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Technical note

Influence of optimizing protocol choice on the integral dose value in prostate radiotherapy planning by dynamic techniques – Pilot study

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ABSTRACT

Aim: The purpose of this study was to compare the values of integral dose, calculated for treatment plans of dynamic radiotherapy techniques prepared with two different optimization protocols.
Background: Delivering radiation by IMRT, VMAT and also HT techniques has an influence on the low dose deposition of large areas of the patient body. Delivery of low dose can induce injury of healthy cells. In this situation, a good solution would be to reduce the area, which receives a low dose, but with appropriate dose level for the target volume.
Materials and methods: To calculate integral dose values of plans structures, we used 90 external beam radiotherapy plans prepared for three techniques (intensity modulated radiotherapy, volumetric modulated arc therapy and helical tomotherapy). One technique includes three different geometry combinations. 45 plans were prepared with classic optimization protocol and 45 with rings optimization protocol which should reduce the low doses in the normal tissue.
Results: Differences in values of the integral dose depend on the geometry and technique of irradiation, as well as optimization protocol used in preparing treatment plans. The application of the rings optimization caused the value of normal tissue integral dose (NTID) to decrease.
Conclusion: It is possible to limit the area of low dose irradiation and reduce NTID in dynamic techniques with the same clinical constraints for OAR and PTV volumes by using an optimization protocol other than the classic one.

1. Introduction

In recent years, techniques using beam intensity modulation, both intensity modulated radiotherapy (IMRT), volumetric

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modulated arc therapy (VMAT) and helical tomotherapy (HT), have become frequently used in clinical practice. One can say that in some locations, on account of dose distribution conformality to the target area, better dose reduction in organs at risk or shorter therapy sessions, IMRT techniques substitute conventional three dimensional conformal radiotherapy (3DCRT).[1–3]

Despite significant advantages, there is a problem associated with the use of both IMRT, VMAT and HT as they have the dose bath effect.[4] Dose bath effect or low radiation dose in normal tissue area is clearly observable when low isodose on CT scans are compared between the 3DCRT and IMRT techniques as is dose reduction in the organ at risk (OAR) volume for IMRT techniques plans towards 3DCRT.

Integral dose (ID) is defined as a product of mean dose and tissue volume for contemplated organs or structure (1).[5]

$$ID = D_{\text{mean of structure}} \times V_{\text{structure}} \quad (1)$$

In the case of normal tissue, the term normal tissue integral dose (NTID) is used, defined as a difference between ID deposited in the body (in healthy tissue) and ID deposited in the clinical target volume (CTV) (2).

$$NTID = ID_{\text{normal tissue}} - ID_{\text{CTV}} \quad (2)$$

In prostate location, both the bladder and the rectal wall are in close proximity or they have a common part with the planning target volume. It is very important in the case of prostate cancer therapy, on account of patients' quality of life and side effects, to reduce high dose to the bladder and rectal wall,[6,7] but integral dose reduction in these organs would also be beneficial.

According to As Low As Reasonably Achievable rule, it would also be ideal to reduce as much as possible dose delivered to healthy tissue.

Value of Integral Dose for given organs depends on many factors, including the beam energy, density of surrounding tissue, dose calculating algorithm, margin size,[5,8–10] but, primarily, on the choice of radiation technique.

In prostate cancer therapy, in dynamic techniques, ID and low isodose location may be different depending on the number of beams for IMRT, number of arcs for VMAT, and the pitch factor for HT. Another factor, determining the value of ID may be the choice of an optimization process.

In this pilot study, we report the use of two optimization processes for planning of the same patient to explore their influence over the value of the integral dose in the volume of healthy tissue and OAR.

2. Materials and methods

To prepare plans, five prostate cancer patients were selected. The patients had been previously treated with external beam radiotherapy. CTV was defined between 28 and 51 cm^3 (entire prostate – without nodes and seminal vesicles). CTV with 1 cm margin (unsymmetrical to the rectum site 0.7 cm) creating PTV extent 120–160 cm^3. Common part PTV and rectum did not exceed 15% of the volume of the rectum and the common part of the PTV and bladder did not exceed 25% of the volume of the bladder.

The criterion for patients selection, besides PTV and CTV volumes, was organs at risk volume. Bladder filling was defined between 150 and 250 cm^3, rectum volume between 65 and 90 cm^3, femoral heads between 60 and 80 cm^3. Organs at risk and CTV contouring was performed by the same doctor.

To determine normal tissue volume, which ranged from 17 to 25 l, two limits were used: the upper one – between third and fourth lumbar vertebrae, and the lower one – three CT scans below the biggest ring.

To optimize data collection, five auxiliary structures were created: body ID volume (normal tissue volume defined earlier), a sphere with a margin of 1 mm around the PTV, created to make a high dose gradient between the target and healthy tissue volumes during the optimization process (used in IMRT and VMAT) and three rings. First ring of 2 cm around PTV, second of 2 cm around the first one and third of 2 cm around the second one. Ring structures were used to plan optimization by reducing the dose to healthy tissue.

IMRT plan was made with the following geometry: 5 beams (0, 60, 110, 250, 300 deg), 7 beams (0, 50, 100, 150, 210, 260, 310 deg), 9 beams (0, 40, 70, 110, 150, 210, 250, 290, 320 deg).

VMAT plans have been prepared with 1 arc (160–200 deg), 2 arcs (170–190 and 160–200 deg) and 3 arcs (181–179 deg and two previous combinations) geometry.

Tomotherapy plans were prepared using three pitch factors: 0.215; 0.287 and 0.430. Parameters used in HT plans were the Modulation Factor (MF) = 2.6; Field Width (FW) = 1.0 cm and pitch factors defined earlier.

For all 5 patients, unified optimization protocols were used for planning. Structures weight during the optimization were identical for IMRT and VMAT, and different for HT, because another treatment planning system was used for HT. Criteria of clinical constraints for OARs and PTV in all techniques were the same.

For one patient, 18 plans were prepared (6 IMRT, 6 VMAT, 6 HT plans) – 9 with normal optimization (only one auxiliary structure – 1 mm around PTV for IMRT and VMAT and without this structure for HT) and 9 with rings optimization.

Dose calculation algorithm in IMRT and VMAT optimization was AAA version 10.0.28 in the Eclipse treatment planning system by Varian, in Tomtherapy CCC version 4.3 in TomoTherapy Planning System by Accuracy.

6 MV X-ray beam was used in all prepared plans, and for IMRT and VMAT FF beam with Millennium 120 Leaf MLC.

To calculate integral dose values for each patient, Aoyama formula was used, and the difference between normal tissue and CTV integral dose to calculate NTID.

3. Results

Differences in values of integral dose between techniques are not great, but we can point to lower ID in some of these groups and to some trends (Fig. 1).

In the bladder, integral doses are similar for IMRT and HT techniques. For VMAT technique in this structure, they are slightly higher.