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Dosimetry Planning Method of Postoperative Proton Therapy for Breast Cancer with Metallic Expander Valve Installed

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The effect of the metal valve of the breast expander on the dose distribution of postoperative proton therapy for breast cancer was studied. Using a patented phantom with an anatomical shape of the breast, it was found that a dose failure occurs in the chest area. A method for dosimetric planning of postoperative proton therapy for breast cancer was developed taking into account the effect of the metal valve of the expander based on correct contours of the irradiated area, eliminating the effect of a dose failure.

Keywords: Proton therapy, dosimetric planning, breast cancer, expander, radiation therapy.

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Delivery of therapeutic doses in proton therapy requires accurate assessment of the water-equivalent thickness of materials along the trajectory of the therapeutic beam [1]. A breast expander containing elements with a high atomic number (specifically, a metallic valve) may introduce uncertainty into the determination of the water-equivalent thickness [2]. This uncertainty is normally attributable to the artifacts induced by metallic components of the expander [3], which distort the actual shape of the metallic valve and the density of surrounding tissues [4]. Thus, the aim of the present study is to develop a method for dosimetric planning of postoperative radiation therapy for breast cancer based on correct outlines of the irradiated area.

A patented phantom with an anatomical breast shape [5], which is shown in Fig. 1, was used in the study.

Its surface was prepared by photopolymer 3D printing on a Mars 3 Pro printer (Elegoo, China), and the internal components of the phantom are made of epoxy resins that imitate the density of an aqueous medium. A stainless steel valve of a Mentor breast expander (Johnson & Johnson, United States) was positioned within the equivalent aqueous medium, but did not come into contact with the phantom walls. The phantom has a technological opening: a slit for dosimetric film, which was used to measure the distribution of the absorbed dose and analyze the obtained data in the sagittal plane perpendicular to the posterior surface of the breast expander valve.

Two different algorithms were used for dosimetric planning. The first method involved dosimetric planning without recreating the outlines of the true shape of the metallic expander valve and without correcting the density of the area subject to artifacts. In the second case, dosimetric planning involved outlining the true shape of the metallic expander valve and estimating the density of surrounding structures subject to artifacts (Fig. 2).

A Brilliance Big Bore computerized tomography scanner (Philips, United States) was used for the topometric CT study. Outlining and dosimetric calculation were performed in the Pinnacle 16.2 proton and photon radiation therapy planning system (Philips, United States) using the IMPT method and a calculation algorithm based on Pencil Beam with a proton beam energy varying from 101 to 177 MeV.

The method of dosimetric planning of postoperative radiation therapy for breast cancer with account for the influence of the metallic expander valve consists in reconstructing the correct shape of the valve and estimating the density of surrounding structures. We matched the outlines of the expander valve to its actual appearance (Fig. 2) and eliminated the artifacts distorting its visible shape by adjusting the display window so that only the valve boundaries remained visible. The density coefficient of stainless steel was then assigned to the resulting outline, since artifacts formed false air cavities within the valve in the process of topometric CT study. The surrounding anatomical structures subject to artifacts were then outlined with an assessment of their density; i.e., the density of an aqueous medium was assigned to the phantom, and the densities of muscle, fatty tissue, and the aqueous medium of the filled expander were assigned to the patient (Fig. 2).

It should be noted that test dosimetric plans were calculated three times by the two mentioned methods to take the errors in beam transport and outlining into account. More test plans are not needed, since the surfaces and internal components of the phantom are not subject to geometric and density changes.

The presence of a calibration curve of the topometric computerized tomography scanner in the dosimetric plan-

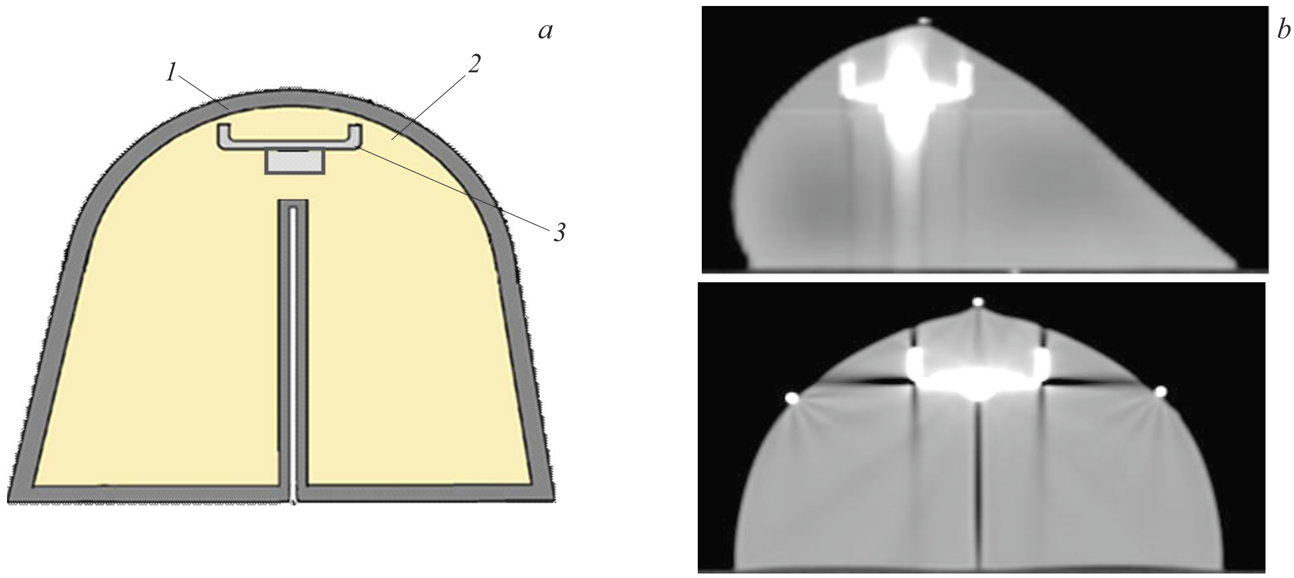

Figure 1. Schematic diagram (*a*) and CT scans (*b*) of the phantom with an anatomical breast shape. *1* — 3D-printed phantom surface; *2* — interior part of the phantom made of epoxy resins; and *3* — metallic expander valve.

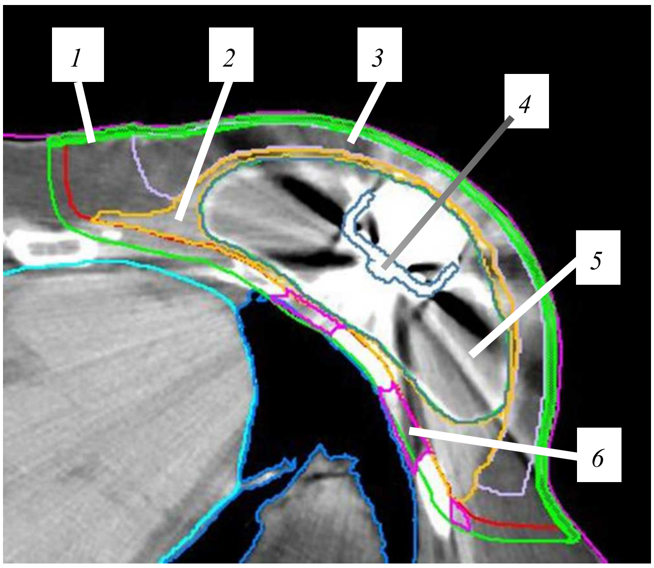

Figure 2. Outlining of the metallic expander valve and surrounding anatomical structures suffering from artifacts. *1* — Skin, *2* — pectoralis major muscle tissue, *3* — adipose tissue, *4* — metallic expander valve, *5* — aqueous medium of the filled expander, and *6* — muscle tissue of the internal intercostal muscle.

ning system with samples of a high atomic number and the availability of a „wide window" in the topometric study are crucial for the application of the method of postoperative radiation therapy for breast cancer with account for the influence of the metallic expander valve.

The phantom with an anatomical breast shape was irradiated at a Proteus®PLUS (IBA, Belgium) proton therapy complex using the thin scanning proton beam technique.

A region of „dose failure" (reduction by 25.1% on the average) was identified (Fig. 3, *a*) in the measurement data corresponding to the first type of dosimetric planning.

The results of analysis of dosimetric films with dose distributions obtained using the method of dosimetric planning of postoperative radiation therapy for breast cancer with correct topometric outlining and careful attention the true shape of the metallic expander valve and the density of surrounding structures revealed that this „dose failure" was eliminated (Fig. 3, *b*).

Postoperative irradiation of breast cancer in patients with an expander is a topical issue for photon and proton radiation therapy. The use of a method of dosimetric planning of postoperative radiation therapy for breast cancer with account for the influence of the metallic expander valve is a solution to this complex problem. Compared to photon beam therapy, proton therapy suffers somewhat more from the discussed issue, since incorrectly determined densities have a significant impact on the change in the true range of protons.

Our experiments on simulation of breast irradiation in proton therapy with the phantom of an anatomical breast shape and the obtained results suggest the following conclusions.

1. A region of „dose failure," which leads to insufficient local irradiation and possible relapses in the patient, is observed in the chest wall area if the expander valve shape is not corrected and the density of structures subject to artifacts is not taken into account and estimated.

2. A correct expander valve outline and renormalization of the structure density contribute to optimization of the dose distribution of proton irradiation and help eliminate the „dose failure" region.

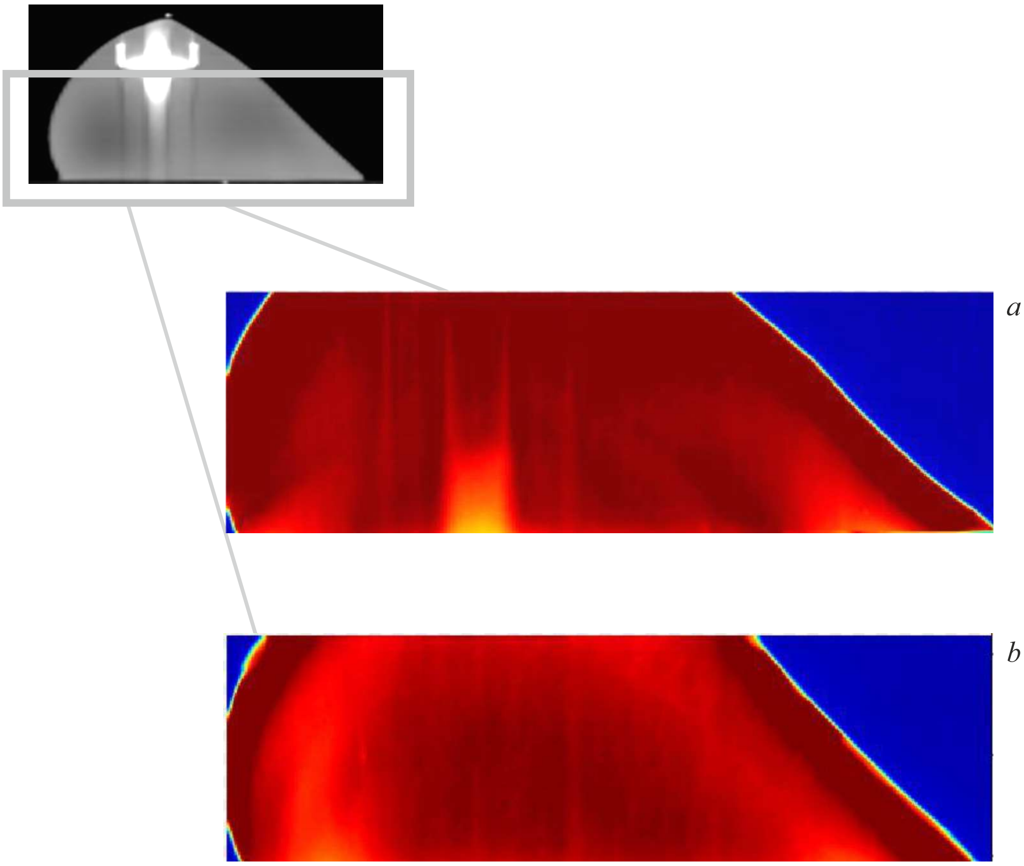

Figure 3. Results of film dosimetry. *a* — Dosimetric planning of the first type and the „dose failure" region; *b* — dosimetric planning of the second type and elimination of „dose failure."

3. The proposed method of dosimetric planning of postoperative radiation therapy for breast cancer with account for the influence of the metallic expander valve may be applied in clinical settings in both proton and photon radiation therapy.

This article does not contain any studies involving human participants.

Conflict of interest

The authors declare that they have no conflict of interest.

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