Medical Dosimetry ▮ (2015) ▮▮▮–▮▮▮

Medical Dosimetry

journal homepage: www.meddos.org

Skin Dose Differences Between Intensity-Modulated Radiation Therapy and Volumetric-Modulated Arc Therapy and Between Boost and Integrated Treatment Regimens for Treating Head and Neck and Other Cancer Sites in Patients

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ARTICLE INFO

Article history:
Received 30 March 2015
Received in revised form
27 July 2015
Accepted 27 September 2015

Keywords:
Skin dose
VMAT
IMRT
Treatment regimen

ABSTRACT

The purpose of this study was (1) to evaluate dose to skin between volumetric-modulated arc therapy (VMAT) and intensity-modulated radiation therapy (IMRT) treatment techniques for target sites in the head and neck, pelvis, and brain and (2) to determine if the treatment dose and fractionation regimen affect the skin dose between traditional sequential boost and integrated boost regimens for patients with head and neck cancer. A total of 19 patients and 48 plans were evaluated. The Eclipse (v11) treatment planning system was used to plan therapy in 9 patients with head and neck cancer, 5 patients with prostate cancer, and 5 patients with brain cancer with VMAT and static-field IMRT. The mean skin dose and the maximum dose to a contiguous volume of 2 cm^3 for head and neck plans and brain plans and a contiguous volume of 5 cm^3 for pelvis plans were compared for each treatment technique. Of the 9 patients with head and neck cancer, 3 underwent an integrated boost regimen. One integrated boost plan was replanned with IMRT and VMAT using a traditional boost regimen. For target sites located in the head and neck, VMAT reduced the mean dose and contiguous hot spot most noticeably in the shoulder region by 5.6% and 5.4%, respectively. When using an integrated boost regimen, the contiguous hot spot skin dose in the shoulder was larger on average than a traditional boost pattern by 26.5% and the mean skin dose was larger by 1.7%. VMAT techniques largely decrease the contiguous hot spot in the skin in the pelvis by an average of 36% compared with IMRT. For the same target coverage, VMAT can reduce the skin dose in all the regions of the body, but more noticeably in the shoulders in patients with head and neck and pelvis cancer. We also found that using integrated boost regimens in patients with head and neck cancer leads to higher shoulder skin doses compared with traditional boost regimens.

Introduction

Patients with head and neck cancers and prostate cancers comprise a large number of patients treated with radiation therapy. Radiation Therapy plays a major role in definitive and adjuvant treatments, but it can be toxic. Often patients have complex-shaped planning target volumes (PTV), with many organs at risk (OAR) surrounding these volumes. Therefore, treatment planning needs to create conformal dose distributions and avoid OARs.[1,2] Intensity-modulated radiation therapy (IMRT) and volumetric-modulated arc therapy (VMAT) are 2 techniques used currently to produce highly conformal dose distributions. Studies have shown VMAT and IMRT to produce similar dose distributions regarding to the target coverage and OAR dose reductions.[3-6]

IMRT and VMAT use an inverse planning technique, dividing each beam into a number of beamlets. The beamlets are weighted to create fluence patterns to satisfy predetermined organ tolerance criteria.[7] IMRT uses a number of fixed gantry fields to deliver optimized dose distributions, whereas VMAT delivers optimized dose distributions using dynamic multileaf collimator (MLC) motion while the gantry rotates. VMAT plans offer additional degrees of freedom. The MLCs move dynamically, but during gantry rotation, the gantry speed as well as the dose rate may vary. Concerning dose distribution, VMAT plans tend to spread

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http://dx.doi.org/10.1016/j.meddos.2015.09.001
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dose more than IMRT plans, resulting in larger low-dose regions, while reducing unwanted higher-dose regions.[8] An organ directly affected by this delivery difference is the skin. IMRT plans can create hot spots of dose in skin that can be avoided using VMAT. It is known that skin reactions occur in patients with head and neck cancer when using IMRT.[9] Hot spots can occur in the skin on the shoulders, especially when patients with head and neck cancer have involved nodes in the supraclavicular region as well as in patients in whom the target is at a great depth, such as the pelvis.

In addition, different treatment regimens in head and neck cancers may also lead to differences in skin doses. Two treatment regimens are often used; a sequential boost in which 2 treatment plans (primary and boost) are delivered separately and an integrated treatment plan in which a single plan is optimized to deliver different prescribed doses to different targets in the same number of fractions. Owing to the ability to conserve organ doses with IMRT and VMAT, the dose escalation to different targets in the integrated regimen is available.[10]

The purpose of this investigation was (1) to quantify the dose sparing in the skin between VMAT and IMRT plans for different tumor locations, specifically the head and neck, pelvis, and brain, and (2) to quantify differences in the skin dose between a traditional boost regimen and an integrated boost regimen.

Materials and Methods

The Varian Eclipse system was used for treatment planning. The dose calculation algorithm implemented in Eclipse is the anisotropic analytical algorithm (v11, Varian Medical Systems, Palo Alto, CA). The accuracy of the anisotropic analytical algorithm-implemented Eclipse system in the buildup region has been investigated and shown to provide more accurate results in comparison to the PBC algorithm because of its improved electron contamination source model, making it a better choice for calculation of absorbed dose in the skin.[11] In addition, the Eclipse system used to calculate dose distributions included the patient immobilization masks in the external body contour to improve the accuracy of the skin dose calculations.

A total of 19 patients were selected for this retrospective planning study, and treatment was planned with VMAT and IMRT. Therapy was planned for 9 patients with head and neck cancer with complex-shaped targets, with involved nodes extending into the supraclavicular region. Planning was also done for 5 patients with prostate cancer: 3 with involved nodes, 1 with prostate bed, and 1 prostate without involved nodes. Therapy was planned for the 5 patients with brain cancer with different lobes involved. The IMRT delivery technique was sliding window. Each plan was generated to achieve the same coverage with the same organ constraints. VMAT and IMRT plans were planned with no special sparing of skin and were developed as clinically acceptable, deliverable treatment plans. The regions of the skin that were part of the target volume were not considered in mean or contiguous volume dose calculations.

Patients with head and neck cancer

VMAT plans used 2 full arcs and IMRT plans used 7 fields at varying angles from 20° to 340° depending on the patient's anatomy, both using 6-MV photons. The orientation is such that a gantry angle of 180° is anterior posterior for a patient in a supine position. Overall, 6 of the head and neck plans had traditional sequential prescription, where a primary plan delivered a 50.4-Gy dose to involved nodes and primary targets in 24 fractions after which a boost plan delivered a 69.3-Gy dose to primary targets in 33 total fractions. Two plans were prescribed using an integrated boost technique, where primary targets received a 70-Gy dose, primary node targets received a 63-Gy dose, and secondary nodes received a 56-Gy dose in 35 fractions. One of these integrated boost technique prescriptions was planned with a traditional boost technique as well, with both IMRT and VMAT plans to observe the skin dose difference with different prescription regimens.

To quantify skin dose, 3 different regions for the jaw, neck, and shoulders were denoted. The skin was contoured 5 mm from the surface in axial slices in which PTVs were present. In the shoulder skin region, only the anterior skin was considered, as this was where the hottest skin doses and possible skin reactions occur.

In the neck and jaw region, all skin except the extreme posterior region was considered. The posterior region was ignored because of very low skin doses. The mean skin dose as well as the maximum dose in a contiguous 2 cm^3 of skin ($D_{2contig}$) in all 3 regions were denoted. To obtain the 2-cm^3 volume, dose contours were created to visually observe the hottest skin regions, and $D_{2contig}$ was contoured from these regions. The mean dose of the contiguous contoured volume was noted.

Patients with prostate cancer

The prostate plans were planned using 2 full arcs for the VMAT plans. Overall, 7 fields spaced by 50° from 50° to 350° were used for all IMRT plans, except in a patient without nodal involvement. For this case, 1 arc for the VMAT plan and 5 fields at angles of 40°, 120°, 180°, 240°, and 320° for IMRT were used. All plans used 10-MV photons. The prescriptions of the primary plans were a 50.4-Gy dose in 28 fractions to the nodes and prostate PTV and a boost to a 79.2-Gy dose in 44 fractions to the prostate PTV. The prostate-alone plan prescription was a 79.2-Gy dose in 44 fractions and the prostate bed prescription was a 70.2-Gy dose in 39 fractions.

The skin dose was contoured to be 5 mm deep from the surface circumferentially around the patient in axial slices where PTV contours were present. Dose statistics were noted for the mean skin dose in this region and the maximum dose, which was a contiguous 5 cm^3 of skin ($D_{5contig}$). The $D_{5contig}$ was obtained in the same manner described for $D_{2contig}$.

Patients with brain cancer

The brain planning technique used 2 partial arcs for VMAT plans and 5 fields with various spacing for IMRT. The arcs for VMAT plans covered the same angle range as IMRT plans and ranged from 180° to 210°. The prescriptions varied from a 45-Gy dose in 25 fractions (with a boost to 54 Gy) to a 60-Gy dose in 30 fractions. All plans used 6-MV photons.

To quantify the skin dose, the skin was contoured 5 mm deep from the surface in slices where PTV was present and contoured 5° to 10° past the edge of each partial arc used for planning. In a case, a noncoplanar static field was used, and the skin contoured included the skin in this beam's eye view. The mean skin dose in this region was denoted, as well as the maximum dose, which was a contiguous 2 cm^3 of skin ($D_{2contig}$). $D_{2contig}$ is obtained in the same manner as described earlier.

It has been seen that the skin dose difference between VMAT and IMRT was very similar with and without boost plans. Therefore, a composite of both a primary and a boost plan was completed for each region for one patient to demonstrate this effect, and for all other patients, the primary plan was used for skin dose comparisons. For another patient, in the head and neck region, a primary and a boost plan were completed for comparison against the integrated boost technique.

Results

The mean skin dose and $D_{2contig}$ or $D_{5contig}$ depend on the modality of either VMAT or static-field IMRT. VMAT, in general, proved to spare these skin dose statistics, although not for every case. There is a dependence on the location and depth of the tumor. The regions of the skin that may have been a part of the target volume were not considered in mean or contiguous volume dose calculations. However, regions of the skin directly adjacent to the target volumes tended to increase mean and maximum skin dose calculations.

Skin doses for head and neck treatment

For head and neck plans, the skin dose was on average lower when using VMAT rather than IMRT. Table 1 shows the mean skin dose and difference for each plan, and Table 2 shows the corresponding data for $D_{2contig}$ skin dose. The largest observed difference between the 2 modalities was in the shoulder for both the mean dose in the contoured regions of interest and the $D_{2contig}$. VMAT reduced the mean skin dose by 142 cGy, a relative difference of 5.6%. VMAT reduced the $D_{2contig}$ by 268.9 cGy or 5.4%. VMAT reduced the mean skin dose and the $D_{2contig}$ in the jaw and the neck region, but not as remarkably as in the shoulder region. VMAT reduced the neck mean skin dose and the $D_{2contig}$ by less than 4% and in the jaw by 5% for both on average. Figure 1 shows the dose distribution for patient 16 with the corresponding dose-volume histogram (DVH) for targets and skin regions.

Another important finding of this study is that, when comparing integrated boosts with traditional boosts, a traditional boost had a lower $D_{2contig}$, specifically in the shoulder region, and a slightly