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The use of *in vivo* dosimetry within the combined treatment of uterine corpus cancer

Relevance: Radiotherapy is the standard post-surgery treatment in patients with uterine corpus cancer. However, radiotherapy affects 90.0–100.0% of the volume of risk organs. Information on the actual dose delivered to critical structures is needed to ensure the quality of radiotherapy.

The purpose of this study was to determine the impact of the type of ionizing radiation on the dose load on the rectal mucosa using *in vivo* dosimetry.

Results: At the first and tenth sessions of treatment using a cobalt apparatus, the *in vivo* dosimetry showed that the minimum value of the dose received during the tenth cycle was higher by 0.1 Gy. That is, the deviations from the planned dose were less at the same maximum values. Both the average value and the median during the tenth cycle were also moderately higher. The relative difference between the dose planned and received during the tenth cycle was higher than during the first cycle by an average of 1.12575%, with a median of 0.82214. When conducting radiotherapy using a linear accelerator, the average and median values were higher in the second measurement despite almost identical minimum and maximum values. The relative difference between the planned and received doses during the tenth cycle was higher than during the first cycle by an average of 0.55619%, with a median of 0.42948.

Conclusion: The conducted study showed an intra- and interindividual variability of *in vivo* dosimetry results during radiotherapy of genital cancer patients. *In vivo* dosimetric control showed that the relative difference between the doses calculated and received by the rectal mucosa upon reaching of 20.0 Gy dose in comparison to the first irradiation cycle was twice higher on the ROCUS-AM cobalt apparatus vs. the Clinac 600 C linear accelerator.

The data obtained during the investigation indicates the need to develop innovative approaches to topometric preparation of genital cancer patients and to continue their dosimetric monitoring to establish the causes of discrepancies in the results.

Keywords: radiation therapy (RT), uterine corpus cancer, dose load, *in vivo* dosimetry, quality assurance.

Introduction. Radiation therapy (RT) is the standard adjuvant treatment in the majority of cases of uterine corpus cancer. The purpose of post-surgery RT is to irradiate the bed of the removed uterus and lymphatic drainage paths to prevent locoregional recurrence [1].

Such a volume of irradiation affects 90.0–100.0% of risk organs, i.e., the rectosigmoid colon, bladder, and 20.0–30.0% of the small intestine. According to the literature, it results in significant complications of the treatment, including cystitis, enterocolitis, and rectitis [2–5].

The existing 3D individual dosimetric planning programs are based on international principles of the definition of three tumor radiation levels depending on high, medium, or low risk. Such an approach ensures rational radiation of the tumor at reduced radiation of healthy organs, which are inevitably exposed to radiation due to their anatomical localization [6].

Still, the optimistic forecasts provided by dose-volume histograms do not allow to exclude high risks of complications with high radiation doses [6]. This actualizes the need to obtain information on the actual dose delivered to critical structures to ensure the quality of RT since even a small change in the beam orientation, or the patient positioning can significantly change the dose received [7].

In vivo dosimetry is used as an additional tool to control the quality of RT [8] since up to date it is the best way to assess the dose delivered to the patient. One of the purposes of *in vivo* dosimetry is to compare the doses according to the indications of the detector with theoreti-

cal values calculated using the Treatment Planning System (TPS) [8, 9].

The purpose of this study was to determine the impact of the type of ionizing radiation on the dose delivered to the rectal mucosa using *in vivo* dosimetry.

Materials and methods: We analyzed the treatment outcome of 110 patients with stages IB-II uterine corpus cancer treated at the RT Department of Grigoriev Institute for Medical Radiology of National Academy of Medical Science of Ukraine in 2016–2019. The age of the patients varied from 41 to 85 years; the average age was 61.0±8.4 years.

The study involved 95 (86.3%) patients with stage I (T1bNxM0) and 15 (13.7%) patients with stage II (T2NxM0) uterine corpus cancer. All patients underwent a combined treatment, which included surgery in the scope of uterine extirpation with appendages as the first stage and a post-surgery RT as the second stage.

The post-surgery external-beam RT (EBRT) was delivered using a Clinac 600 C linear accelerator with three-dimensional (3D) CT-based planning or a ROCUS-AM cobalt apparatus with two-dimensional (2D) planning. EBRT followed a classical fractionation technique with the fraction dose of 2.0 Gy 5 times a week up to the total boost dose of 40.0–50.0 Gy.

The patients underwent *in vivo* dosimetry during the first and tenth EBRT sessions using a PTW-Freiburg UNIDOS-E apparatus. Variations in the actual dose were assessed in gynecological cancer patients using *in vivo* dosimetry after

the first session and in the middle of the post-surgery EBRT (upon reaching the boost dose of 20.0 Gy).

Results and Discussion:

The range of the dose delivered by the ROCUS-AM gamma-therapeutic apparatus to the rectal mucosa in the first measurement amounted to 1.60-1.97 Gy. Taking into account the permissible measurement error (PE) of 3.0% (1.94–2.06 Gy), the dose received by the rectum was lower than planned in 49 (98.0%) patients; 1 (2.0%) patient received a standard dose. The mean and median values of the dose measured at the first session were similar and amounted to 1.811 and 1.807 Gy, respectively.

The difference between the calculated and the actual dose ranged from 0.028 to 0.3979 Gy, with the mean value of 0.18807. The median relative deviation from the dose planned at the first session was equal to 0.19255 Gy for the patients treated with the ROCUS-AM apparatus.

With the repeated dosimetry upon reaching of the boost dose of 20.0 Gy, the absorbed dose ranged from 1.70 to 1.96 Gy. Given the PE 3.0% (1.94-2.06 Gy), the dose received by the rectum was again lower than planned in 49 (98.0%) out of 50 patients. The mean and median values of the dose received in the second measurement were similar and amounted to 1.830 and 1.837 Gy, respectively.

The difference between the planned and the actually received doses ranged from 0.038 to 0.2937 Gy, with the mean value of 0.16921. The median relative deviation from the planned dose at the second session was equal to 0.16215 Gy for the patients treated with the ROCUS-AM apparatus.

The comparison of dosimetric data obtained *in vivo* at the first and tenth sessions revealed that the minimum value of the actual dose received was 0.1 Gy higher at the tenth session. That is, deviations from the planned dose were less at the same maximum values. Both the mean and the median values at the tenth session were also slightly higher.

The analysis of the relative difference between the planned and received doses showed that the dose received at the tenth session was higher than at the first session by an average of 1.12575%, with a median of 0.82214.

The dose absorbed at the first RT session using the Clinac 600 C linear accelerator amounted to 1.56–2.19 Gy. The dose absorbed by the rectal mucosa was less than planned in 24 (40.0%) out of 60 patients, exceeded the planned in 9 (15.0%) patients, and was within acceptable limits in 27 (45.0%) patients. According to *in vivo* dosimetry, the mean and median values of the actually received dose at the first session on the Clinac 600 C linear accelerator were equal to 1.9539 and 1.9791 Gy, respectively.

The difference between the planned and the actual dose in the first measurement ranged from -0.19 to 0.4302 Gy, with the mean value of 0.046. the median relative deviation from the calculated dose at the first session was equal to 0.0209 Gy for patients treated with the Clinac 600 C accelerator.

At the second measurement (tenth EBRT session), the dose to the rectal mucosa was lower than calculated in 23 (38.3%) out of 60 patients, higher than calculated in 10 (16.7%) patients, and was within acceptable limits in 27 (45.0%) patients. The dose absorbed during RT using the Clinac 600 C linear accelerator upon reaching of 20 Gy amounted to 1.59-2.11 Gy. According to *in vivo* dosimetry, the mean and median values of the actually received dose at the second measurement were equal to 1.9411 and 1.9662 Gy, respectively.

The difference between the calculated and actual dose ranged from -0.1103 to 0.4034 Gy, with the mean value of 0.05887. The median relative deviation from the calculated dose at the second measurement was equal to 0.0338 Gy for patients treated with the Clinac 600 C accelerator.

The comparison of dosimetric data obtained *in vivo* at the first and tenth sessions in patients treated with the Clinac 600 C apparatus revealed that both the average and the median values were higher at the second measurement despite the almost identical minimum and maximum values.

Table 1 presents a comparative analysis of data obtained during *in vivo* dosimetry: the dose actually received by the rectal mucosa at the first and tenth EBRT sessions; the actual difference between the calculated dose (2.0 Gy) and the dose received at the first and tenth sessions; the relative difference depending on the type of radiation, as well as the significance of the obtained results.

Table 1 – Comparative analysis of data obtained by *in vivo* dosimetry depending on the type of radiation

	Rank 1 Sum	Rank 2 Sum	U	Z	p-level	Z	p-level	Valid N CLINAC 600	Valid N ROKUS-AM	2*1sided
Dose, actually received at the first session	4249.500	1528.500	352.500	6.66146	0.000000	6.66163	0.000000	60	50	0.000000
Actual difference at the first session	2122.500	3655.500	352.500	-6.66146	0.000000	-6.66163	0.000000	60	50	0.000000
Dose, actually received at the tenth session	4087.000	1691.000	515.000	5.64361	0.000000	5.64373	0.000000	60	50	0.000000
Actual difference at the tenth session	2285.000	3493.000	515.000	-5.64361	0.000000	-5.64373	0.000000	60	50	0.000000
Relative difference	3561.000	2217.000	1041.000	2.34889	0.018830	2.34890	0.018830	60	50	0.018553

The analysis of the relative difference between the calculated and actually received doses showed that the dose received at the tenth session was higher than at the first session by an average of 0.55619%, with a median of 0.42948.

Conclusions: The study revealed the presence of intra- and interindividual variability of *in vivo* dosimetry results during RT in patients with uterine corpus cancer. The use of photon irradiation (3D-planning) ensures that the actual dose corresponds to the planned in 45.0% of patients, while only 2.0% of patients have dose matching when they are treated with a gamma-therapeutic device (2D-planning).

In vivo dosimetric monitoring showed that upon reaching the boost dose of 20.0 Gy the relative difference between the dose calculated and actually received by the rectal mucosa in comparison to the first RT session on the ROCUS-AM apparatus was 2.0 times higher compared to the Clinac 600 C accelerator.

Our data indicate the need to develop new approaches to the topometric preparation of patients with genital cancer.

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