Original article

Comparison of 2D- and 3D-guided implantation in accelerated partial breast irradiation (APBI)

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Abstract

Purpose: In this study two different pre-planning methods (2D vs. 3D) were compared in respect to the implant quality as judged by volumetric and dose parameters of the treatment plans. The aim of this work was to evaluate the influence of the imaging modalities used for pre-planning purpose to the treatment plan quality.

Material and methods: Twenty-four patients treated with HDR multicatheter implants were randomly selected for experiment. All patients underwent breast conserving surgery. Flexible catheters were implanted into the breast through the template. Inter-catheter distance, number of planes and catheters were adjusted, in respect to the size and location of the target. Pre-planning was used to evaluate the implant geometry in respect to the target. Needles number and position were modified if necessary. There were two experimental subgroups consisted of 12 patients each. Different pre-planning procedure was employed in each group. In the first group 2D X-ray imaging system was used. In the second one the 3D pre-planning method based on CT was performed. Treatment plans were evaluated with parameters calculated based on dose-volume histograms (DVHs). Volumetric and dose parameters were used for comparison of the dose distribution between the two experimental subgroups.

Results: The mean value of target coverage $V_{PTV}100$ is higher for 3D pre-planning than for 2D (91.7% vs. 86.1%). The dose that covers 90% of the PTV (D90) is also higher for 3D pre-planning than for 2D (4.2 Gy vs. 3.6 Gy). Similar relation can be observed for the values of dose homogeneity index where DHI obtained for 3D pre-planning is 0.60 and 0.53 for 2D. All differences were statistically significant with $p < 0.05$.

Conclusions: Analysis presented in this paper showed that 3D pre-planning method improves the geometrical quality of the implant.

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Key words: HDR brachytherapy, breast cancer, APBI, pre-planning.

Purpose

Over the past decade the role of accelerated partial breast irradiation (APBI) for patients with early stage breast cancer has emerged as an alternative to the conventional whole breast irradiation with external beam [1-7]. APBI with high dose rate (HDR) interstitial implants significantly reduces the overall treatment time and leads to lower radiotherapy-associated side effects because of the smaller treated volumes [2, 6, 8-11]. However, in this method, the precise target definition and implant quality are crucial for accurate and conformal delivery of the prescribe dose to the PTV with simultaneous sparing of normal tissue and organs at risk (lung at the treated side and skin) [2, 3, 6, 10].

A pre-planning procedure which involves different imaging modalities facilitates the localization of the target and provides guidance for implant parameters (template size, number of planes and catheters). Preplanning methods increase the dosimetric quality of the implant [12, 13]. Orthogonal films (2D imaging) and CT simulation (3D imaging) are the guidance techniques which can be used to assure the appropriate catheter position with respect to the marked lesion [6]. In our institute, 2D pre-planning was employed for the group of the earliest patients treated with HDR multicatheter implants. Since the cone beam CT (CBCT) simulator was installed in the operating theatre in the Brachytherapy Department both pre-planning and treatment planning procedures have been 3D based.

In this study two different pre-planning methods (2D vs. 3D) were compared with respect to the implant quality as judged by volumetric and dose parameters of the treatment plans. The aim of this work was to evaluate the influence of the imaging modalities used for pre-planning purposes on the treatment plan quality.

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Material and methods

Twenty-four patients treated with HDR multicatheter implants were randomly selected for the experiment. All patients underwent breast conserving surgery. The cavity wall, after lumpectomy, was marked with surgical titanium clips. Flexible catheters were implanted into the breast through the template, in a triangular pattern. Inter-catheter distance, number of planes and catheters were adjusted, with respect to the size and location of the target defined as a marked lesion with 0.5-2 cm margins. In the analyzed treatment plans two or three-plane implants were used for all patients with 1.0-1.4 cm separation between the catheters.

Pre-planning

Pre-planning was used to evaluate the implant geometry with respect to the target. Number and position of needles were modified if necessary.

There were two experimental subgroups consisting of 12 patients each. A different pre-planning procedure was employed in each group. In the first group the 2D X-ray imaging system IBU-D (Integrated Brachytherapy Unit by Nucletron B.V.) was used. Fluoroscopic films were taken before insertion of needles to evaluate the location of the surgical clips and after the implantation procedure to assess the geometric quality of the implant.

In the second group the 3D pre-planning method was performed with the Simulix Evolution Simulator (Nucletron B.V.). Before implantation of needles, cone beam CT acquisition was performed to evaluate the location of the surgical clips. After inserting the needles, the second acquisition was performed to evaluate the position of the needles in relation to the marked lesion.

Treatment planning

Finally, for treatment planning purposes, CT was performed for each patient with a 3 mm slice thickness. Treatment plans were created in the planning system Oncentra MasterPlan version 3.1. The planning target volume (PTV) including the lumpectomy cavity with required margin was delineated on CT slices and the catheter positions were reconstructed. Basal dose points related to the active source positions were used. The distance and active source positions were individually defined for each catheter taking into account the localization of the PTV. Geometric optimization combined with graphical one were used for each plan. The delivered dose was 32 Gy in eight fractions (4 Gy per fraction). Treatment plans was evaluated with parameters calculated based on dose-volume histograms (DVHs). Volumetric and dose parameters were used for comparison of the dose distribution between the two experimental subgroups. In order to quantify the dose distribution the following parameters and indices were evaluated: PTV volume (VPTV), the dose that covers 90% of the PTV (D90), relative value of the PTV volume receiving 100 and 150% of the prescribed dose ($V_{PTV}100$, $V_{PTV}150$), absolute volume of implant receiving 100 and 150% of the prescribed dose (V_I100, V_I150) and the dose homogeneity index ($DHI = 1 – V_I150/V_I100$).

Statistical analysis was done with Statistica 7.1. Differences with a p value < 0.05 were regarded as significant.

Table 1. Comparison of selected parameters for subgroups

		2D pre-planning	3D pre-planning
Patient number		12	12
Catheter number		13 (9-18)	13 (11-17)
PTV Volume [ccm]		70.2 (18.5-283.4)	47.2 (19.2-106.4)
Target	$V_{PTV}100$ [%]	86.1 ± 6.3	91.7 ± 4.4
	$V_{PTV}150$ [%]	47.9 ± 10.3	45.2 ± 9.9
	D90 [Gy]	3.6 ± 0.6	4.2 ± 0.3
Implant	V_I100 [ccm]	76.5 (27.7-255.6)	65.5 (27.1-134.2)
	V_I150 [ccm]	36.1 (10.6-107.7)	26.1 (8.2-49.3)
DHI		0.53 ± 0.07	6.0 ± 0.06

Results

The results of our study are shown in Table 1. Some of the most important parameters for verification of treatment plans are: target coverage with 100% isodose, the dose that covers 90% of the PTV and dose homogeneity index. Mean values of all parameters are different between groups. The mean value of target coverage $V_{PTV}100$ is higher for 3D pre-planning than for 2D (91.7% vs. 86.1%). The dose that covers 90% of the PTV (D90) is also higher for 3D pre-planning than for 2D (4.2 Gy vs. 3.6 Gy). A similar relation can be observed for the values of dose homogeneity index where DHI obtained for 3D pre-planning is 0.60 and 0.53 for 2D.

Mann-Whitney U test was used to compare the $V_{PTV}100$ and D90 between groups. Statistical analysis shows that the differences between 2D and 3D pre-planning groups for considered parameters are statistically significant ($p = 0.006$ for $V_{PTV}100$ and $p = 0.013$ for D90). The mean values of $V_{PTV}100$ and D90 with standard errors (SE) and standard deviations (SD) are graphically shown as box diagrams in Fig. 1 and Fig. 2, respectively. Figure 3 presents box diagrams comparing mean values with standard errors (SE) and standard deviations (SD) of dose homogeneity indices (DHIs) for 2D and 3D pre-planning groups. Student's t-test confirmed statistically significant differences with $p = 0.013$.

Discussion

CT-guided implantation allowed the needles to be inserted precisely with respect to the target volume [13]. Improvement in implant quality increases the dose distribution conformity and homogeneity without extensive use of the optimization algorithms. Insufficient implant quality may result in lower PTV coverage which needs to be improved with optimization. Modification of the dwell times may produce overdose areas inside the treated volume; it reduces the homogeneity of the dose distribution and influences the cosmesis.

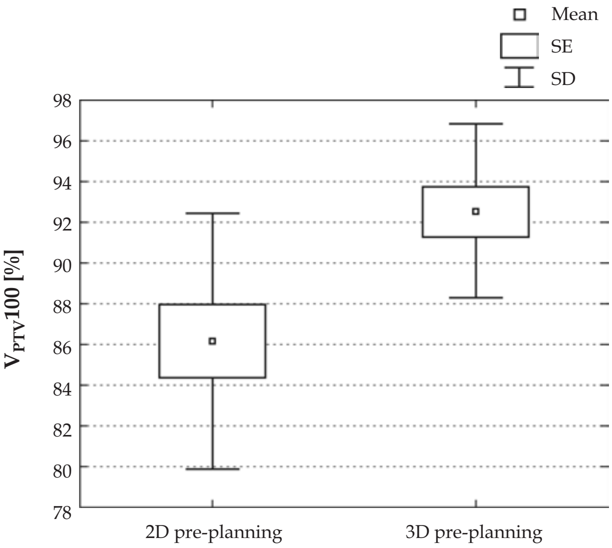

Fig. 1. Box diagrams comparing target 100% coverage between groups for which 2D and 3D pre-planning were used

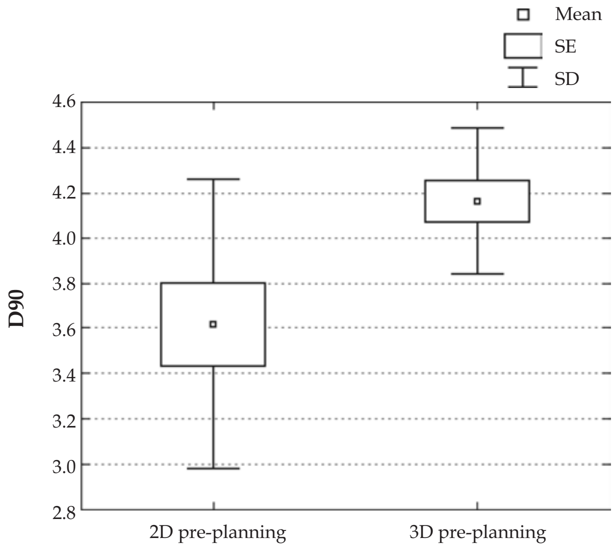

Fig. 2. Box diagrams comparing D90 between groups for which 2D and 3D pre-planning were used

In brachytherapy planning it is highly recommended to deliver at least the prescribed dose to the target with acceptable homogeneity of the dose distribution [9]. However, in some situations planning involves finding a balance between homogeneity and sufficient coverage.

The results of this study show that replacing the 2D pre-planning method with the 3D one seems to be the right solution, resulting in higher values of target coverage and dose homogeneity index simultaneously.

Similar results were demonstrated by Cuttino *et al.* [13]. Their study showed a significant increase of all dosimetric parameters when the traditional implantation technique under fluoroscopic guidance was changed to a CT-guided method.

Conclusions

In the Cancer Centre in Gliwice, APBI with HDR multicatheter implants was introduced in May 2006. To reach the dosimetric and volumetric goals we are still trying to improve our procedure. First we replaced 2D planning with CT-based treatment planning, then 3D pre-planning was introduced into APBI practice. The analysis presented in this paper shows that the 3D pre-planning method improves the geometric quality of the implant, which benefits the dosimetry. Continued practice is necessary to find more factors which may improve our results.

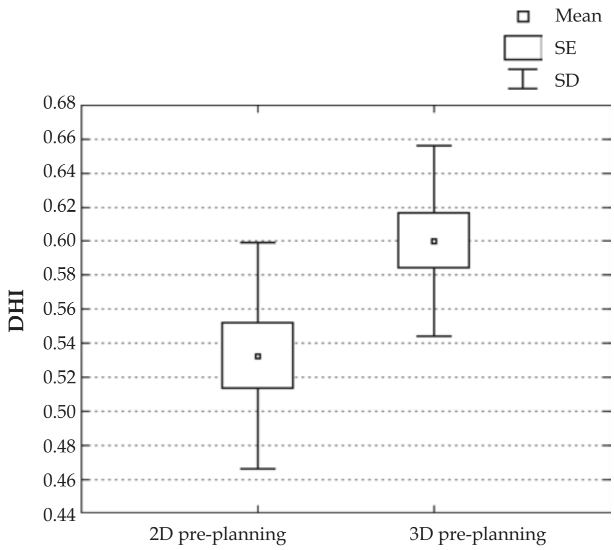

Fig. 3. Box diagrams comparing dose homogeneity index (DHI) between groups for which 2D and 3D pre-planning were used

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