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Original article

A dosimetric analysis of 6 MV versus 15 MV photon energy plans for intensity modulated radiation therapy (IMRT) of carcinoma of cervix

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ABSTRACT

Background: Intensity modulated radiotherapy (IMRT) is being used to treat carcinoma of cervix (Ca Cx). Integral dose to normal tissue and increased leakage are the concern about IMRT. 6 MV photon beam is a good choice of energy for Ca Cx IMRT treatment.
Aim: The objective of this study was to compare intensity modulated radiotherapy (IMRT) plans generated by 6 MV and 15 MV photon energies for carcinoma of cervix (Ca Cx) with regards to dosimetric parameters of planning target volume (PTV) and organs at risk (OAR), homogeneity index (HI), conformity index at 98% level (CI 98%), integral dose to normal tissue (NTID) and total number of monitor units (MUs).
Material and methods: A cohort of 16 patients was selected for this study. All patients were to receive a dose of 50 Gy in 25 fractions. IMRT plans were generated for both energies using same dose–volume constraints.
Results: Our results show a comparable coverage of planning target volume (PTV) for both energies. Volume of PTV receiving a prescription dose is $97.8 \pm 0.5\%$ and $98.8 \pm 0.4\%$ for the 6 MV and the 15 MV plans. Volume of PTV receiving a dose of 107% is $4.4 \pm 7.8\%$ and $16.1 \pm 22.2\%$. Bladder and rectum mean doses for the 6 MV and the 15 MV photon plans were 39.8 ± 3.0 Gy and 40.0 ± 3.2 Gy, and 35.8 ± 3.1 Gy and 36.0 ± 3.1 Gy, respectively. Homogeneity index (HI) for both energies was 1.04. The conformity indices at 98% isodose (CI 98%) were 1.3 ± 0.1 and 1.4 ± 0.1 for 6 MV and 15 MV photon plans, respectively.
Conclusions: We conclude that a 6 MV photon is a good choice for Ca Cx IMRT as it produces a highly conformal, homogeneous plan with superior target coverage and better OAR sparing.

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1. Introduction

Carcinoma of cervix (Ca Cx) is a common gynecological cancer among women around the world.[1] Radiation therapy has a long history in the treatment of Ca Cx. Three-dimensional conformal radiotherapy (3DCRT) for Ca Cx had been commonly delivered through a four-field beam arrangement untill intensity modulated radiotherapy (IMRT) came into practice. 3DCRT for carcinoma of cervix is most commonly delivered with high-energy photons. IMRT is an advanced form of a conformal radiation therapy. It conforms the prescription radiation dose to the shape of target tissue in three dimensions resulting in the sparing of normal surrounding tissues.[2] IMRT involves multiple beams from different directions having nonuniform fluences. These beams are optimized to deliver a high dose to the target volume and an acceptably low dose to the surrounding normal structures. Sparing the surrounding normal tissue may reduce the risk of toxicity.

It has been shown that IMRT significantly reduces the volume of normal tissues irradiated to high doses in patients with gynecologic tumors.[3,4] IMRT is increasingly being used nowadays in cervical cancer since several studies have reported its dosimetric and clinical benefit over a conventional whole pelvis external beam radiotherapy.[5–7] In IMRT, total numbers of monitor units (MUs) are two to three times higher than in the conventional radiotherapy. That raises the concern about leakage radiation and secondary malignancy.[8,9] Huq et al.[10] showed a 40% increase in leakage between the leaves with high-energy photons (25 MV) compared to low energy (6 MV); the measured average leakage was 2.5% and 3.5% for 6 MV and 25 MV, respectively. Higher leakage may lead to a higher dose to the patient outside the irradiated volume. The concern about leakage and secondary malignancy makes photon beam energy an important parameter to be selected during IMRT planning.[11] We have generated IMRT plans using low energy photons as well as high-energy photons. In this paper, we have studied the effect of beam energy on the quality of IMRT plans for Ca Cx. This paper investigates whether 15 MV beam IMRT offers a better target coverage and normal tissue sparing than 6 MV. Dosimetric parameters of target and OAR used for the comparison were mean dose, maximum dose, homogeneity index (HI), conformity index at 98% isodose level (CI 98%), integral dose to normal tissue (NTID), dose outside the target and total number of MUs for the plans generated for both energies.

2. Materials and methods

2.1. Patients characteristics

In this study we compared and evaluated the treatment plans in terms of dosimetric parameters using 6 MV and 15 MV photons for Ca Cx patients of different stages (II to III B). A cohort of 16 patients was selected retrospectively, who received treatment with 3DCRT or IMRT for Ca Cx. The median anterior-posterior and right–left separation, of the patient body, for the cohort was 21.0 ± 2.9 cm (ranging from 15 cm to 27.0 cm) and 34.0 ± 4.1 cm (ranging from 28.6 cm to 41.9 cm), respectively. Median PTV volume was $981.8 \pm 290.3\ cm^3$ (ranging from $648.6\ cm^3$ to $1804.7\ cm^3$). The rectum and bladder volumes were $83.5 \pm 37.6\ cm^3$ (ranging from $37.0\ cm^3$ to $152\ cm^3$) and $144.7 \pm 80.9\ cm^3$ (ranging from $66.1\ cm^3$ to $332.5\ cm^3$) respectively. We have found that a part of bladder and rectum is overlapping with PTV. We have calculated the non-overlapping volume of bladder (Bladder minus PTV) and rectum (Rectum minus PTV). The Bladder minus PTV volume was $98.1 \pm 58.6\ cm^3$ varying from $26.9\ cm^3$ to $226.6\ cm^3$. Rectum minus PTV volume was $60.8 \pm 30.7\ cm^3$ varying from $20\ cm^3$ to $117\ cm^3$.

2.2. Simulation, target and OAR delineation

CT simulation was done for all the patients in supine position. All patients were immobilized with a thermoplastic cast (Orfit Industry, Belgium). CT scans of each patient were obtained in the treatment position using LightSpeed VCT 64 slice CT scan (GE Medical Systems, LLC, Waukesha, WI, USA). CT scans were obtained at 2.5 mm slice thickness. The CT scans were obtained from the L2 vertebral body to 5 cm below the ischial tuberosities, which is consistent with other researchers.[6] All patients were CT scanned with full bladder. All patients were simulated, planned and treated in a similar manner. All structures, gross target volume (GTV), clinical target volume (CTV), planning target volumes (PTV) were marked by radiation oncologist using ICRU recommendations.[12] Interobserver variability of contouring was not considered in this study. A uniform margin of 0.5 cm was used to create PTV from CTV expansion. Li et al.[13] recommended the use of 0.83 cm as a CTV–PTV margin for pelvic tumors (including prostate and gynecologic malignancies) based on mega voltage cone beam CT (MVCT) imaging. Santanam et al.[14] used a margin of 0.7 cm for gynecological malignancy. Mundt et al.[7] used 1 cm PTV margin which greatly increased the volume of normal tissue irradiated. They found that upper and lower body immobilization may allow smaller PTV expansion resulting in a less normal tissue irradiation. Reduction in CTV to PTV expansion can be accomplished through an improved immobilization and the use of online imaging.[15] As we use pelvic immobilization and kilovoltage (kV) imaging and cone beam computed tomography (CBCT) for our patient's setup, and it is a known fact that the kV imaging has superior soft tissue contrast,[16] we have taken a 0.5 cm margin to create PTV. Rectum, bladder, small bowl and both femoral heads were marked as organs at risk (OAR). A non-overlapping structure for bladder (Bladder minus PTV) and rectum (Rectum minus PTV) was created using Boolean operation during structure delineation to optimize the dosimetry. To evaluate the dose to normal tissues (NT), a structure NT, consisting of non-PTV tissue, was created by contouring all the tissue within the external skin contour of the patient.

2.3. Treatment objective and planning

All patients were planned to a total dose of 50 Gy in 25 fractions. Our goal was to cover 98% PTV volume to 98% of the prescription dose. Dose to rectum and bladder was restricted