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Research Article

Verification of tangential breast treatment dose during 2D treatment planning

Y.P.Y.P. Ariyasinghe[1]*, A.J. Hilmi[1], C. Jayalath[2], V. Sivakumar[2], V.P.S. Perera[3]

1. *National Hospital Kandy, Kandy, Sri Lanka*
2. *Department of Physics, University of Peradeniya, Peradeniya, Sri Lanka*
3. *Department of Physics, The Open University of Sri Lanka, Nawala, Sri Lanka*

Abstract

This study presents a water phantom study of verification of tangential breast treatment dose calculations in a two-dimensional treatment planning system (TPS) at the Department of Radiotherapy, in a National hospital in Sri Lanka. Measurements were made using a 0.6 cc Farmer-type cylindrical ionization chamber with an electrometer in a breast phantom made of water field Perspex structure. The measured doses in the breast were compared with calculations made on a two-dimensional radiotherapy treatment planning software THERAPLAN®PLUS version 3.55 using the digitized breast phantom contour. Overall, the measurements obtained from the TPS had an accuracy of ±5% compared to the direct measurements while most of the measurements lie within ±3%. And dose in the chest wall was below the tolerance level of the lung and heart. Thus, it was concluded that TPS calculations and dose distributions are within the clinically acceptable accuracy level of international standards (ICRU report 50).

Keywords: Radiotherapy dose calculation algorithm verification, tangential breast irradiation.

* Corresponding author: yapaariyasinghe@gmail.com

ORCID ID: https://orcid.org/0009-0003-8231-2373

1. INTRODUCTION

Radiation therapy uses ionizing radiation in the treatment of malignant cells with the aim of targeting a precisely measured dose of radiation to a defined tumor volume, sparing the surrounding healthy tissues and the critical organs as much as possible [1]. According to the National Cancer Incidence and Mortality data of Sri Lanka, 31848 new cancer patients were recorded in 2019, within that 26 percent of female patients having breast cancer [2]. The epidemiology of breast cancer worldwide reports that every one million new cases of breast cancer occur representing 18 percent of all cancer cases [3].

Radiotherapy of breast cancer is difficult because of the complex geometry of the target volume, which includes the breast, the adjacent lymph nodes, and the presence of critical organs such as the lungs and heart [4]. Ideally, the dose distribution should be as homogeneous as possible to avoid areas of under dose or overdose, which can result in insufficient tumor control or late sequelae (unacceptable fibrosis) and poor cosmesis [5]. The critical parameters to verify treatment plans for breast radiotherapy are the accuracy of the dose calculation and the homogeneity of the dose distribution of the treatment plan.

Three-dimensional (3D) Radiotherapy TPS are now common in radiotherapy departments offering improved accuracy and enhanced visualization in the radiotherapy treatment planning process. However, the Department of Radiotherapy of this particular hospital uses a two-dimensional (2D) treatment planning system, THERAPLAN®PLUS version 3.55 (MDS Nordion, Canada). The use of radiotherapy is complicated by the complex geometry and large variability of the target volume for different patients. More accurate dose calculation from TPS could be expected, particularly by increasing the amount of treatment site data input. The absolute dose at the prescription point is of prime importance in radiotherapy treatment planning. Monitor units are calculated to this point and the dose distributions are relative to this calculated value.

In this study, the accuracy of the radiation dose calculation algorithm employed in THERAPLAN®PLUS version 3.55 was evaluated for different conditions simulating tangential breast treatment. THERAPLAN®PLUS uses the Clarkson equation for the calculation of the relative dose at any point on the axis of a radiation beam and Pencil Beam spread function Data (PBD) in the calculation of the relative dose at any point [6]. A 0.6 CC Farmer-type cylindrical ionization chamber with an electrometer was used to measure the dose distribution at the axial mid-plane of the breast phantom made of Perspex structure filed with water. This study is an important part of quality assurance procedures to accurately validate a treatment planning system.

2. MATERIALS AND METHOD

2.1. Preparation of 2D Breast Phantom

The breast phantom shown in Figure 1 was prepared using Perspex sheets. The phantom was designed to simulate the 2D anatomical and radiological characteristics of a breast. It was a very effective model for measuring radiation dose and optimizing breast radiation therapy treatments.

Figure 1. Prepared Perspex breast phantom.

2.2. Treatment Planning

At the 2D treatment planning, a single patient contour at midplane was acquired using lead wire, which is transcribed onto a sheet of graph paper, with reference points identified. In this study, the cross-section of the phantom's curved surface could be assumed as the patient's breast contour as shown in Figure 2.

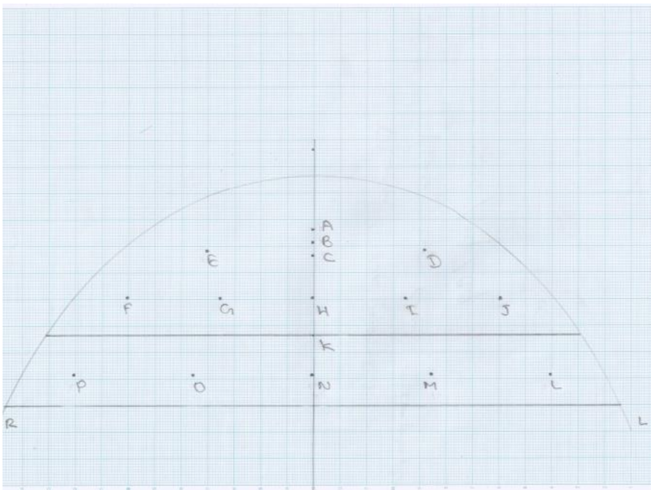

Figure 2: Cross section of the phantom's curved surface, PTV, and measurement points.

A transverse line registered the mid-transverse plane of the breast phantom. Planning Target Volume (PTV) and calculation point A to P were marked on the slice (Figure 2).

The contour of the phantom curved surface shown in Figure 2 was digitized by tracing the graph paper while identifying measurement points (Figure 3). The Radiotherapy department uses SSD, tangential fields, and compensating wedges technique for breast radiotherapy. In this exposure, a half-beam block and 30-degree wedges were used. In the treatment planning, a 30-degree wedge was used to compensate for the missing tissue. From this simulation procedure, a field size of 18 cm in length and 14 cm in width was used. A fraction size of 2 Gy as the prescribed dose was set at the normalized point A in Figure 2. The point A was selected to be two-thirds of the distance along the midline of the mid-transverse of the breast contour from the borderline of PTV to prepare uniform dose distribution. Percentages of doses at points A to P and monitor units for both beams were computed using the TPS.

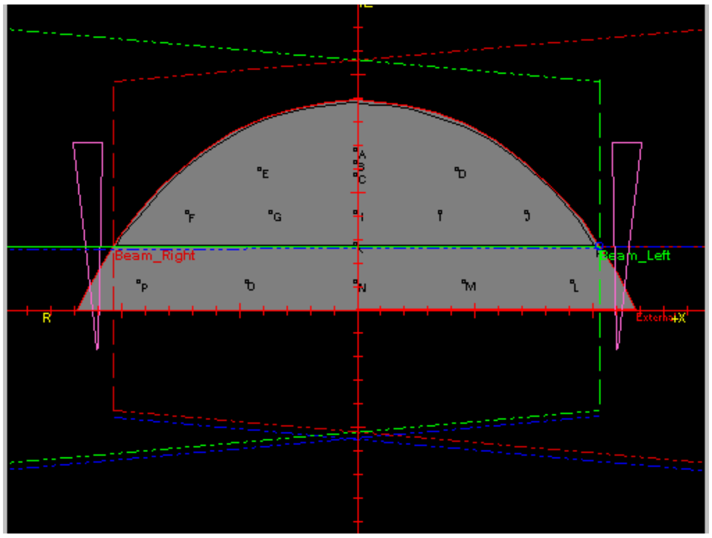

Figure 3: Screenshot - Beam arrangement of Breast Radiotherapy, Right and left fields with half beam blocks and wedges on TPS, THERAPLAN®PLUS.

2.3. Dosimetry

Measurement points A to P were determined and marked on the phantom using laser beams in the mold room. Quality Assurance (QA) tests were done to ensure the accuracy of the radiotherapy machine, before taking dosimetric measurements. The output calibration of the treatment machines was performed using a 0.6 CC ionization chamber (PTW Freiburg 30001-2125) and electrometer (PTW Freiburg UNIDOS T 10002) by following IAEA TRS

398 protocol in a standard 30 cm × 30 cm × 30 cm water phantom to ensure that machine output is same as the data fed to the TPS [7].

The breast phantom was placed on the treatment couch of the teletherapy machines (THERATRINIC 780 E, MDS Nordion, Canada) and aligned using laser beams. Machine parameters were set as gantry - 270^{o}, collimator - 0^{o}, field width - 14 cm, height - 18 cm with SSD - 80 cm for the right side beam, and for the left side beam gantry angle was changed to 90^{o}. Half beam block and 30-degree angle wedges were used as planned by TPS, THERAPLAN®PLUS. The 0.6 CC ionization chamber was placed on point A marked at the midplane of the breast phantom and the phantom was exposed from both the right and left side. The dose of measurement at point A was measured using the 0.6 CC ionization chamber and the electrometer by following the IAEA TRS 398 protocol [7]. The same procedure was followed by changing the ionizing chamber positions, from points A to P to determine dose rates at each point.

3. RESULTS AND DISCUSSION

The plot of the calculated isodose line in the sagittal breast midplane using TPS, THERAPLAN®PLUS was shown in Figure 4. The plot of the dose distribution in Figure 4 shows that the dose was between 95% and 107 % of the prescribed dose in the PTV of the breast phantom according to ICRU recommendation [8]. Therefore, this beam arrangement with beam modifications which used half beam blocks and 30-degree angle wedges is suitable for radiotherapy treatment for a real breast cancer patient.

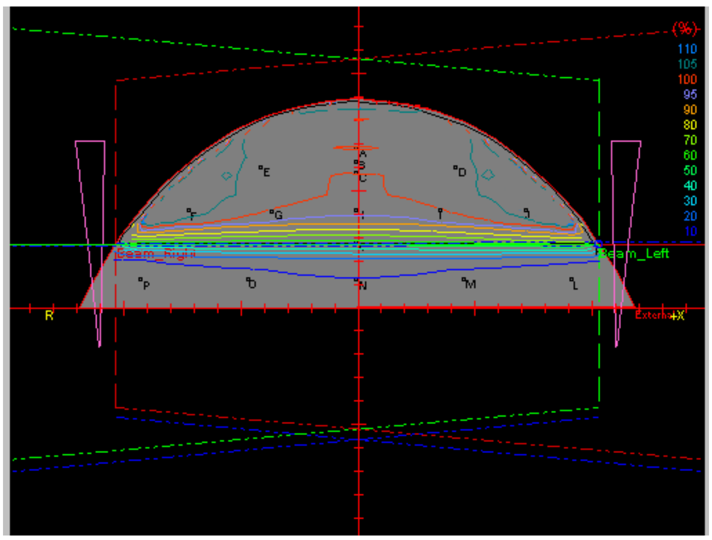

Figure 4: Screenshot – Dose distribution (Isodose line) in the breast treatment plan on TPS, THERAPLAN®PLUS.

The electron density of phantom-made Perspex and water are 3.24 x 10^{23} electrons/g and 3.34 x 10^{23} electrons/g respectively [9]. Basic dose distribution data are usually measured in a water phantom, which closely approximates the radiation absorption and scattering properties of muscle and other soft tissues [9]. Another reason for the choice of water as a phantom material is that it is universally available with reproducible radiation properties. The calculated doses derived from the TPS, THERAPLAN®PLUS were compared with the measured doses in the breast phantom. Each measurement point was analyzed for percentage difference using the following Equation [10].

$$\text{percentage difference} = \frac{(\text{measured dose} - \text{calculated dose}) \times 100}{\text{measured dose}}$$

The dose variation and percentage difference at different measurement points were shown in Figure 5. Overall, the measurements in the PTV area at points A, B, C, D, E, F, G, H, I, and J confirmed that the dose calculations are within an accuracy of, ±5% while most measurements varied within ±3%. The ICRU report 50 recommends target dose uniformity within +7 % and –5 % relative to the dose delivered to a well-defined prescription point within the target [9]. At points below the shielding area, dose difference percentages were also within the accuracy of, ±5%.

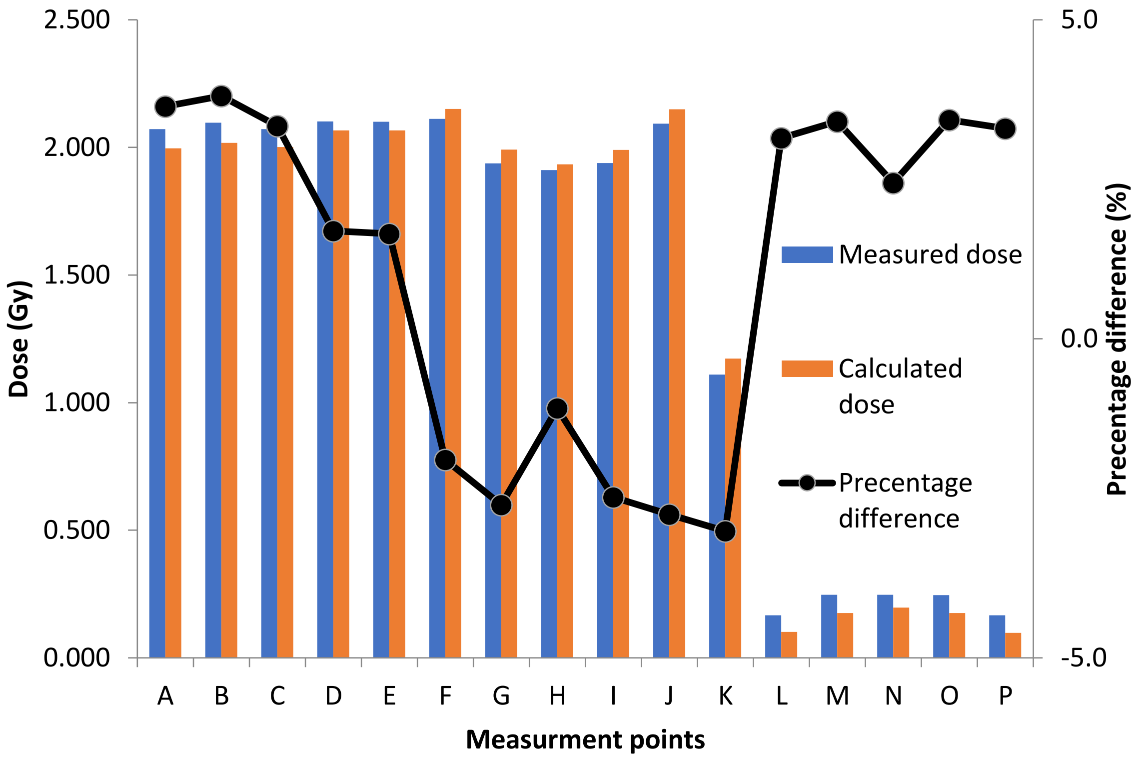

Figure 5: The dose variation and percentage difference at different measurement points

However, doses of points in the chest wall (below the half beam block shielding) L, M, N, O, and P were below 0.3 Gy per fraction. Compared to the values in the PTV area, it was a very small value and below the tolerance dose values of the lung and heart. Therefore, the treatment technique and calculations planned with TPS, THERAPLAN®PLUS were accurate according to ICRU recommendation. The overall results give confidence in the dose calculations for breast treatments.

4. CONCLUSIONS

This work assessed the accuracy of monitor unit and dose distribution calculations performed by the THERAPLAN®PLUS version 3.55 planning system for a particular breast treatment by using a breast phantom and an ionization chamber. Overall, the measurements confirmed the dose calculations within an accuracy of $\pm$5% with most measurements lying within ± 3%. The overall results give confidence in the dose calculations for radiotherapy treatments by using the THERAPLAN®PLUS version 3.55 planning system.

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