

Investigation of Effect of Deformity in Dose Calculation by Treatment Planning System using Farmer Chamber

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Abstract— Purpose: Accuracy in dose prediction of dose calculation algorithms is very important aspect in external beam radiation therapy. This study investigates the effect of deformity on dose calculations computed by treatment planning system.

Methods: A phantom (30x30x30 cm³) containing rectangular solid water blocks and two 5cm air gaps was used for central axis dose calculations computed by collapsed cone convolution superposition algorithm (CCCS) and Pencil Beam Convolution algorithm (PBC) in Oncentra Dynamic Environment treatment planning system. Phantom is scanned by computed tomography scanner and the image data set is transferred to the planning workstation. Depth dose measurements were taken using a cylindrical ionisation chamber for identical beam parameters and monitor units as in the depth dose computations. The calculated and the measured percent depth dose (PDDs) were then compared. The data presented in this study included 6MV photon beam and field sizes of 3x3 cm², 5x5 cm², 10x10 cm² and 15x15 cm².

Results: The x ray beams traversed through the different media and interact as per the densities of the inhomogeneous material and deposits dose. The collapsed cone convolution superposition was within $\pm 1.1\%$ in the first water medium. However, upon traversing the first air gap and reentering the water medium, in comparison to the measurement s, the CCCS under predicted the dose , with difference ranged from -1.2% to -3.1% for 3x3 cm², from -2.4% to -4.1% for 5x5 cm², from -2.3% to -6.2% for 10x10 cm² and -1.2% to -6.1% for 15x15 cm². After the second air gap, the CCS continued to under predict the dose , and the difference ranged from -3.3% to -3.1% for 3x3 cm², from -2.1% to -5.3% for 5x5 cm², from -2.1% to -6.4% for 10x10 cm², and from -1.3% to -5.4% for 15x15 cm².

Conclusion: The CCCS under predicted the dose in water medium after the photon beam traversed the air gap region.

Keywords: Collapsed Cone Convolution Superposition, Treatment planning system, Dose calculation

I. INTRODUCTION

In conventional radiation therapy treatment planning systems (TPS), photon dose calculation algorithms typically report the absorbed dose as dose to water (Dw). Dose calculation algorithms employed in the TPS aim to best match the computed results with the measurements, which are performed in water phantoms. In recent years, there has been significant interest in using dose calculation algorithms that are based on Monte Carlo (MC) approach, which can report the absorbed dose in dose to medium (Dm) mode. In the Dm mode, the absorbed dose is computed to the medium contained in the dose voxel of the material. Siebers et al¹ suggested that the conversion of Dm to Dw may be desirable in some of the situations when MC based calculations are used in external beam photon radiation therapy. Currently,

dosimetric calibration protocols of external beam photon radiation therapy^{2,3} are based on Dw mode, and the use of either Dm or Dw for MC based photon dose calculations remains a debating topics.⁴

Many authors have conducted the evaluation of dose calculation algorithms for external beam radiation therapy.⁵⁻¹⁶ Rana et al investigated the dose prediction accuracy of Acuros XB algorithm and anisotropic analytical algorithm (AAA) for different field sizes and air gap thickness. The results from that study revealed that dose prediction errors are upto 3.8% for Acuros XB and upto 10.9% for AAA could occur during radiation therapy treatment. Furthermore, the study by Rana et al demonstrated the limitation of dose calculation algorithms when treating a smaller size of tumor, especially when large air gaps are created by immobilization devices. In our study we will study the dose prediction accuracy of collapsed cone and Pencil beam algorithm in case of deformed skull by Oncentra dynamic Planning Environment treatment planning system version 4.3(Elekta , Stockholm, Sweden). The analysis of prediction accuracy was done by comparing the point doses at different depths for both CCC and PBC algorithms.

II. METHODS AND MATERIALS

This study utilizes a 6 Megavoltage(MV) X-ray beam from Siemens Oncor Impression Plus medical linear accelerator (Siemens, Germany). For all dose computation and measurements, the source to axis distance (SAD) setup was used. The CCC superposition model uses an algorithm in which dose is computed from first principles, thereby accounting for patient heterogeneity and other modifiers.¹⁷ This is done by modelling the energy fluence of the beam exiting the gantry head, computation of the total energy released per unit mass (TERMA) in the tissue volume, superposing the TERMA with an energy kernel, and accounting for electron contamination which is then added to the photon dose.¹⁷⁻¹⁹

III. MEASUREMENT AND CALCULATION

The phantom is scanned using the CT scanner and the data is transferred to the treatment planning system using digital imaging communication in medicine (DICOM) network. An inhomogeneous phantom (30x30x30 cm³) composed of rectangular solid water blocks and two 5 cm air gaps was manufactured and scanned using Siemens Somatom CT scanner (Siemens Medical Solutions USA, Inc., Malvern, PA). The 3D structure set was created using the oncentra treatment planning system. The central axis depth dose calculations were then performed using CCCS for open field sizes 3x3 cm², 5x5 cm², 10x10 cm², and 15x15 cm², and for 100 monitor units (MUs). The dose calculation grid size was kept 3mm for the calculation purposes

In water medium of inhomogeneous phantom at different depths the measurement was performed using

cylindrical ionization chamber (PTW Farmer Chamber, 0.6 cm³ sensitive volume) for identical beam parameters and same number of monitor units(MUs) was fired in all the cases for the measurement purposes. The measurements at each depth were repeated three times. The calculated and measured depth doses were then compared. The difference between

percentage depth dose (PDD) were computed by CCCS with the measured value using the equation mentioned below:
 $\Delta(PDD_d) = (CCCS - MEAS / MEAS) \times 100$
 Where, PDD_d= percent depth dose at depth, d; CCCS= collapsed cone convolution superposition; MEAS= measurement value.

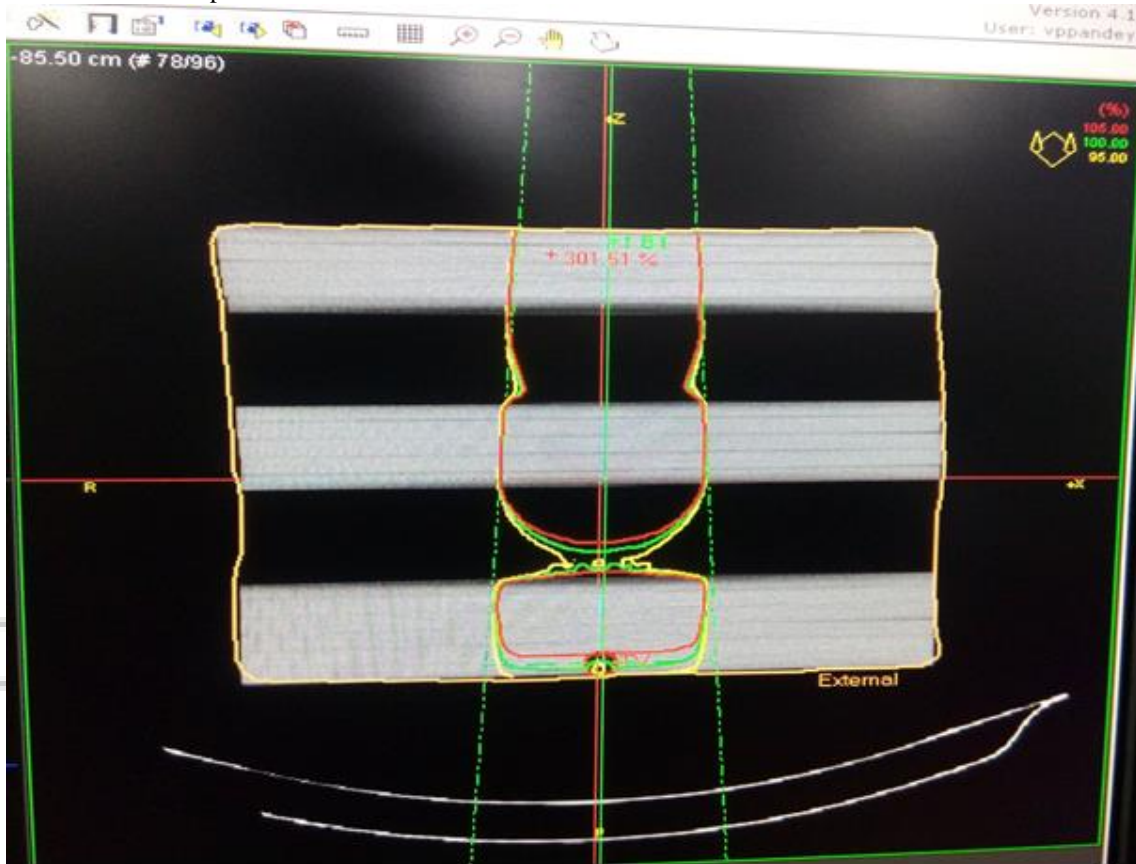


Fig. 1:

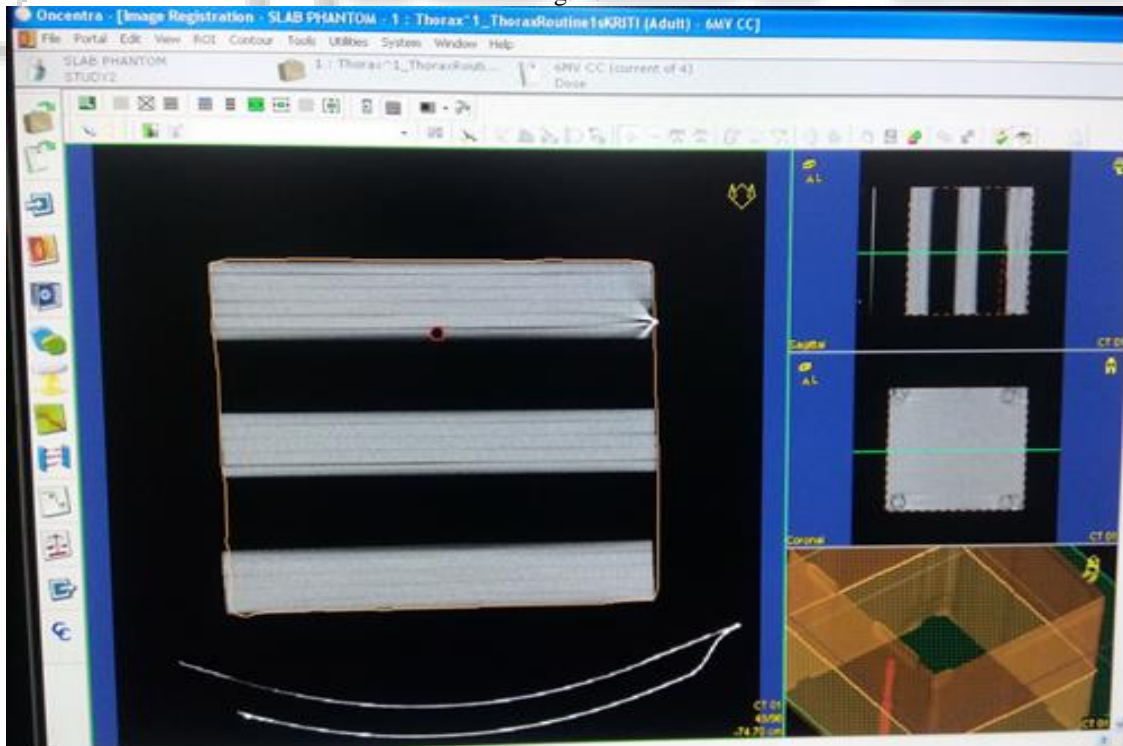


Fig. 2:



Fig. 3:

IV. RESULTS

The measured PDDs and calculated PDDs are presented for field sizes 3x3 cm², 5x5 cm², 10x10 cm² and 15x15 cm².

A. First Water Medium

In the first water medium, the CCCS predicted the PDD within $\pm 1.5\%$ of of measured PDD. The highest dose prediction error (-1.5%) was obtained for the smallest test field size i.e 3x3 cm².

B. Second Water Medium

In the second water medium (i.e after the first air gap), the CCCS under predicted the PDD at all four depths for all four test field sizes. Specifically, dose prediction errors ranged from -1.2% to -3.1% for 3x3 cm², from -2.4% to -4.1% for 5x5 cm², from -2.3% to -6.2% for 10x10 cm² and -1.2% to -6.1% for 15x15 cm².

C. Third Water Medium

In the third water medium, the CCCS continued to under predict the PDDs at all depths for all test field sizes. Specifically, dose prediction errors ranged from -3.3% to -3.1% for 3x3 cm², from -2.1% to -5.3% for 5x5 cm², from -2.1% to -6.4% for 10x10 cm², and from -1.3% to -5.4% for 15x15 cm².

V. DISCUSSION

Dose calculation accuracy of CCCS has been evaluated by comparing the calculated and measured PDD at multiple depths in an inhomogeneous slab phantom containing two air gaps. Although the CCCS had good agreement with the measurement in the first water medium, the results showed

the limitation of CCCS in predicting doses in second water medium (i.e after the first air gap) as well as in the third water medium (i.e after the second air gap). As the photon traverses the air gap, loss of lateral scatter increases within the air gap, and this caused decreased scatter dose contribution to the points along the central beam axis. Furthermore, media of different density can cause the electronic disequilibrium at and near their heterogeneity interface.²⁰⁻²⁷ Thus, dose discrepancies seen in the water media after the air gaps may be due to improper beam modelling within CCCS.

VI. CONCLUSION

The results of this study showed that the CCCS under predicted the depth doses in water medium after the photon beam traversed the air gaps. In actual clinical situation there may be high density material such as bone and low density material like muscle and air gaps into the patient which may further decreased the dose calculation accuracy. Special attention must be given during the patient setup since large air gap between the patient body and immobilization device may further lead to unacceptable dose errors. Precise beam modelling and accurate HU value in every clinical situation is playing a vital role.

VII. CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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