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

**Marta MOCNA, Grzegorz ZWIERZCHOWSKI**

**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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Greater Poland Cancer Centre
15th Garbary St.
61-866-Poznań

**Address for correspondence:**
Marta Mocna
Department of Medical Physics
Greater Poland Cancer Centre
15th Garbary St.
61-866 Poznań
e-mail: marta.mocna@gmail.com

## 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.

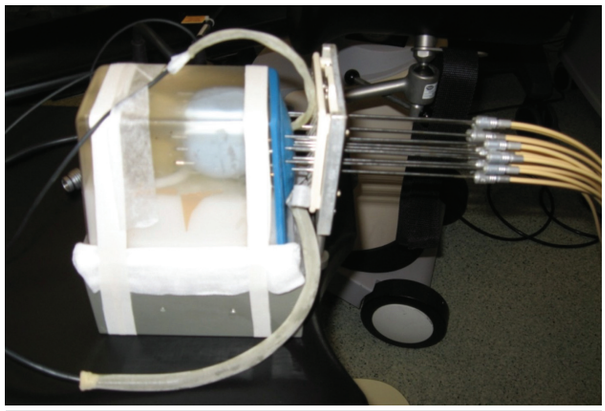

**Fig. 1.** The tissue-equivalent phantom with needles placed, bladder and rectum probes, used for dosimetric verification of the dose distribution in real time prostate brachytherapy

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.

**Table 1**. Doses measured using different optimization algorithms (GO, IO, BIO) by semiconductor probes implemented in used tissue-equivalent phantom: DU in urethra, DR in rectum with mean values (DM) and standard deviation (SD)

| Series of measurements | GO | | IO | | BIO | |
|---|---|---|---|---|---|---|
| | DU [Gy] | DR [Gy] | DU [Gy] | DR [Gy] | DU [Gy] | DR [Gy] |
| 1 | 11,14 | 10,11 | 15,81 | 8,96 | 14,76 | 8,72 |
| 2 | 11,12 | 10,09 | 15,82 | 8,98 | 14,74 | 8,70 |
| 3 | 11,14 | 10,12 | 15,80 | 8,96 | 14,72 | 8,69 |
| Dm | 11,13 | 10,11 | 15,81 | 8,97 | 14,74 | 8,70 |
| SD | 0,01 | 0,01 | 0,01 | 0,01 | 0,02 | 0,01 |

**Table 2**. Doses calculated in Oncentra Prostate® vs. 3.0.9 treatment planning system using different optimization algorithms

| Optimizationalgorithm | Urethra | | Rectum | |
|---|---|---|---|---|
| | D10 [Gy] | Dmax [Gy] | D10 [Gy] | Dmax [Gy] |
| GO | 11,41 | 13,59 | 9,11 | 10,77 |
| IO | 13,49 | 15,91 | 7,97 | 9,29 |
| BIO | 12,81 | 14,84 | 7,92 | 9,13 |

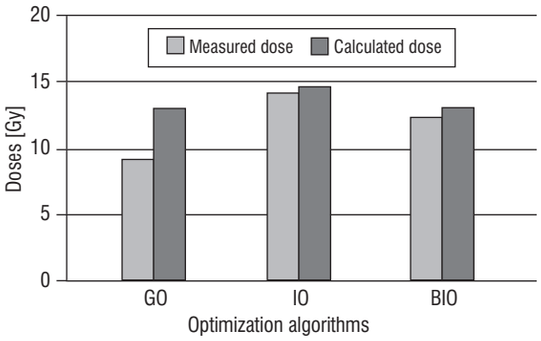


**Fig. 2.** The tendencies in dose distribution in urethra achieved by using different optimization algorithms (GO-Geometrical Optimization, IO-Inverse Optimization, BIO-Blind Inverse Optimization)

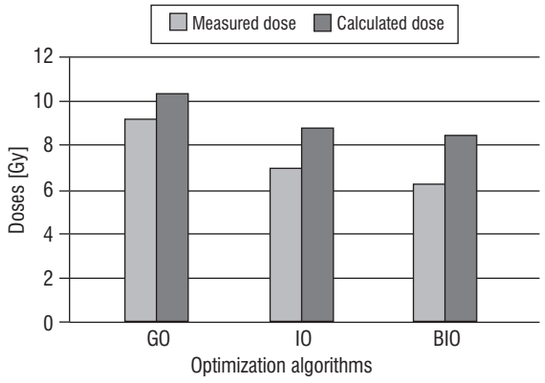


**Fig. 3.** The tendencies in dose distribution in rectum achieved by using different optimization algorithms (GO-Geometrical Optimization, IO-Inverse Optimization, BIO-Blind Inverse Optimization)

Maximum doses calculated by TPS are shown in Table 2.

As mentioned above, the trends in dose distribution in OARs achieved by using different optimization algorithms were analyzed. These trends are shown in Figure 2 (for urethra) and Figure 3 (for rectum).

## DISCUSSION

The quality of HDR prostate brachytherapy implantations is evaluated by controlling the dose volume histogram parameters for CTV and OARs. Delivering high homogenous doses precisely to the prostate gland while sparing the dose in urethra and rectum need to be controlled in every clinical case [15]. Geometric dependencies between CTV and critical organs are not common in other clinical cases (OARs inside or in very close proximity to the CTV). That is why in this study the phantom

was used by the authors to perform the measurements using semiconductor probes.

Three series of measurements for each evaluated optimization algorithm were performed. For each received dose in each analyzed OAR and optimization algorithm respectively, the average values with standard deviations (SD) were calculated. This verification confirmed that the optimization algorithms implemented in Oncentra Prostate® vs. 3.0.9 treatment planning system seem to be working correctly. Although there were some technical difficulties with defining the reference points in places where the semiconductor detectors were placed, the whole study gives the opportunity to verify the values of maximal doses calculated by used TPS. Results showed that for some of the measurements the differences occurred between measured and calculated doses, but the final conclusion was based on the qualitative tendencies in achieving dose distribution acceptable from a clinical point of view in chosen OARs. Analyzing these tendencies, the highest maximum doses in the rectum were measured and calculated using GO, the lowest maximum doses were measured and calculated using BIO. Results achieved for the urethra were the same, meaning the tendencies also show that the highest maximum doses were measured and calculated for the same optimization algorithm but this time it was IO. The lowest measured and calculated doses in the urethra were achieved using GO.

Technical problems with precise localization of the active area of semiconductor probes are also very important while in-vivo dosimetry is going to be performed. Controlled measurements of the doses deposited in irradiated volumes are rather difficult to achieve. Detectors are located in a high dose gradient area and inaccurate positioning (even single millimetres of shift) of semiconductor detectors could have a strong influence on the measured doses.

Needle implantation could be 'non-optimal'. From a clinical point of view, anatomy of the patient could be the limiting factor in achieving eligible dose distribution. In such conditions even small differences in dose distribution for critical organs could be the determinant factors for treating or not treating the patient using a particular treatment plan. When the whole procedure is time limited (patient in anaesthesia) fast and reliable tools for achieving clinically acceptable treatment plans are essential during daily practice.

In operation theatre conditions, in-vivo dosimetry during real time procedure is in most cases difficult to perform. The use of a phantom ensures repeatable geometric relations between the needles (implant) and treated volume and corresponding organs at risk and also makes dose distribution verification possible. Knowing the limitations of optimization algorithms is essential to make proper clinical decisions during real-time planned brachytherapy of the prostate.

## CONCLUSIONS

1. The tissue-equivalent phantom used by the authors was useful for measurements using semiconductor rectum and bladder probes in real time prostate HDR brachytherapy.

2. On the basis of qualitative analysis of the calculated and measured doses, the correctness of dose distribution achieved by using different optimization algorithms implemented in Oncentra Prostate vs. 3.0.9 treatment planning system was proved.

3. The calculations demonstrate that when the same geometry of the whole implant is used (volume of CTV, OARs' volume, number of needles) the final dose distribution depends only on the used optimization algorithm.

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