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Original Research Article

Optimizing radiosurgery with photons for ocular melanoma

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ABSTRACT

Background and purpose: Photon radiotherapy has been established for the treatment of ocular melanoma (OM). Here we investigate the planning qualities of two different planning approaches, a combination of dynamic conformal arcs (DCA) complemented with multiple non-coplanar static intensity-modulated (IMRT) fields (DCA-IMRT), and volumetric modulated arc therapy (VMAT) in combination with automated planning (AP).
Materials and methods: Thirteen consecutive patients treated for ocular melanoma with curative intent on a Linac-based radiosurgery system were analyzed. Fractionated stereotactic radiosurgery (fSRS) was applied using 50 Gy in 5 fractions using the combination of DCA-IMRT. Plans were reviewed and the thirteen cases were compared to plans obtained with optimized automated VMAT based on a set of 28 distinct patients treated with DCA-IMRT who were selected to generate the AP model for the prediction of dose volume constraints.
Results: Overall, plan quality of DCA-IMRT was superior to AP with VMAT. PTV coverage did not exceed 107% in any case treated with DCA-IMRT, compared to seven patients with VMAT. The median PTV covered by > 95% was 98.3% (91.9%–99.7%) with DCA-IMRT, compared to 95.1% (91.5%–97.9%) ($p < 0.01$) with VMAT. The median mean dose delivered to the treated eye was 22.4 Gy (12.3 Gy–33.3 Gy) with DCA-IMRT compared to 27.2 Gy (15.5 Gy–33.7 Gy) ($p < 0.01$). Dose to the ipsilateral lacrimal gland and the ipsilateral optic nerve were comparable for DCA-IMRT and VMAT, however, the dose to the lens was lower with DCA-IMRT compared to VMAT.
Conclusions: The combination of multiple arcs complemented with multiple IMRT fields sets the gold standard for fSRS of ocular melanoma for photon therapy.

1. Introduction

Linac-based radiosurgery with photons has been investigated and applied for more than twenty years [1,2]. Classical radiosurgery of ocular melanoma (OM) uses multiple conformal arcs with multi-leaf collimators prescribing to the 80% isodose line [1]. Photons have been shown to achieve adequate target coverage for treating ocular melanoma compared to protons [3,4], and acceptable to excellent clinical results have been reported for Linac-based radiosurgery [5–7]. The challenge with photons relies in achieving steep dose gradients avoiding unnecessary dose to neighbouring structures. Eye positioning for photon therapy is more complex as compared to proton therapy due to variable beam angles used. Approaches with open eye gaze fixation or forced fixation with suction-based devices may rule out specific beam field geometries and thus limit the degree of freedom to optimize the dose distribution. The most patient-convenient approach is to have the patient positioned with eyes closed without any need of medication or specific interventions, and a X-ray based positioning verification system based on tissue markers surrounding the tumor and target structure and treating patients with their eyes closed has been proposed previously [8].

Volumetric modulated arc therapy (VMAT) has been increasingly promoted in radiosurgery during the last years mostly because it can treat multiple lesions with one isocenter [9,10]. However, the combination of non-coplanar arcs with IMRT improves dose coverage and homogeneity, because it allows steep dose fall-offs by adding static IMRT [11]. Here we investigate, whether automated planning with multiple, non-coplanar modulated arcs, known as VMAT or IMAT (intensity modulated arc therapy) could result in treatment plans comparable to the quality of plans with DCA-IMRT.

2. Materials and methods

2.1. Patients

For this retrospective treatment planning comparison, patients

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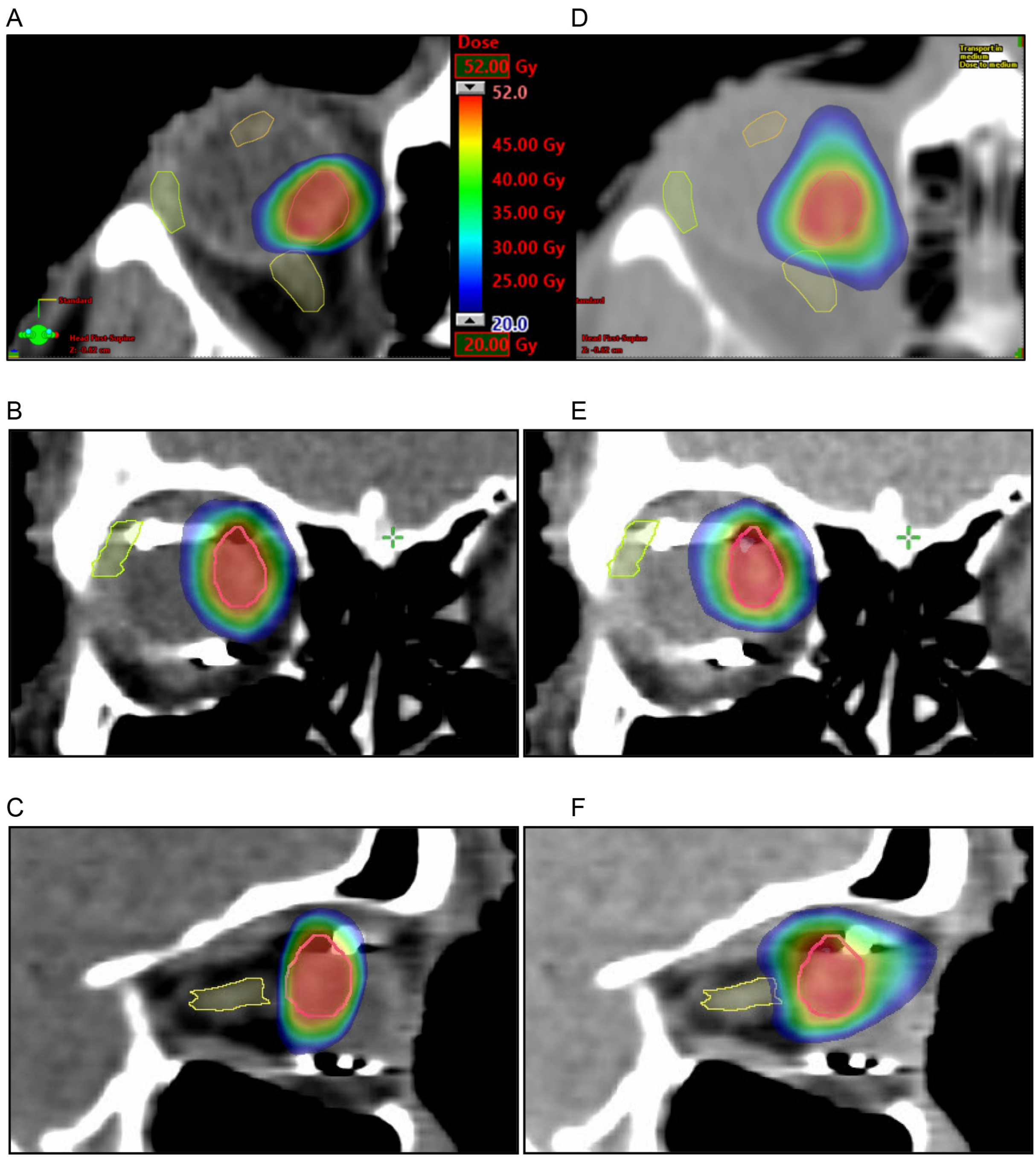

Fig. 1. Isodoses of DCA-IMRT (a,b,c) and VMAT (d,e,f) of a representative case. Axial (a and d), coronal (b and e), and sagittal planes (c and f). Scale as in Fig. 1a applies to all images, showing dose ranging from 20 to 52 Gy.

treated between 2014 and 2016 for curative radiotherapy of ocular, non-metastatic melanoma were enrolled. Patients were treated with a dose fractionation of 5 × 10 Gy on five consecutive days. All patients included into this study have given their approval to use their data for scientific research, and all were treated with the Hybrid-Arc™ technique. Prior to radiotherapy planning, three ophthalmological tantalum markers (Altomed Ltd., Boldon, UK) were attached on the sclera surrounding the tumor. A fourth marker was sutured to the opposite half of the bulb. Magnetic resonance imaging (MRI) and a planning computer tomography (CT) were obtained and fused images served for target volume definition. The gross tumor volume (GTV) was outlined on the MRI obtained after placement of the peritumoral fiducial markers and verified on the CT images. The margins to obtain the planning target volume (PTV) were two mm in general and occasionally three mm in the direction of the vitreous body or in direction of retinal detachment.

The treated plans for DCA-IMRT were manually optimized for a photon linear accelerator (Novalis-TrueBeam™; BrainLab and Varian Medical Systems) with a dynamic high-definition multi-leaf collimator. The dose was normalized to the mean value of the PTV. Clinically accepted and delivered treatment plans served as reference in this study. All treatment plans were verified with the physician before treatment. During treatment image-guidance by means of the ExacTrac™ 6.0.6 and Robotics® 2.0. (BrainLab, Feldkirchen, Germany) was used, positioning was verified prior to each beam or arc fraction. Tantalum markers were used for the positioning verification. The daily energy dose fractions of flattening filter free (FFF) 5.6 MeV photons were delivered by the frameless BrainLab® radiosurgery system.