RapidArc: Initial experience in high grade glioma

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▶ ***Original article***

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Received: Oct. 2012
Accepted: Jan. 2013

Int. J. Radiat. Res., October 2013; 11(4): 203-206

ABSTRACT

Background: Identify the optimal technique of radiotherapy for patients with high grade glioma. Our initial year of experience with RapidArc radiation therapy. ***Materials and Methods***: Planning CT scans of 50 patients with grade IV glioma were reviewed and three plan sets by 3D Conformal Radiotherapy (3DCRT), Intensity Modulated Radiotherapy (IMRT) and Rapid Arc (RA) were generated and the plans were compared. ***Results***: Planning target Volume (PTV) coverage is comparable. However IMRT and RA give better sparing of critical structures. Treatment time and Monitor Units (MU) for Rapid Arc is much less compared to IMRT. ***Conclusion***: If PTV is near to the Organs at Risk (OAR), then IMRT gives good result in comparison to 3DCRT plans. Rapid Arc is faster than IMRT and 3DCRT for same dose prescription to PTV and constraints of OAR.

Keywords: *High grade glioma, radiotherapy planning, organ at risk, planning target volume, 3D conformal radiotherapy, intensity modulated radiotherapy, Rapid Arc.*

INTRODUCTION

Intensity-modulated arc therapy (IMAT) was proposed as alternative to tomotherapy [1-4]. Multiple arcs were applied in which the aperture defined by the multileaf collimator (MLC) of a conventional accelerator changed dynamically whereas gantry rotation speed and dose rate remained constant. The IMAT technique was shown to deliver highly conformal dose distributions in times comparable to other conformal treatment times. Recently, intensity-modulated treatment with a single arc was proposed, whereby gantry speed and dose rate are modulated in addition to multileaf collimator aperture [5, 6]. The treatment of WHO grade IV glioma is surgery followed by chemoradiation [7]. Many of them present with a large tumor volume and surrounding edema. A minimum of 2.5 cm margin given around the residual/ post operative region invariably results in a large Clinical Target Volume (CTV), Compared to the dismal response of patients in the past, recent results show improved survival due to improved surgical techniques and chemoradiation [7] techniques. A minimum of 60Gy was prescribed in all the cases. Delivery of this high dose of radiation to a large CTV which approaches or overlaps the critical structures like brainstem or chiasm needs expertise. Improved planning and treatment delivery systems are necessary to achieve the dose constraints of OAR, hence minimizing acute and late toxicity. RapidArc radiotherapy technology from Varian Medical Systems is one of the most complex delivery systems currently available, and achieves an entire intensity-modulated radiation therapy (IMRT) in a single gantry rotation around the patient [8,9]. The calculation of the dose distribution can be performed with a clinically acceptable accuracy using the calculation algorithm [10, 11] AAA (Anisotropic Analytical Algorithm).

MATERIALS AND METHODS

Ten patients with malignant glioma of WHO grade IV were included in our analysis. All patients were planned for radiotherapy upto 60 Gy along with concurrent Temozolamide [7] (75mg/m2).Patients were positioned with an immobilization mask system. Continuous 3 mm CT scans of the head were obtained with a 16-slice spiral CT scanner in supine position with Briliance Big Bore (Phillips). The clinical target volume (CTV) was defined by preoperative GTV or residual post operative tumor with a safety margin of 2.5 cm in all directions except bones and, modified to include edema where necessary. For the creation of the planning target volume (PTV) the CTV was expanded with 0.5 cm in all directions. The OAR included brainstem, chiasm, optic nerve and lens. For each patient three different treatment plans were created using 3D conformal, IMRT (sliding window) and RapidArc techniques [12]. All techniques were generated using the Eclipse planning system (Version 8.6). The calculations were conducted with the HD-120 leaf multi-leaf collimator (MLC). The plans were calculated with 6 MV photons. The number of fields was 2–5 for 3D conformal plans. One to four subfields were added if necessary. For 3D plans the dose rate of 300 MU/min was used. For IMRT plans 5–7 fields were used with 300MU/min [13]. For peripheral tumors the use of 5 fields was adequate to cover the PTV. For RapidArc the single arc treatment field was split into 177 control points. The beam aperture was defined for each control point by MLC changes and gantry angle. The dose rate varied between 100 MU/min and a maximum of 600 MU/min. To minimize the contribution of tongue and groove effect during treatment the collimator was rotated to about 45°. The tolerance level for maximum dose to the lens was 6.0 Gy and 54.0 Gy for brain stem, chiasm and optic nerves [14]. Dose–volume histograms (DVH) of OARs were generated for all used treatment techniques. The coverage of PTV was calculated as ratio of target volume covered by 95% isodose line divided by the volume of PTV. Other used criteria for PTV were Dmax, D1%, D95%, conformity index (CI95% = ratio of target volume covered by 95% isodose line divided by total volume covered by that isodose line) and inhomogeneity index (In = difference of D5% and D95%) [15,16]. Additionally treatment time and number of monitor units were analyzed. After creation of intensity-modulated treatment plans, verification plans were generated. Therefore the original patient treatment plan was projected to a CT scan of the imrt'MatriXX (IBA, Germany) [17] including 4 cm polymethylmethacrylate (PMMA) slabs above and beneath the active measuring area. The two dimensional ionization chamber arrays consist of a 32×32 matrix of 1024 parallel-plate ionization chambers. The ionization chambers are arranged in a square of 24 cm×24 cm as active measuring area. Each chamber has 0.4 cm diameter and 0.55 cm height. The distance between each ionization chamber is 0.75 cm from centre to centre of adjacent chambers. The sensitive volume of each single ionization chamber is 0.07 cm^3. Each of the 1024 independent ionization chambers is read out with a custom microelectronics chip. The isocenter was positioned at the active measuring area. The 2D dose distribution in the active measuring area in frontal CT slice was exported with resolution of 1 mm to software OmniPro (IBA, Germany). The measured dose distribution was generated in movie mode and interpolated into resolution of 1 mm. The analysis was made using gamma evaluation [18, 19] to compare the measured and calculated dose distributions. The gamma evaluation criteria were 3% and 3 mm. The data available by comparing the 3 plan sets were tabulated and analyzed (table 1).

Table 1. Dosimetric statistics.

	3DCRT	IMRT	Rapid Arc
PTV Coverage(%)	85±5	97±5	95±5
$D_{95\%}$(Gy)	53.5±2	57±3	55±4
CI_{95}	0.61±0.09	0.87±0.05	0.90±0.05
In(Gy)	8.5±2	6.2±3	7.5±4
D1%(Gy)	64±1.5	62.8±3	62.5±4
V_{105}(cm^3)	9.3±7.5	5.4±4.7	3.3±2.5
	OAR		
Optic Nerves D1 (Gy)	32±20	31±17.5	30±16.5
O. Chiasm D1%(Gy)	45±12	42±10	41±10
Brainstem D1%(Gy)	50±10	48.5±5	48±4

RESULTS

Table 1 showed that the CI95% was slightly higher for RapidArc (0.90) relative to IMRT (0.87) but much higher than 3D conformal technique (0.61). Nevertheless PTV coverage was higher for IMRT (97%) than for RapidArc (95%) and 3D conformal technique (85%). If considering patients with PTV located distant to OAR (in this case optical nerves, chiasm and brainstem) PTV coverage for 3D conformal technique was 95%. The inhomogeneity was higher for 3D conformal technique (8.5Gy) than for RapidArc (7.5Gy) and lowest for IMRT (6.2Gy). D1% of the PTV was equal for all the three techniques. In contrast D1% of OAR was highest for 3D conformal technique and lowest for RapidArc. The dose to OAR was always below the acceptable limits and comparable for all the three techniques. All the OARs received slightly less dose by RapidArc than by IMRT or 3D conformal technique. The number of monitor units was 1.5 times lower for RapidArc and 2 times higher than 3D conformal technique. We found that the irradiation time of RapidArc fields was 3 times faster than that of IMRT and 1.5 times faster than that of 3D conformal technique. RapidArc was even about 5 times faster than IMRT because of additional time that is necessary to move the gantry between different IMRT fields.

DISCUSSION

This study analyzed RapidArc, sliding window IMRT and 3D conformal technique for patients with malignant glioma. The inferences drawn by comparing the plan sets of our study has been tabulated and presented in table 2. The dose to all OAR was equivalent or lower for RapidArc than for conventional IMRT. Fogliata *et al.* [20] described for small benign brain tumors that the target coverage resulted basically equivalent among conventional IMRT and RapidArc. Intensity modulated techniques have a good PTV coverage and conformity even if PTV was close to the OAR. The advantages of 3D conformal technique were less monitor units, short treatment time and small low-dose areas. Low-dose areas are suspected to induce secondary cancer as late consequence [21]. Smaller number of monitor units gives less scattered radiation. 3D conformal technique is a fair method when the PTV is far off from OARs. The major advantage of RapidArc over IMRT is less monitor units and less treatment time. Another advantage of RapidArc over conventional IMRT was lower V105%.Fast treatment decreases chances of error due to patient movement after verification by imaging. If the PTV coverage is acceptable, RapidArc should be selected due to faster treatment. When PTV coverage is not satisfactory with RapidArc conventional IMRT should be preferred.

CONCLUSION

If PTV is near to the OAR, then IMRT gives good result compared to 3DCRT. Rapid Arc is faster then IMRT and 3DCRT for same prescription dose to PTV and OAR constraints. If PTV is far away from OARs, 3D conformal technique can be applied with few monitor units, short delivery time and with good PTV coverage.

Table 2. Comparison of three planning techniques.

	3DCRT	IMRT	RapidArc
Advantage	•Small low-dose areas. •Few monitor units. •Short treatment time.	• Very good PTV coverage. • Low inhomogeneity	•Very short treatment time. •Good PTV coverage.
Disadvantage	•Poor PTV coverage, if PTV is nearby OAR. •Poor conformity and high inhomogeneity.	•Long treatment time. •Many monitor units.	•Large low-dose areas.
Recommendation	•If PTV is distant to the OAR.	•If not 3D conformal or RapidArc.	•If PTV coverage is acceptable.

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