Original research article

Is volumetric modulated arc therapy with constant dose rate a valid option in radiation therapy for head and neck cancer patients?

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Abstract

Background: Intensity-modulated radiotherapy (IMRT) improves dose distribution in head and neck (HN) radiation therapy. Volumetric-modulated arc therapy (VMAT), a new form of IMRT, delivers radiation in single or multiple arcs, varying dose rates (VDR-VMAT) and gantry speeds, has gained considerable attention. Constant dose rate VMAT (CDR-VMAT) associated with a fixed gantry speed does not require a dedicated linear accelerator like VDR-VMAT. The present study explored the feasibility, efficiency and delivery accuracy of CDR-VMAT, by comparing it with IMRT and VDR-VMAT in treatment planning for HN cancer. Methods and materials: Step and shoot IMRT (SS-IMRT), CDR-VMAT and VDR-VMAT plans were created for 15 HN cancer patients and were generated by Pinnacle3 TPS (v 9.8) using 6 MV photon energy. Three PTVs were defined to receive respectively prescribed doses of 66 Gy, 60 Gy and 54 Gy, in 30 fractions. Organs at risk (OARs) included the mandible, spinal cord, brain stem, parotids, salivary glands, esophagus, larynx and thyroid. SS-IMRT plans were based on 7 co-planar beams at fixed gantry angles. CDR-VMAT and VDR-VMAT plans, generated by the SmartArc module, used a 2-arc technique: one clockwise from 182° to 178° and the other one anti-clockwise from 178° to 182°. Comparison parameters included dose distribution to PTVs (Pmean, D2%, D50%, D95%, D98%, and Homogeneity Index), maximum or mean doses to OARs, specific dose-volume data, the monitor units and treatment delivery times.

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1. Background

Radiation therapy for head and neck cancer is challenging because of the complex anatomy of the region as tumors are often located in close proximity to crucial structures at high risk of toxicity. Therefore, reducing the dose to these organs needs to be balanced against appropriate coverage of target volumes. Head and neck tumors were conventionally treated with 3-dimensional (3D) conformal radiotherapy which has been replaced by intensity-modulated radiotherapy (IMRT). The latter improves target volume coverage sparing organs at risk (OARs) of toxicity.

In recent years, a new form of IMRT, i.e. volumetric-modulated arc therapy (VMAT), has gained considerable attention. It delivers radiation in single or multiple arcs, at varying dose rates (VDR-VMAT) and gantry speeds. VMAT was reported to be as good as IMRT in terms of target volume coverage and OAR sparing with the advantages of using fewer monitor units (MU) and taking less time to deliver treatments. Consequently, the patient undergoes a shorter restriction time in the thermoplastic mask and treatment is safer with less risk of intra-fractional error. Furthermore, more patients can be treated in the Radiation Oncology Center.

VDR-VMAT requires a dedicated linear accelerator and treatment planning modules, all of which are costly. A cheaper option is constant dose rate VMAT (CDR-VMAT) associated with a fixed gantry speed because a dedicated linear accelerator is not required, although specific treatment planning software is.

The present study explored the feasibility, efficiency and delivery accuracy of CDR-VMAT and compared it with IMRT and VDR-VMAT in radiotherapy treatment plans for patients with head and neck cancer.

2. Methods and materials

A sample of patients with stage III-IV head and neck cancer was retrospectively selected from among those who had undergone IMRT at our Radiation Oncology Unit. Treatment plans were re-calculated (see below) for 15 patients (13 male, 2 female; age range 46–79 years of age, mean age 63 years, median 64; 5 had oropharyngeal cancer, 5 hypo-pharyngeal cancer and 5 larynx cancer).

Results: Compared with SS-IMRT, CDR-VMAT significantly reduced the maximum doses to PTV1 and PTV2 and significantly improved all PTV3 parameters, except $D_{95\%}$ and $D_{95\%}$. It significantly spared parotid and submandibular glands and was associated with a lower $D_{mean}$ to the larynx. Compared with VDR-VMAT, CDR-VMAT was linked to a significantly better $D_{mean}$ to the PTV3 but results were worse for the parotids, left submandibular gland, esophagus and mandible. Furthermore, the $D_{mean}$ to the larynx was also worse. Compared with SS-IMRT and VDR-VMAT, CDR-VMAT was associated with higher average monitor unit values and significantly shorter average delivery times.

Conclusions: CDR-VMAT appeared to be a valid option in Radiation Therapy Centers that lack a dedicated linear accelerator for volumetric arc therapy with variable dose-rates and gantry velocities, and are unwilling or unable to sanction major expenditure at present but want to adopt volumetric techniques.

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