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Original research article

Treatment planning evaluation of sliding window and multiple static segments technique in intensity modulated radiotherapy

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ARTICLE INFO

Article history:
Received 28 March 2012
Received in revised form
12 August 2012
Accepted 19 October 2012

Keywords:
Conformity index
Homogeneity index
Uniformity index
Organs-at-risk
Intensity modulated radiation therapy

ABSTRACT

Background: The demand of improved dose conformity of the tumor has been increased in radiation therapy with the advent of recent imaging facilities and efficient computer technologies.

Aim: We compared the intensity modulated radiotherapy (IMRT) plans delivered with the sliding window (SW IMRT) and step and shoot (SS IMRT) techniques.

Materials and methods: Thirteen patients were planned on 15 MV X-ray for five, seven, nine and thirteen beams direction making the dose constraints analogous. Eclipse treatment planning system with Helios inverse planning software, and Linear Accelerator Varian 2100 C/D with 120 multileaf collimators (MLCs) were used. Gamma analysis was applied to the data acquired with the MapCheck 2^{TM} for different beam directions plan in the sliding window and step and shoot technique to meet the 95% pass criteria at 3%/3 mm. The plans were scrutinized using D_{mean}, D_{max}, D1%, D95%, dose uniformity index (UI), dose conformity index (CI), dose homogeneity index (HI) and monitor units (MUs).

Results: Our data show comparable coverage of the planning target volume (PTV) for both the sliding window and step and shoot techniques. The volume of PTV receiving the prescription dose was 99.8 ± 0.05% and the volume of PTV receiving the maximum dose was 107.6 ± 2.5% in both techniques. Bladder and rectum maximum mean doses for the sliding window and step and shoot plans were 38.1 ± 2.6% and 42.9 ± 10.7%. Homogeneity index (HI) for both techniques was 0.12 ± 0.02 and 0.13 ± 0.02, uniformity index (UI) was 1.07 ± 0.02 and 108 ± 0.01 and conformity index at 98% isodose (CI 98%) was 0.96 ± 0.005 and 0.96 ± 0.005 for the sliding window and step and shoot techniques, respectively, and MUs were 10 ± 12% lower in the step and shoot compared to the sliding window technique.

Conclusion: All these factors indicate that coverage for PTV was nearly identical but dose to organs-at-risk (OARs) was lower in the step and shoot technique.

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http://dx.doi.org/10.1016/j.rpor.2012.10.003

1. Background

The advent of inverse planning systems and methods for delivering nonuniform radiation intensities have ushered in the epoch of the intensity-modulated radiation therapy (IMRT), representing the state of the art in the treatment of many cancers.[1] IMRT modulates the beam to create a conformal dose distribution around the target, while minimizing dose to the surrounding normal tissues, and enables tumor dose escalation. IMRT plans also improve the conformity and homogeneity indices.[2] Both the static, also known as (step and shoot), and dynamic (sliding window) methods of IMRT dose delivery have been developed.

IMRT can be delivered using a conventional MLC, binary MLC or a physical compensator. Among the three, a conventional MLC is the most commonly used. IMRT delivery using a conventional MLC involves either a segmental MLC (SMLC)-based or dynamic MLC (DMLC)-based approach. Although the former involves the delivery of radiation when MLC leaves are stationary, in the latter case MLC leaves move as the radiation is delivered. The main advantage of using a DMLC is that the continuous leaf motion enables the delivered intensity to closely match with the optimal fluence calculated by the inverse treatment planning (ITP) algorithm, accurately preserving both the spatial and intensity resolutions. On the other hand, an SMLC approach resembles a conventional multi-segmented treatment and requires approximating the intensity profile into discrete intensity levels, resulting in a lower resolution.[3]

Numerous comparisons between the different delivery methods have been undertaken utilizing dose volume histogram (DVH) parameters to determine the superiority of any particular technique.[4,5] The SS IMRT may be convenient to verify and is technically less demanding than an SW treatment. A SW IMRT-based delivery requires more monitor units (MU) than the SS method, as the beam is kept on throughout the delivery of radiation.[6] The leakage radiation from collimator leaves and scattered radiation are also different for the two delivery techniques. A difference in integral dose delivered to the surrounding tissues or the volume receiving low dose is thus expected between the two methods due to the difference in the required MU to deliver the same prescription dose.

Slosarek et al. have shown that SW IMRT is independent of the beam rate but these differences are minor.[7] Kry et al. have shown that depending on the treatment energy, IMRT using step and shoot requires 3.5–4.9% times more monitor units than the conventional treatment.[8] These figures are likely to increase with the use of dynamic IMRT. Chui et al. have shown that a SW IMRT requires 20% more MUs as compared to static IMRT.[9] Alaei et al. have shown that SS required on average 15% fewer MUs than a SW with 15% longer treatment time than an SS IMRT treatment.[10] This can lead to an increase in the low-dose volume as well as the risk of radiation-induced malignancies. The issue of integral dose or the total cumulative dose received by tissues is clinically relevant because of the anticipated higher risk of second malignancies associated with a higher integral dose.[11,12]

The main objective of this study is to evaluate the effect of the two IMRT delivery techniques, SW and SS IMRT, using the Eclipse treatment planning system for PTV and healthy normal tissue surrounding the tumor-bearing area.

2. Materials and methods

The Eclipse radiation treatment planning system (RTPS) (Eclipse, Varian 6.5, build 7.1.59, Varian Associates, Palo Alto, CA) with the pencil beam convolution algorithm and Helios inverse planning software was used for optimization and isodose distribution for all IMRT treatment plans in this study. A Varian 2100 C/D (Varian Medical System, Palo Alto, CA) with 120 leaf millennium MLC was used to deliver the treatments. Absolute dose measurements were performed with a cylindrical ionization chamber N30001 (PTW Freiburg, Germany). In our clinic, the calibrated output is adjusted to be 1 cGy = MU to water with a field size of 10 cm × 10 cm and source to surface distance (SSD) of 100 cm with the detector at the depth of the maximum dose according to TG-51 protocol.[13] Thirteen patients were planned on 15 MV X-ray for five, seven, nine and thirteen beams direction making the dose constraints similar.

The MapCHECK 2™ (Model 1177, Sun Nuclear, Melbourne, FL) was used for verification of both the static and dynamic IMRT technique due to their ease of use and immediate readout of results. Gamma analysis was employed to test the acceptability of the delivered plan with a 95% pass criteria at ±3%/±3 mm criterion (Fig. 1).[14]

Prostate patients were chosen which were treated to 50 Gy in 25 fractions of 2 Gy in 7 weeks in conventional 3 DCRT. The boost was given by IMRT in 2 Gy of 8 fractions. CT images of 5 mm thickness at different transverse sections away from the mid plane were taken to create a 3D image.

Partial rectum and partial bladder were created by subtracting the bladder and rectum from PTV using a Boolean operator. All plans with SW and SS techniques of IMRT were generated on the same CT data set with identical structures. The five field IMRT plan was generated for each patient for SW and SS techniques with gantry angles of 135°, 75°, 0°, 285°, and 225°. The seven field IMRT plan for SW and SS techniques had gantry angles of 180°, 105°, 60°, 30°, 330°, 300°, and 255°. The nine field IMRT plan for SW and SS techniques had gantry angles starting with 0° and ended at 320° every 40°. The thirteen field IMRT plan for SW and SS techniques had gantry angles of 160°, 130°, 110°, 80°, 60°, 40°, 0°, 320°, 300°, 280°, 250°, 230°, and 200°.[15] Constraints were applied to obtain possible minimum doses to critical organs without compromising the PTV coverage of at least 95% dose to 95% of PTV volume.

This work was also projected to furnished Monitor units, DVH comparisons among several fields and exercised DVH to calculate D_{mean}, D_{max}, $D_{1\%}$, $D_{95\%}$, dose uniformity index (UI), dose conformity index (CI) and dose homogeneity index (HI) for dose coverage of planning target volume (PTV) and D_{mean}, D_{max}, $D_{15\%}$, $D_{25\%}$, $D_{35\%}$, $D_{50\%}$ volume of the organ at risk were analyzed for the critical organ sparing.

To assess the target coverage and normal tissue sparing the following factors were used.

1. The uniformity index was defined as:

$$UI = \frac{D_5}{D_{95}}$$