMAT plans. However, there was a reduction of maximum dose in low volume structures like a right eye by 5.3% (93.48 cGy) ($P = 0.49$), left eye by 4.92% (69.37 cGy) ($P = 0.12$), right optic nerve by 3.67% (73.43 cGy) ($P = 0.10$), and left optic nerve 3.89% (71.79 cGy) ($P = 0.14$) respectively using FFF beam planning as compared to FF beam. For the rest of the OAR's like brainstem and optic chiasm, the FFF beam yielded higher maximum doses by 1.98% (83.74 cGy) ($P = 0.57$) and 5.18% (175.30 cGy) ($P = 0.18$) respectively as compared to FF beam.

Similarly, analysis of near max ($D_{2\%}$) dose to the OAR's showed a decrease in dose using FFF beam planning to the right eye by 3.52% (42.87 cGy) ($P = 0.24$), left eye by 2.36% (26.73 cGy) ($P = 0.26$), right optic nerve by 2.84% (48.81 cGy) ($P = 0.35$), and left optic nerve 1.51% (28.01 cGy) ($P = 0.38$) respectively as compared to FF beam.

On the contrary, using FFF beam planning an increase in near max ($D_{2\%}$) dose was observed in the brainstem and optic chiasm by 0.18% (6.52 cGy) ($P = 0.55$) and 1.58% (53.01 cGy) ($P = 0.20$) respectively as compared to FF beam.

The PTV and OAR's coverage showed no significant differences in radiotherapy dose between the FFF VMAT planning and FF VMAT planning. The details of PTV dose coverage, HI, CN, monitor unit, Low dose volumes, mean dose, Integral dose, and OAR's doses were tabulated in **Table 3**.

Figure 3. (A) Average variation of low dose volumes – (i) V5, (ii) V10, (iii) V20, (iv) V30 and Mean Dose in the patient, (B) Integral dose to the whole body with error bars and P-value for both FF and FFF beam respectively.

Table 3. Comparison of PTV Parameters, Monitor Units Low, Dose Volume, Integral Dose and OARs between 6MV_FF and 6MV_FFF VMAT Planning.

Parameters		(Mean ± SD)		Percentage Difference	P-value
		6MV_FF	6MV_FFF		
PTV	V ₉₅ (%)	95.99± 0.68	95.68±1.53	0.32	0.28
	D _{max} (Gy)	6584±71.43	6598.11±93.53	-0.21	0.30
	D _{2%} (Gy)	6270.3±57.92	6279.41±67.52	-0.14	0.10
	D _{98%} (Gy)	5616.49±75.08	5607.16±98.69	0.17	0.54
	D _{mean} (Gy)	6038.22±45.65	6032.97±52.20	0.09	0.57
	HI	0.08±0.01	0.08±0.03	0.0	0.07
	CN	0.89±0.05	0.92±0.01	-3.37	0.02
Monitor Unit	MUs	594.74±110.91	614.74±118.99	-3.36	0.01
Low Dose Volume	V ₅	1922.18±547.30	1898.81±547.30	1.22	0.11
	V ₁₀	1566.54±461.62	1545.79±442.62	1.32	0.03
	V ₂₀	1017.25±373.74	1010.13±368.18	0.7	0.04
	V ₃₀	719.5±303.51	719.97±300.23	-0.06	0.82
	Mean	1100.50±468.97	1090.96±462.39	0.87	0.03
Integral Dose		5713.110.±1873.82	5661.35±1823.70	0.91	0.03
OAR's	Brainstem	4229.29 ± 1810.17	4312.82±1804.90	-1.98	0.57
	Optic Chiasm	3384.28 ± 1961.93	3559.65±1931.11	-5.18	0.18
	Right Eye	1763.93 ± 1582.66	1670.38±1448.35	5.30	0.49
	Left Eye	1410.69 ± 973.52	1341.35±925.81	4.92	0.12
	Right Optic Nerve	2000.75 ± 1678.65	1927.41±1609.33	3.67	0.10
	Left Optic Nerve	1845.58 ± 1626.64	1773.71±1609.33	3.89	0.14
	Brainstem	3620.48 ± 1718.53	3627.21 ± 1707.40	-0.18	0.55
	Optic Chiasm	3355.38 ± 1842.23	3408.35 ± 1839.84	-1.58	0.20
	Right Eye	1218.03 ± 769.99	1175.12 ± 1138.28	3.52	0.24
	Left Eye	1132.81 ± 733.69	1106.10 ± 732.98	2.36	0.26
	Right Optic Nerve	1718.78 ± 1486.12	1669.99 ± 1516.49	2.84	0.35
	Left Optic Nerve	1855.34 ± 1591.00	1827.24 ± 1599.50	1.51	0.38
	Normal Brain	D _{mean} (cGy)	2816.38 ± 2816.38	2827.52±790.29	-0.40

Abbreviations: PTV = Planning Target Volume, D_{max} = Maximum Dose, D_{mean} = Minimum Dose, D_{mean} = Mean Dose, HI = Homogeneity Index, CN = Conformation Number, SD = Standard deviation, FF = Flattening Filter, FFF = Flattening Filter Free.

V_x is the volume receiving x% of the prescribed dose. D_{x%} is dose received by x% of volume.

Discussion

The main aim of this study is to determine the use of flattening filter-free (FFF) mode of a linear accelerator for volumetric modulated arc radiotherapy (VMAT) in patients with brain neoplasms and compare the dosimetric variation in treatment planning between the FFF VMAT planning and the flattening filter (FF) VMAT planning. A major amount of work has been published on Varian FFF (Varian Medical System, Palo Alto, CA, and the USA), but there was limited literature available on Elekta (Elekta Oncology Systems, Crawley, UK) FF on this specific site.

The maximum dose and near max dose to the PTV was higher in the FFF mode but the mean dose was less in comparison with the FF mode which was found by many authors like Sun et al.²⁴

Our study showed that the treatment planning with FFF beams resulted in plans of equal quality in terms of PTV coverage compared with flattened beams. No significant differences were found in dose coverage for PTV in both plans.

We also found that there was a tendency for FFF beams to be more favorable for medium (200-400) cc and larger size target volume target volumes (> 400 cc) while FF is more suitable for smaller target volumes (< 200 cc) as shown in **Figure 4**. The effect of FF vs. FFF beam on tumour volume was previously studied by Reggiori et al²⁵ showed that FFF beam is more favourable for intermediate volume tumours ($100 \text{ cm}^3 \leq \text{PTV volume} \leq 300 \text{ cm}^3$) and FF beam for the smaller and larger tumours. Also, some studies found FFF to be suitable for PTV lengths of more than 10 cm and volume > 200 cc, even some insignificant and minimal difference was observed by Lang et al and TM Dang et al.^{26,27}

FFF beam was giving equal dose homogeneity as FF beam plans, the same as found by Gasic et al,⁸ but they were not statistically significant. So in combination with the VMAT technique FFF beam can be used for the delivery of homogeneous doses to PTVs, with comparable dose coverage to flattened beam plans.

Also, the Conformation Number (CN) value of PTV in FFF VMAT planning was significantly higher as compared to FF VMAT planning, which may be due to the rapid reduction of off-axis dose and lower beam energy.²⁸ This improvement in Conformation number was also observed by Ong et al.²⁹

Figure 4. Variation of PTV coverage (%) for different ranges of PTV volume - (i) <200 cc, (ii) 200-400 cc, and (iii) >400 cc with their standard deviation for both FF and FFF beam respectively.

There was a significant reduction in low dose volumes like V_{10} and V_{20} observed with FFF beam planning and variation of these volumes shown in **Figure 3**, as stated by G Kragl et al,³⁰ that the peripheral dose was, in general, smaller for treatment plans calculated because in FFF beam mode the major source of scattered radiation was removed. Even in clinical conditions, dose outside of a target will be governed by many criteria such as location, size, and shape of a target in addition to the degree of modulation and technique used and their flexibility with beam characteristics.

As described by Hrbacek J et al and Titt et al,^{5,31} the dose reduction outside a field can be achieved by the use of small field sizes and higher energy FFF beams. In our finding there was no such reduction observed in V_5 for the smaller target like < 200cc volume even with an increase in PTV volume, there was a slight low dose volume reduction observed in V_{10} and V_{20} and integral dose volumes respectively. All the variations were shown in **Table 4**.

The maximum dose and near max dose to the brainstem, optic chiasm was higher in FFF compared with FF planning. The mean dose to the normal brain was equal in both planning, however, the maximum dose and near max dose to eyes and optic nerves were less in FFF as compared to FF planning. There were no statistically significant differences observed between radiotherapy doses in the majority of organs at risk (OAR) between the FFF planning and FF planning groups.

Table 4. Percentage difference in FF and FFF beam's low dose volumes (V_5 V_{10} V_{20} and V_{30}), Mean Dose and Integral Dose with different range of PTV volume (<200cc, 200 – 400 cc, >400cc)

PTV Volume in cc	Difference (%)				Mean Dose	Integral Dose(Gy.L)
	V_5	V_{10}	V_{20}	V_{30}		
<200	-0.06	1.40	1.15	-0.34	1.20	0.73
(200-400)	0.80	0.67	0.28	-0.33	0.48	0.32
> 400	2.12	1.95	0.94	0.21	1.09	1.59

We found that FFF beams require significantly higher MUs as compared to FF beams, and this is likely because of the conically shaped dose distribution that results in different dose levels between the central and peripheral areas of the field as previously reported.³² Also, the higher MUs were mainly utilized to achieve a homogeneous dose distribution. The FFF beam shape needs to be compensated by a higher number of small segments and MUs as described by earlier studies.^{33,34} But as FFF beam having a higher dose rate will take less beam on time as compared to FF beam, so overall treatment time will be less for FFF beam, special consideration to be taken for very high dose rates requires a stringent patient monitoring protocol during beam delivery because a maximum dose of 1 Gy can be delivered in 3.3 sec.³⁵

Some articles had been described the radiobiological effects of the FFF beam on the specific type of cells and these are limited to in vitro studies. In general clinical practice, the fractionated schedule had been taken, but no data are available yet for high dose rate and multiple fractionations. So far, studies with a high dose rate FFF beam concluded no effect of high dose rate on clonogenic cell³⁶⁻³⁸, on another hand, Lohse et al³⁹ showed decreased clonogenic cell survival and one pre-clinical Vivo study found differential response between normal and tumour tissue in mice⁴⁰. So, there is a deficiency of in-vivo radiobiological effect of the FFF beam and a prospective clinical trial is required for fractionated high dose rate therapy to determine the tumour response, acute and late toxicity.

Conclusions

Using the FFF beam with VMAT we can achieve similar dose coverage to the PTV with homogeneous dose distribution and increased conformity to the target volume as compared to the FF beam. There is a statistically significant reduction in low dose volume to the normal tissue which can reduce the chances of secondary cancer risk associated with radiotherapy treatment. With an increase in dose rate, the reduction in total treatment delivery time is achieved. The FFF beam showed maximum dose reduction in OARs like eyes, optic nerve. Our results allude that using FFF beams with VMAT is doable for the treatment of high-grade brain neoplasms, and the delivery mode of FFF beam in VMAT may yield similar results to FF beam which should be confirmed in a large scale prospective clinical trial.

Abbreviations

FFF: Flattening Filter Free
 FF: Flattening Filter
 OAR: Organ at Risk
 VMAT: Volumetric Modulated Arc Therapy
 PTV: Planning Target Volume
 MU: Monitor Unit
 CN: Conformation Number
 HI: Homogeneity Index
 DVH: Dose Volume Histogram

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