Dosimetric verification of the dose calculation algorithms in real time prostate brachytherapy

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SUMMARY

BACKGROUND: During real time prostate brachytherapy different calculation algorithms can be used which gives the opportunity to modulate the dwell times and positions of the source and consequently the dose distribution and values of therapeutic indices [1].

AIM: The aim of this study was the dosimetric verification (in-phantom) of three optimization algorithms for dose calculation during real-time prostate brachytherapy.

MATERIALS/METHODS: Three optimization algorithm were evaluated: geometric optimization (GO), inverse optimization (IO) and blind inverse optimization (BIO). Then treatment plans for the tissue-equivalent phantom were prepared. For each plan the same CTV, organs at risk (OARs: urethra, rectum), number of needles and geometry of implant were used.

RESULTS: Measured mean doses and their standard deviations for GO, IO and BIO were respectively: 11.13 Gy and 0.01 Gy, 15.71 Gy and 0.01 Gy, 14.74 Gy and 0.02 Gy for the urethra and 10.11 Gy and 0.01 Gy, 8.97 Gy and 0.01 Gy, 8.70 Gy and 0.01 Gy for the rectum. Comparison between doses measured by semiconductor detectors and calculated doses revealed differences in the range from 0.10 Gy between doses compared in the urethra for IO and BIO even to 2.46 Gy for GO for the same analyzed organ. For the rectum these differences were between 0.32 and 0.66 Gy.

CONCLUSIONS: Qualitative comparative analysis performed for a phantom study for 3D-CBRT prostate treatment proved the correctness of verifi ed optimization algorithms implemented in Oncentra Prostate vs. 3.0.9.

KEY WORDS: real time brachytherapy, dose verification, dose measurements, semiconductor detectors

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BACKGROUND

External beam radiotherapy followed by a temporary high dose rate afterloading implant is a clinically used procedure for the treatment of prostate cancer. The second part of this combined schedule consists of 3D conformal real time HDR brachytherapy (3D-CBRT) with an Iridium 192 source and it is used mostly as a boost [3, 4, 5, 6]. The single radioactive stepping source moves through all the implanted needles according to the prepared in real-time treatment plan. Delivering higher radiation doses precisely to the prostate and achieving optimal dose conformity is possible with the ability to optimize dwell times and positions along the implanted needles [7]. The use of different calculation algorithms gives the opportunity to modulate these dwell times and positions of the source which result in dose distribution modulation and consequently the values of therapeutic indices.

In the Brachytherapy Department of the Greater Poland Cancer Centre, 3D-CBRT is applied in a single treatment session or in 2 fractions giving 15 or 10 Gy per fraction [6, 8]. Planning and execution of real-time prostate brachytherapy is carried out in HDR bunker [9]. The whole treatment procedure is ultrasonography guided irradiation of CTV – pros-

tate gland while sparing the dose to organs at risk (urethra, bladder) [10, 11, 12]. The whole geometry is reconstructed based on transverse images from transrectal ultrasound (TRUS). Next the pre-planning procedure is carried out. Treatment plan based on reconstructed geometry (Virtual Plan, VP) is prepared. The number of needles and their positions are defined to achieve the clinically acceptable dose distribution for the treated patient [13, 14]. After needle insertion under ultrasound guidance, new image set acquisition is performed. Anatomical structures are redefined and the positions of needles are verified [15]. Then optimization is performed for the new geometry of implant and volumes of interest which are reconstructed in real time. Dose distribution is calculated even several times to generate the plan which can be accepted from a clinical point of view. This final plan is called Live Plan (LV) and it is used for treatment delivery [9].

AIM

The aim of this study was the dosimetric verification (*in-phantom*) of three different optimization algorithms used in the dose calculation process during real-time prostate brachytherapy by comparing the doses calculated in Oncentra Prostate® vs. 3.0.9 treatment planning system with doses measured by using semiconductor detectors.

MATERIALS AND METHODS

Doses in urethra and rectum were measured with semiconductor detectors: single semiconductor detector bladder probe (T9113 PTW Freiburg®) and flexible five semiconductor detectors rectum probe (T9112 PTW Freiburg®). These detectors are dedicated to in-vivo dosimetry. The flexible bladder probe has one detector with 3 mm diameter which is located 8 mm from the tip of the probe. The second used probe (rectum) consists of five single detectors. They are spaced 15 mm apart from each other, which increases the probability to measure the maximum of the rectum dose. Both probes were connected to the detector connection box, which was linked to a Multi Channel Dosimeter MULTIDOS PTW Freiburg®. Probes were placed in an anatomical tissue-equivalent phantom – semiconductor bladder probe in the urethra and semiconductor rectum probe in the rectum. Apart from placement of probes, the whole treatment and planning procedure was done as usual. The phantom used in the study with probes and implanted needles is shown in Figure 1.

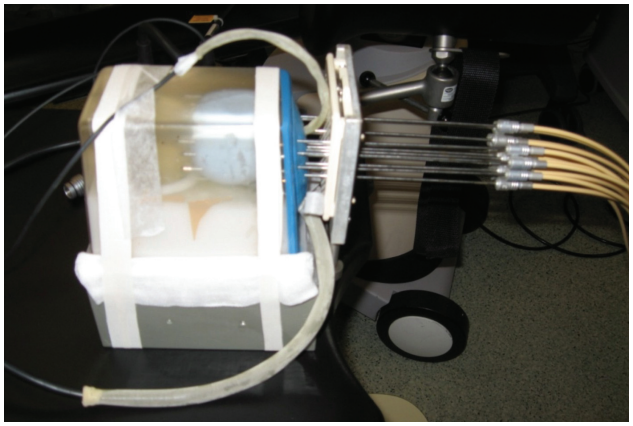

Fig. 1. The tissue-equivalent phantom with needles placed, bladder and rectum probes, used for dosimetric verification of the dose distribution in real time prostate brachytherapy

After acquisition of images treatment plans for tissue-equivalent phantom were prepared using Oncentra Prostate® vs. 3.0.9 treatment planning system. For each optimization algorithm (GO, IO, BIO) three plans were prepared. In each plan the volume of CTV, the volume of OARs, number of needles and geometry of implant were exactly the same. Prostate (CTV), urethra, rectum and used probes were outlined on ultrasound images. Unfortunately there was no technical possibility to determine reference points in places where the detectors were placed. That is why the authors decided to compare maximum doses calculated in used TPS with measured doses and to analyze the tendencies in dose distribution which is assumed to be acceptable from a clinical point of view [16–19].

RESULTS

Three series of measurements for each used optimization algorithm were made. The prescribed dose was 10 Gy in every case. Results of doses measured using semiconductor probes with mean values and standard deviation (SD) are shown in Table 1.