Available online at www.sciencedirect.com
ScienceDirect
journal homepage: http://www.elsevier.com/locate/rpor

Review

Influence of segment width on plan quality for volumetric modulated arc based stereotactic body radiotherapy

Karthikeyan Nithiyanantham[a,c,*], *Ganesh Kadirampatti Mani*[b,c], *Vikraman Subramani*[a,c], *Karrthick Karukkupalayam Palaniappan*[a,c], *Mohanraj Uthiran*[a], *Sennniandavar Vellengiri*[a], *Sambasivaselli Raju*[a], *Sanjay S. Supe*[b], *Tejinder Kataria*[a]

[a] *Division of Radiation Oncology, Medanta – The Medicity, Gurgaon, Haryana, India*
[b] *Department of Radiation Physics, Kidwai Memorial Institute of Oncology, Bangalore, Karnataka, India*
[c] *Research and Development, Bharathiar University, Coimbatore, Tamilnadu, India*

ARTICLE INFO

Article history:
Received 9 August 2013
Received in revised form
9 October 2013
Accepted 11 March 2014

Keywords:
VMAT SBRT
Optimization
Minimum segment width
Small field measurements

ABSTRACT

Aim: To study the influence of segment width on plan quality for volumetric modulated arc based stereotactic body radiotherapy.

Background: The redundancy of modulation for regularly shaped small volume tumors results in creation of many small segments and an increase of monitor units, with a consequent prolongation of treatment and uncertainty in treatment delivery.

Materials and methods: Six cases each in lung, abdomen and liver were taken for the study. For each case, three VMAT SBRT plans were generated with different penalties on minimum segment width of 0.5, 1.0 and 1.5 cm. A comparison was made on the metrics of dose volume histogram, dosimetric indices, monitor units (MUs) and delivery accuracy.

Results: The mean reduction of total MUs when compared with 0.5 cm plan was observed as 12.7 ± 6.0% and 17.5 ± 7.2% for 1.0 cm and 1.5 cm of minimum segment width, respectively. The *p* value showed a significant degradation in dosimetric indices for 1.5 cm plans when compared with 0.5 cm and 1.0 cm plans. The average deviation of measured dose with TPS calculated was 3.0 ± 1.1%, 2.1 ± 0.84% and 1.8 ± 0.9% for 0.5, 1.0 and 1.5 cm, respectively. The calculated gamma index with pass criteria of 2% dose difference and 2 mm distance to agreement was 95.9 ± 2.8%, 96.5 ± 2.6% and 97.8 ± 1.6% as calculated for 0.5, 1.0 and 1.5 cm of penalties, respectively. In view of the trade off between delivery efficiency and plan quality, 1 cm minimum segment width plans showed an improvement.

Conclusions: VMAT SBRT plans with increased optimal value of minimum segment width showed better plan quality and delivery efficiency for stereotactic body radiotherapy.

* *Corresponding author*. Tel.: +91 9971972886.
E-mail addresses: nithiyakarthik@gmail.com, nithiyakarthik@yahoo.com (K. Nithiyanantham).

http://dx.doi.org/10.1016/j.rpor.2014.03.003

1. Background

Intensity modulated arc therapy is a widely accepted mode of delivery for all regimens of radiotherapy. This novel radiation technique, named as Volumetric Modulated Arc Therapy (VMAT), allows a simultaneous variation of three parameters during treatment delivery, i.e. gantry rotation speed, treatment aperture shape via movement of MLC leaves and dose rate. VMAT is a time efficient treatment delivery platform capable of producing highly conformal dose distributions with a single 360° arc.[1] There is a significant increase in delivery of stereotactic body radiotherapy (SBRT), a kind of ablative treatment, with volumetric modulated arc delivery, because of better reduction of doses to surrounding critical organs and normal structures with a short delivery time.[2] SBRT has emerged as an alternative treatment option to surgical resection for patients who are medically inoperable; giving excellent local control rates (up to 95%).[3] Delivering SBRT with the technique of intensity modulation can improve dose conformity compared with conventional radiotherapy[4] by creating many beamlets that are differently weighted in the treatment planning optimizing software. Several planning studies have evaluated the performance of VMAT in delivering SBRT.[5–8] Generally, VMAT planning has a two-stage optimization in which fluence-map-based optimization algorithm calculates optimized fluence maps as a series of discrete beam angles and subsequently, an arc sequencer algorithm converts the fluence maps for multiple fixed-angle delivery to those for arc delivery while optimizing an MLC leaf shape sequence.[9] VMAT uses sweeping leaf sequencer to create an arc treatment plan using an MLC to shape a radiation field so that the delivered dose volume conforms well to a given prescribed dose volume.

SBRT delivers a very high dose per fraction of radiation for five or fewer fractions. Most tumors planned for SBRT are early in stage, more localized, regular and smaller in dimension. Moreover, it has the major challenges in patient immobilization, contouring, and respiratory organ motion management and delivery accuracy. For SBRT, a crucial patient specific planning target volume is required to improve a targeting and delivery accuracy as well as to potentially reduce the dose to surrounding normal tissues and critical organs. Besides, organ motion has become an important consideration for SBRT treatment planning for tumors in the thorax, abdomen and prostate that are known to move with breathing motion.[10] The management of motion control is established with the setup of motion encompassing methods such as respiratory gated imaging, breath hold technique, forced shallow breathing with abdominal compression, etc. Also, a stringent tolerance limit is required in MLC leaf position to deliver the dose in small and highly complex apertures created by the VMAT optimization. However, the redundancy of modulation for regularly shaped small volume tumors creates a large number of smaller segments with a consequent increase in monitor units, treatment time and dosimetric uncertainties. The dose calculation algorithm has a difficulty in predicting the dose accurately for these segments because of the lack of charged particle equilibrium and requires precise modelling of lateral electron scatter.[11] Unlike conventional radiotherapy, any small uncertainty in the dose calculation for the small, narrow and irregular segments will have a notable impact on the accuracy of delivering the requisite high dose per fraction. Young et al. have discussed the use of edge penalty during optimization that reduces the required MUs up to 30% by avoiding the creation of complex apertures and increases accuracy of dose delivery with gamma passing rate from 79.5% to about 95.4%.[12] Hence the creation of such smaller segments can be controlled with sequencing parameters by the segmentation of theoretical fluence into deliverable MLC segments. The minimum segment width parameter in the segmentation process has a significant role in the creation of segments with different sizes and shapes. This study investigates the plan delivery and quality with different penalty on segment width in volumetric modulated arc (VMAT) delivery for SBRT cases.

2. Methods and materials

2.1. *Patient selection and simulation*

A total of 18 patients treated for SBRT were taken for this study. This included six cases each of lung, abdomen and liver sites. For the lung, stage I/II non-small-cell lung cancer and for the liver, hepatocellular carcinoma and metastatic tumors were taken, while abdominal cases studied were pancreas, lymph nodes and adrenal gland tumors. The average PTV volume for lung, liver and abdomen cases were 38.8 cm^3 (range 18.6–58.6 cm^3), 120.1 cm^3 (range 30.9–280.3 cm^3) and 154.6 cm^3 (range 30.9–280.3 cm^3), respectively. All these patients were simulated with the vac-lac immobilization system with hands above the head position for both simulation and treatment procedure. For all the patients, simulation study were done with computed tomography imaging on *64 slice* Biograph mCT 15 cms above and below the upper and lower limit of the target to encompass all organs at risk and obtain geometric and dosimetric information for the treatment setup. The patients were scanned in a continuous mode with gantry rotation time of 0.5 s and reconstructed in 2 mm slice thickness for precise target delineation. Since tumors of the lung, liver, and abdomen are prone to move with respiratory motion, Active Breathing Coordinator system was applied for patients undergoing treatment for lung and liver cancers to manage the respiratory motion. For patients with other intra-abdominal tumors, a stringent immobilization was done using BodyFix system from Elekta.

2.2. *Contouring and dose prescription*

Based on multimodality imaging process, gross tumor volume (GTV) for all the sites were defined on primary CT image by an experienced radiation oncologist and checked with radiologist as per the multidisciplinary protocol of the institution. Using CMS FocalSim 4.6v (Elekta, Maryland Heights, MO, USA) virtual simulation workstation patient-specific margins were applied for the GTV to the planning target volume (PTV) expansion with superior/inferior marginal range of 7–10 mm and axial margin of 5–7 mm. In addition, organs at risk (OARs), such as the lung, liver, spinal cord, heart, kidneys and, if relevant, bowel, esophagus were delineated corresponding to the tumor