Radiotherapy and Oncology 93 (2009) 593–596

Contents lists available at ScienceDirect

Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

Brain tumor radiotherapy

Radiotherapy of malignant gliomas: Comparison of volumetric single arc technique (RapidArc), dynamic intensity-modulated technique and 3D conformal technique

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ARTICLE INFO

Article history:
Received 18 March 2009
Received in revised form 26 September 2009
Accepted 3 October 2009
Available online 10 November 2009

Keywords:
IMRT
RapidArc
Radiotherapy
Treatment technique
Brain tumors

ABSTRACT

Purpose: The analysis was designed to identify the optimal radiation technique for patients with malignant glioma.
Methods: A volumetric-modulated radiation treatment technique (RapidArc), an IMRT technique and a 3D conformal technique were calculated on computed tomograms of 14 consecutive patients with malignant glioma. The treatment plans were compared with each other using dose–volume histograms.
Results: The 3D conformal technique showed a good PTV coverage, if PTV was distant to organs at risk (OAR). If PTV was nearby OAR, the 3D technique revealed a poor PTV coverage in contrast to both intensity-modulated techniques. The conventional IMRT technique showed a slightly better PTV coverage than RapidArc. The advantages of RapidArc were a shorter treatment time, less monitor units and a small $V_{107\%}$.
Conclusions: If PTV is distant to OAR, the use of 3D conformal technique is sufficient. Otherwise an intensity-modulated technique should be used. RapidArc was faster than conventional IMRT and should be preferred if PTV coverage is adequate.
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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. Three dynamic parameters can be continuously varied to create IMRT dose distributions – the speed of rotation, beam shaping aperture and delivery dose rate [1]. The variation of three dynamic parameters is used to cover the planning target volume with clinically acceptable dose and to spare organs at risk and normal tissue. Due to volumetric single arc the treatment can be performed in less time than conventional IMRT plans. The technique is similar to Tomotherapy in that a full 360 deg of beam directions is available for optimization but is fundamentally different in that the entire dose–volume is delivered in a single source rotation. The technique is referred to as volumetric-modulated arc therapy (VMAT). The RapidArc treatment technique was investigated by Otto [2]. The aim was to improve conformal avoidance of treatments and to reduce the treatment time per fraction. Volumetric IMRT on a theoretical basis has already been investigated for other clinical cases [3–6]. Clinical investigations are still unavailable. RapidArc treatments in cervix uteri cases have shown significant improvements in organs at risk and healthy tissue sparing with uncompromised target coverage leading to better conformal avoidance of treatments with respect to conventional IMRT. This, in combination with the confirmed short delivery time, can lead to clinically significant advances in the management of highly aggressive cancer types [7]. Presupposition for clinically significant advances in the management of cancer is the correct calculation of the dose distribution and the correct treatment delivery. Gagne et al. have shown that the calculation of the dose distribution can be performed with a clinically acceptable accuracy using the calculation algorithm AAA (anisotropic analytical algorithm [8]) using a resolution of 2.5 mm or better [9]. Ling et al. have shown that the DMLC movement, variable dose rates and gantry speeds can be precisely controlled during RapidArc [10].

Radiation treatment of patients with malignant glioma has an impact on the clinical outcome of patients, especially in combination with temozolomide chemotherapy [11]. The radiation treatment is complex because of proximity between tumor and organs at risk such as brainstem and chiasm.

The aim of the present study was to investigate the potential clinical role of RapidArc in comparison to sliding window IMRT or conventional 3D conformal technique for malignant glioma of the brain.

Methods and materials

Fourteen consecutive patients with malignant glioma WHO stages III–IV were included in our analysis. All patients underwent

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0167-8140/$ - see front matter
doi:10.1016/j.radonc.2009.10.002

radiochemotherapy with temozolomide [12] and received a total dose of 60.0 Gy to the tumor or preoperative tumor region. All patients were positioned with a mask system (Sinmed, Reeuwijk, Denmark). Continuous 5 mm CT scans of the head were obtained with a single-slice spiral CT scanner in supine position (Somatom Balance, Siemens Medical Systems, Forchheim, Germany).

The gross target volume (GTV) contained the primary tumor/tumor bed defined on the T1-weighted preoperative magnet resonance tomography (MRI). The MRI and the planning CT were matched automatically by treatment planning system (Eclipse, Version 8.5, Varian Medical Systems, Helsinki, Finland). The clinical target volume (CTV) was defined by GTV with a safety margin of 1.5 cm in all directions except bones and parts of the contra lateral brain, where no invasive growth could occur. For the creation of the planning target volume (PTV) the CTV was expanded with 0.5 cm in all directions. The mean volume for PTV was 432.9 cm^3, minimum 310.9 cm^3 and maximum 815.2 cm^3.

For each patient three different treatment plans were calculated – RapidArc treatment plan, intensity-modulated treatment plan with sliding window technique (further noticed as IMRT) and 3D conformal plan with static fields (Fig. 1) [3,13,14]. All techniques were generated using the Eclipse planning system (Version 8.5, Varian Medical Systems, Helsinki, Finland) with consideration of the treatment table during treatment planning process. The calculations were conducted with the Millennium-120 leaf multi-leaf collimator (MLC) (Varian Medical Systems, Palo Alto, CA, USA). The plans were calculated with 6 MV photons.

The 3D treatment plans were split into two parts. The first part was planned up to 52.2 Gy (single fraction 1.8 Gy to avoid late toxicity to organs at risk) with full dose to OAR and second part up to 59.4 Gy with approximately no dose to OAR. The sum plans of these two parts were analyzed. The number of fields was 2–8 for 3D conformal plans. If possible only two perpendicular fields or additional one opposing field was used. One to two subfields were added if necessary. In one patient 8 fields had to be used for adequate PTV coverage because of a large tumor in central location of the brain. For 3D plans the dose rate of 300 MU/min was used.

The two intensity-modulated techniques are planned up to 60.0 Gy (single fraction 2.0 Gy) with a maximum of 90% dose to OAR, which corresponds to a single fraction of 1.8 Gy at OAR. For IMRT plans the dose rate of 200 MU/min was used [15]. For IMRT plans 5–9 fields were used. For peripheral tumors the use of 5 fields was adequate to cover the PTV (9 patients). For other patients it was necessary to make use of additional fields to cover the PTV. For RapidArc plans one arc was used.

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 0 MU/min and a maximum of 600 MU/min and the gantry rotation between 0.0°/s and a maximum of 4.8°/s. To minimise the contribution of tongue and groove effect during treatment the collimator was rotated to about 45°. The exact collimator rotation was optimized between 43.5° and 45.4° by the optimization tool of the treatment planning system. To avoid radiation through

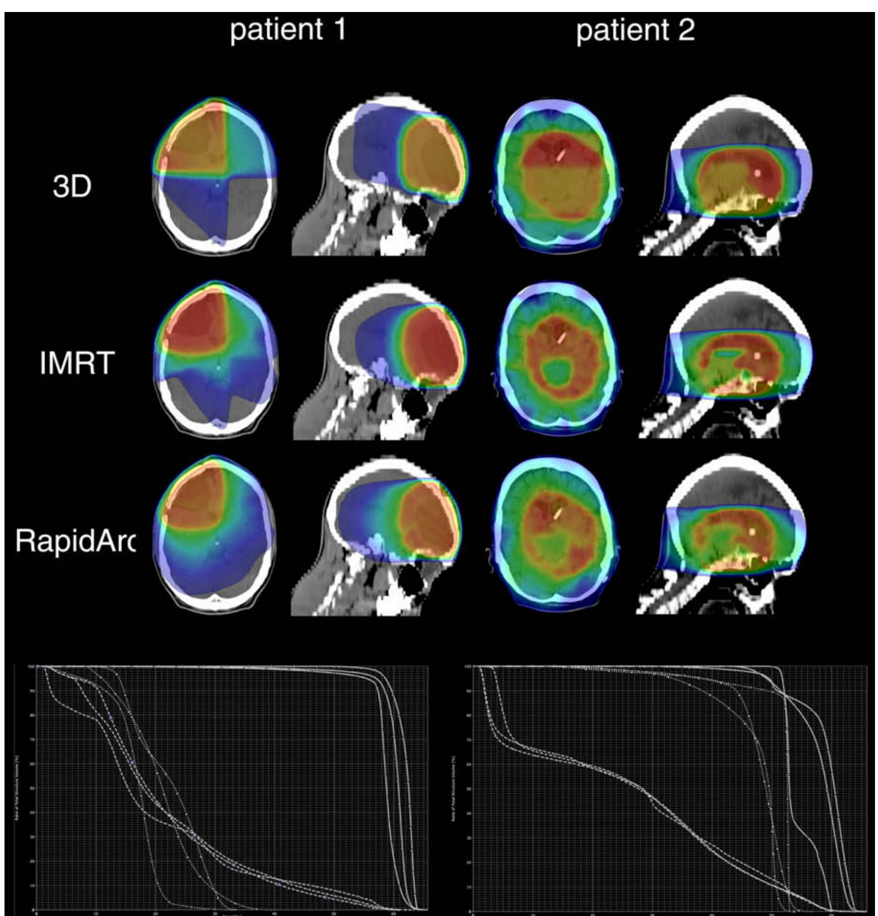

Figure 1. Dose distribution and dose–volume histogram of two patients (axial and sagittal views). The red line represents the PTV and the blue shading represents the 20% isodose line (12.0 Gy). PTV – solid line; brainstem – dotted line; healthy brain – dashed line; points – 3D conformal technique; square – IMRT; triangle – RapidArc.