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STUDY TO EVALUATE THE DOSIMETRIC IMPACT OF DIFFERENT MEDIUM IN LEFT SIDE BREAST IMRT PLANS USING MONACO TREATMENT PLANNING SYSTEM

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ABSTRACT

Background: To evaluate the dosimetric differences between absorbed dose to water (Dw) and absorbed dose to medium (Dm) in Monte Carlo (MC)-based calculations used for left side breast radiation therapy.

Materials And Methods: Total twenty-two left sided breast treated malignancies are analyzed retrospectively. All of them are planned by Monaco treatment planning system (version 5.11.02) with Monte Carlo (MC) algorithm and XVMC dose calculation engine, calculated & reviewed on absorbed dose to medium (Dm) calculations and treated on Elekta Versa HD with agility 160 multileaf collimator LINAC. With all identical parameter absorbed dose to water (Dw) treatment plan is created and all dosimetric parameters are compared with absorbed dose to medium (Dm) calculations for target volumes (PTVs) and organs at risk such as Left and Right Lungs, Spinal cord, Esophagus, Heart and contralateral Breast.

Results: We see that the mean percentage differences between Dm and Dw dose volume parameters in PTV50Gy (range 0.02 to 1.58), PTV40Gy (range 0.001 to 2.21) is small and same is observed for the OARs (range 0.12 to 2.08) except spinal cord. For spinal cord max dose, the differences are around 3.13 ± 1.48.

Conclusion: PTV and most of the OARs remains less affected with respect to Dm or Dw dose calculation methods, care should be taken when clinical treatment plan has the spinal cord max dose is near to the limit of acceptance.

KEYWORDS : TPS, Monte Carlo, Dose-to-water, Dose-to-medium, Radiotherapy

INTRODUCTION

Advanced cancer treatment techniques like IMRT, IGRT and VMAT allow more precise dose deposition in the target volume and an improved control of the normal tissue complications. Therefore, accurate dose calculations are essential to assure the quality of the improved techniques. Conventional model-based algorithms are quite accurate in regions with homogeneous tissue, but its accuracy is limited in heterogeneous medium. Monte Carlo (MC) dose calculation algorithms, on the other hand, provide more accurate results especially in heterogeneous regions. The Monte Carlo method has been demonstrated to be the most accurate dose calculation method for radiation therapy treatment planning and dosimetry verification [1-7]. American association of Physicists in Medicine (AAPM) Task Group-105 (TG-105)[1] has given its recommendation with regards to dose to water and medium but it still needs further discussion to decide if one should use absorbed dose-to-water D_w or -medium D_m for dose calculations, prescription and evaluation.

Conventional dose calculation for radiation therapy treatment planning including both simple correction-based algorithm (such as TAR and Batho method) and more recent model-based algorithm (such as pencil beam and superposition convolution method) are generally report the absorbed dose to water, D_w [1,6,8]. The past clinical experiences as well as calibration protocols (Accelerator and ionization chamber) are also based upon D_w[9]. The input data of TPS (PDD and profiles) are measured in water phantom. The general assumption that water phantom mimics the human body is based on the fact that human body contains water more than 70 percent. Monte Carlo method calculates the energy deposition in different media accurately and reports Dm [10-16], directly by simulating the radiation transport through the body using the electron density information obtained from ct data. Hence a different outcome of using the medium of dose calculation might lead to the change of dose prescription in order to achieve desired radiotherapy outcomes [17-21].

In order to compare MC algorithms with conventional D_w algorithms, the dose comparison should be made to the same medium. Siebers, et.al. suggested a method of converting dose to medium to dose to water using stopping power ratios, based upon the Bragg-Gray cavity theory for MC-based calculation. This feature is inbuilt in Monaco TPS [22], and we use this to compare and analyse the difference of various dose parameters for left breast treatment plans and understand the impact of prescribing in terms of Dose to medium vs Dose to water for left breast treatment cases. In clinical Left breast cases the concerned OARs are Lungs, Heart, Esophagus and Spinal cord (since spinal cord is near to the supra-clavicle node which is included in PTV). We study the Dosimetric differences in PTVs and OARs, which arises between these two calculation methods D_m and D_w, and its practical impact in clinical evaluation.

MATERIALS AND METHOD

Patient Selection

A total of 22 left side breast cases with multiple PTVs including supra clavicle nodes (viz. Chest, Scf or Chest + Scf) of different prescriptions are taken for analysis. Out of 22 cases, 16 cases had a prescription of 50Gy dose in 25 fractions for PTVs and remaining 6 cases had a prescription of 40Gy dose in 15 fractions for PTVs. The plans were delivered using Elekta Versa HD Linear Accelerator equipped with Agility 160 multi-leaf collimator. Plan acceptance criteria was 95% of prescribed dose must cover atleast 98% volume of PTV. Patient prescription details are given in the Table-1.

Table-1: Prescription Details Of Patient Cases

Total number of patient studied	22
Site	left side breast
Prescription 50Gy in 25 fraction	16 cases
Prescription 40Gy in 15 fraction	6 case
Dose to PTV for 16 patient	50Gy
Dose to PTV for 6 patient	40Gy
Dose Prescriptions of PTVs	95% of prescribed dose should get more than 98% volume of PTV

Treatment Planning

All patients underwent a standard CT simulation on GE Optima CT 580W 16 slice CT scanner. CT scans of slice thickness 3mm were acquired and DICOM images is transferred for contouring and planning to Monaco Treatment Planning system (TPS) version 5.11.02 (Elekta, Crawley, UK). Multiple fields (5 to 6 field, Gantry starts from Medial Tangential to Lateral Tangential) with minimum overlapping of Heart and left lung with PTV were placed and IMRT plans created on Monaco TPS using 6 MV photon beams. Dose prescribed to PTV for 16 patients is 50Gy and 6 patients are 40Gy. Dose evaluation and analysis criterion is followed as per ICRU 83. The dose calculation and sequencing properties used for inverse optimization and dose calculation is segment shape optimization with minimum segment width 0.5 cm, Grid size 0.3 cm and statistical uncertainty 1% per calculation.

Monaco treatment planning system uses the Monte Carlo dose calculation algorithm with X-ray Voxel Monte Carlo (XVMC) dose engine for IMRT dose calculation. As recent advances in treatment planning system it provides an option either to use absorbed dose to

water D_w or absorbed dose to medium $D_m$mode [22], for treatment dose calculation, prescription and evaluation. Here we use the Monaco TPS in which we perform MC-based optimization and calculation for absorbed dose to medium D_m which for our analysis, we convert it to absorbed dose to water D_w through an inbuilt feature of Monaco TPS which uses the stopping power ratios based on Bragg Gray Cavity theory [8, 22]. The conversion (Dm to Dw) is done without changing the optimization, sequencing or control points related parameters.

Plan Analysis

The treatment plans are analyzed by using dose volume histograms (DVHs). The dose volume histogram for both types of calculation i.e. dose to medium (D_m) and dose to water (D_w) is generated by using Monaco TPS. Treatment plans are evaluated for various dosimetric parameters of PTVs and organ at risk. The dosimetric parameter analyzed are Maximum dose D_{max}, Minimum dose D_{min}, Mean dose D_{mean} and volume covered by 95% prescribed dose $D_{95\%}$ for PTVs and those analyzed for organ at risk are as below show in Table -2.

Table – 2: Dosimetric Parameter Evaluation Details Of PTVs & OAR

PTVs and Organ at Risk	Dosimetric parameter analysed
PTVs	D_{max}, D_{min}, D_{mean}, $D_{95\%}$
Esophagus & spinal cord	D_{max}, D_{min}, D_{mean}
Heart & Left Lung	D_{max}, D_{min}, D_{mean}, V_{20Gy}, V_{30Gy}
Right Lung	D_{max}, D_{min}, D_{mean}, V_{5Gy}, V_{10Gy}
Opposite Breast	D_{max}, D_{min}, D_{mean}, V_{5Gy}

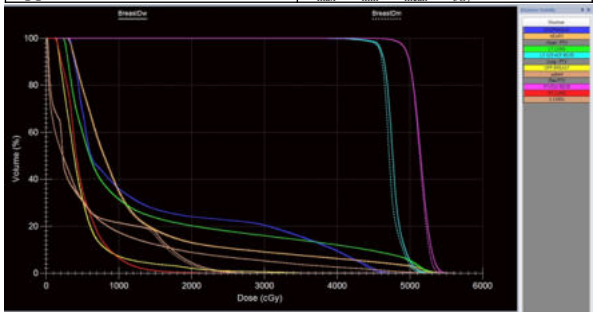

Figure-1: Integral DVH Of One Of The Cases From The Study Set

Figure-1 represents integral dvh for D_m and D_w based calculation for one of the case under the study. D_w/D_m ratios are computed for D_{max}, D_{min}, D_{mean}, V_{5Gy}, V_{10Gy}, V_{20Gy}, V_{30Gy} and for volume covered by 95% prescribed dose $D_{95\%}$ for PTVs and organ at risk. These ratios (D_w/D_m) are plotted for critical organs at risks and also for PTVs. Figure 2a and 2b represents the isodose distribution in case of dose to medium and dose to water calculation respectively.

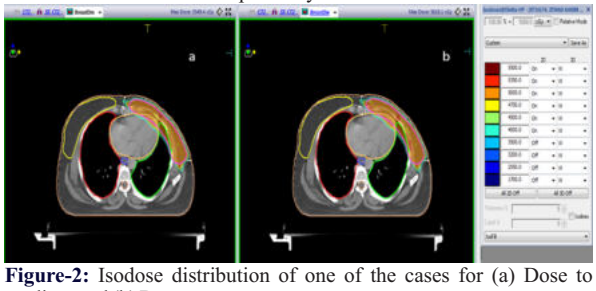

Figure-2: Isodose distribution of one of the cases for (a) Dose to medium and (b) Dose to water

The relative percentage difference Δ between the dosimetric parameters D_w and D_m based plans for each case is calculated using the relation.

$$\Delta = \left[\frac{(D_{wx} - D_{mx})}{D_{mx}}\right] \times 100\ \%\ ,$$

Where 'x' is the corresponding dosimetric parameter (mean dose, maximum dose, etc). The mean and the standard deviation of the percentage variations of corresponding dosimetric parameters corresponding to all patient cases are calculated.

RESULTS:

The percentage variations of D_w with respect to D_m for all critical organs are shown in the Table-3. The mean percentage variation of D_{min} for water versus medium in case of esophagus, heart, left lung, right lung, spinal cord and opposite breast were found to be 0.16, -0.12, -2.08, -0.82, -0.16 and 0.21 respectively. The corresponding value of D_{wmax} with respect to D_{mmax} for esophagus, heart, left lung, right lung, spinal cord and opp breast were obtained as 0.37, -0.22, -0.97, -1.62, 3.13 and -0.68 respectively. Similarly, for D_{wmean} with respect to D_{mmean} for esophagus, heart, left lung, right lung, spinal cord and opp breast are 0.82, 0.56, -0.38, -0.4, 1.75, and -0.53.

Table-3: Percentage variation ± standard deviation of D_w with respect to Dm for critical Organs at risk.

OARs	$\left[\frac{(D_{wx} - D_{mx})}{D_{mx}}\right] \times 100\ \%$						
	Min Dose	Max Dose	Mean Dose	V20Gy	V30Gy	V5Gy	V10Gy
OESOPHAGUS	0.16 ± 2.07	0.37 ± 1.22	0.82 ± 0.3	-	-	-	-
HEART	-0.12 ± 2.7	-0.22 ± 1.76	0.56± 1.94	1.41± 0.69	2.02 ± 1.12	-	-
LT LUNG	-2.08 ± 2.4	-0.97 ± 0.89	-0.38 ± 0.26	-1.47 ± 4.64	-1.59 ± 6.07	-	-
RT LUNG	-0.82 ± 3.37	-1.62 ± 1.36	-0.4 ± 0.28	-	-	-0.52± 0.58	-1.37± 1.46
SPINAL CORD	-0.16 ± 1.09	3.13 ± 1.48	1.75 ± 0.36	-	-	-	-
OPP BREAST	0.21 ± 4.44	-0.68 ± 1.52	-0.53 ± 0.28	-	-	-1.03± 0.82	-

The percentage variations of D_w with respect to D_m for PTVs are shown in Table-4. The mean percentage variation of D_{wmin} with respect to D_{mmin} for PTV50 and PTV40 were obtained as 0.57 and 0.08 respectively. The corresponding value of D_{wmax} with respect to D_{mmax} for PTV50 and PTV40 are 1.58 and 2.12 respectively. Similarly, for D_{wmean} with respect to D_{mmean} for PTV50 and PTV40 are 0.22 and 0.15. The mean $D_{95\%}$ for PTV50 & PTV40 was getting it 0.02 and 0.001 respectively.

Table-4: Percentage Variation Standard Deviation Of D_w With Respect To D_m For Multiple Planning Target Volumes.

PTV	$\left\|\frac{(D_{wmin} - D_{mmin})}{D_{mmin}} \times 100\ \%\right\|$	$\left\|\frac{(D_{wmax} - D_{mmax})}{D_{mmax}} \times 100\ \%\right\|$	$\left\|\frac{(D_{wmean} - D_{mmean})}{D_{mmean}} \times 100\ \%\right\|$	$\left\|\frac{(V_{95\%Dw} - V_{95\%Dm})}{V_{95\%\ Dm}} \times 100\ \%\right\|$
PTV 50Gy	0.57 ± 2.33	1.58 ± 0.99	0.22 ± 0.29	0.02 ± 0.06
PTV 40Gy	0.08 ± 0.71	2.12 ± 1.64	0.15 ± 0.44	0.001 ± 0.07

DISCUSSION:

Various studies have analyzed the systematic difference between the dose computed using conventional analytical algorithms and MC simulation using the procedure developed by Siebers et. al. [8].

The difference between dose calculation D_w and D_m for tissues with densities near 1.0 g/cm^3 is small (1−2%). But this difference can be as high as 15% for higher density materials, such as cortical bone. The reason being the stopping powers of water and that of higher-density materials differ more significantly [1,8]. Dogan *et al.* [21] demonstrated that converting D_m to D_w in MC-calculated IMRT plans introduces a systematic error of up to 5.8% for head and neck tumors and 8.0% for prostate cases.

Historically dose reporting has been done in water but dose calculation in medium is a more accurate representation of radiation transport through the actual medium for monte carlo simulation. There have been 2 schools of thought, one in favour of dose to medium and the other advocating dose to water based calculation. Both the sides have their own sets of logic explaining why the dose calculation to water or medium must be followed for dose prescription and reporting. Those who are in favour of using dose to water based reporting suggests that since past clinical experience are water based and hence it is more compliant to previous clinical data generated from conventional dose calculation algorithm. The accelerator and ionization chamber calibration are also based on D_w. Moreover tumor cells surrounded by medium is more representative of water like, for example a tumor cell embedded in bone matrix.

Those who are in favour of dose calculation in medium suggest that for tissue equivalent material the difference between Dw and Dm will have minimum impact on clinical results and monte carlo results will be more accurate and corresponding to the actual representation of

radiation transport if dose to medium based calculation is performed. The conversion of dose to medium to dose to target adds an extra step in dose calculation and further complicates the process of dose calculation. In addition to this the organ motion will add further uncertainty to dose calculation if dose to water based reporting is done. In our study we have analyzed the systematic differences between D_w and D_m for Left Breast treatment cases. We see that the mean differences between D_m and D_w in PTV50Gy dose volume parameter (0.02 to1.58) & PTV40Gy dose volume parameters (0.001 to 2.12) is small. We see a similar effect in all the OARs (0.12 to 2.08) except spinal cord, difference between D_m and D_w is small. For spinal cord max dose differences around **3.13 ± 1.48**. Unlike other OARs, spinal cord is surrounded by higher density vertebrae which leads to a significant dose difference between D_m or D_w.

The present study evaluates the dosimetric differences between D_m or D_w based calculation for Left sided breast IMRT cases in radiation therapy treatment planning (Monaco TPS) using Monte Carlo based dose calculation algorithm. The present study shows that the PTV and most of the OARs remains less affected with respect to D_m or D_w based calculation, care should be taken when clinical treatment plan has the spinal cord max dose is near to the limit of acceptance.

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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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