Dosimetric Errors of TPS Calculations without Correction for Heterogeneity – A Study Using CIRS Thorax Phantom

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Abstract—**The magnitude of the error in dose calculation using a commercial treatment planning system (TPS) without correction for tissue heterogeneity was assessed. A CIRS Thorax anthropomorphic phantom was used for the study. The phantom was CT scanned, treatment planned and treated with 10 MV photon beams. Dose at points of interested in the phantom was measured and compared with TPS calculation. Significant discrepancies of up to 8% between calculated and measured doses were observed. The results of our experiment indicate that treatment planning with TPS without correction for tissue heterogeneity should be avoided.**

Keywords—**TPS errors, heterogeneity effects, ionization chamber measurement.**

I. INTRODUCTION

ICRU [1] recommends that the dose variation within the Planning Target Volume be kept to within 7% to -5%. ICRU also recommends that the dose to the target should have an accuracy of 5%. To follow this recommendation, all step in treatment planning like dose calculation, patient alignment, and output calibration should have inaccuracy less than 5%. So dose calculation should have an accurate in the range of 2 - 3% [2].

Standard commercial treatment planning systems (TPSs) for high-energy photon radiotherapy often fail in calculating accurately the dose distributions in the presence of heterogeneities. TPS built-in 'classical' heterogeneity correction algorithms usually do not comply with the recommended acceptability criteria of a ± 3% difference between delivered and calculated doses. In previous works, some authors have studied the effect of low-density materials, such as cork, when broad beams [3, 4] are used, and as has been pointed out by the AAPM report [5], TPS calculated values could be inaccurate in low-density materials.

Within this context, the aim of this study is to evaluate the performance treatment planning system without heterogeneity correction for conventional planning. The experiment was evaluated by using a CIRS Thorax anthropomorphic phantom. Dosimetry measurements were made using a farmer ionization chamber.

II. METHODS

The experiments were performed using a liniear accelerator (Varian Clinac 2100C, Palo Alto, USA). Treatment planning were done using a PLATO system (version IRIX 5.3, Nucletron, Netherland). Treatment planning, dose delivery and measurement were done on a CIRS Thorax phantom model 002LFC.

The CIRS Thorax phantom is designed from tissue, lung and bone equivalent materials and provide chamber holder acssesoris. Anterior and lateral markers were attached to the phantom when it was scanned using a Systec Sri CT scan machine and image was produced in laser printer. Then, the image was scanned using a Vidar VXR-12 Plus scan system that is connected to the Plato planning system. Transfer of image from Vidar scanner to Plato system need the scale of image to ensure the accuracy of phantom dimension in the TPS. The phantom image transferred to the TPS was assigned a uniform unit density without inhomogeneity correction.

The planning were done using 10 MV x-ray beams with source axis distance 100 cm and filed size 15 x 15 cm^2 with anterio-posterior (AP/PA) and medio-lateral (ML/LM) fields set up with SAD techniques. The field size of 15 x 15 cm^2 was chosen to cover all measurement points. The planning was executed at dose of 100 cGy and 200 cGy at target point for single beam and oposite anterio-posterior (AP/PA) or oblique medial lateral (ML/LM) techniques respectively. The anterior-posterior measurements was done at source skin distance (SSD) of 89.2 cm at gantry of 0 degree. The SSD of oblique medial lateral was set up at 89.8 cm at gantry of 0 degree and medio lateral position at 30 and 210 degree. The monitor unit (MU) for each treatment beam was calculated for each treatment technique

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and the dose received at all measurement points (tissue, bone, and lung) were also determined for comparison with measurement.

The phantom was irradiated according to the treatment plan and a farmer type ionization chamber (PTW 30001) with an electrometer was used to measure the dose at the measurement points of each materials.

Dose measurement was based on the techniques as describe in IAEA TRS 398 [6]. We use dose to water calibration factor ($N_{D,w}$), temperature and pressure correction factor (k_{TP}), beam quality factor parameters ($k_{Q,Q0}$) to convert the measured meter reading to dose. The dose to water calibration factor is obtained from certificate of chamber. We calculate the temperature and presure correction factor according to data of measurements, whereas the beam quality factor was achieved from TRS 398 tables. The uncertainty of dose measurement using this technique was about 2%.

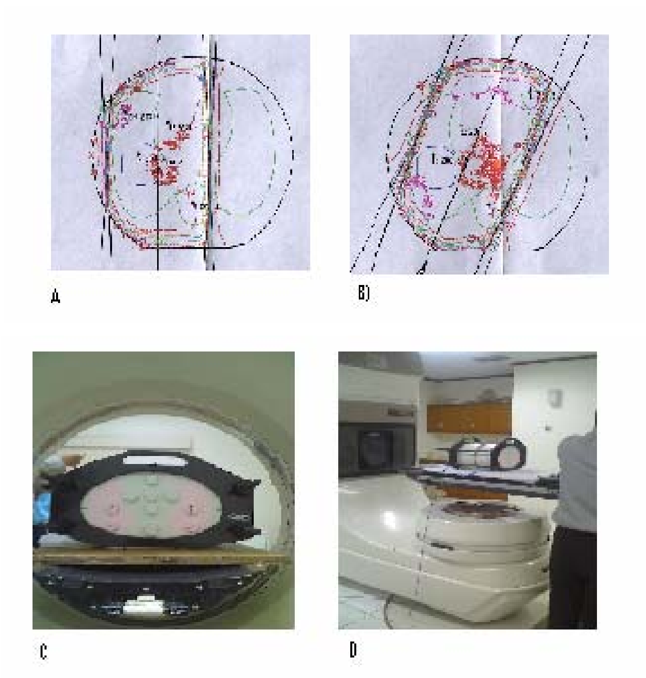

Fig. 1 (a) Planning anterior posterior (AP/PA), (b) Planning oblique medial lateral, (c) Scanning phantom in CT scan machine, and (d) measurements at linac room

III. Result and discussion

The dose data was obtained from multiple measurements. The TPS calculated and measured data at points of interest for different treatment techniques are shown in Table 1 and Table 2.

The discrepancies between the TPS calculated dose values and measurement data with magnitudes exceeding the measurement errors were indications of the inaccuracy of the TPS. Table 1 show that the disagreements between TPS calculations and phantom measurements are 1.3%, 9.27%, 9.72% for tissue, lung, and bone respectively in the anterior posterior (AP) technique, and 5.44%, 5.55%, 4.92% respectively in the posterior anterior (PA) technique. Whereas the discrepancies between calculation and measurement for the AP/PA plan are 1.88%, 7.82%, 6.3% for tissue, lung, and bone respectively.

Table 2 shows that the discrepancies between calculation and measurement in the medial-lateral (ML) beams are 0.64%, 6.09 %, 1.58% for tissue, lung, and bone respectively, but 13.2%, 5.18 %, 2.84% for lateral medial beam. However, discrepancies in the parallel beams ML/LM measurements are 6.28%, 3.29 %, 4.56% for tissue, lung, and bone respectively.

The measurements in the anterior posterior technique showed that the calculation discrepancy was less than 3% for tissue of AP and AP/PA but it is higher than 3% for other tissue structures and treatment techniques. Likewise, the calculation discrepancies for the oblique medial-lateral exposure were less than 3% in tissue and higher than 3% for other tissue structures and techniques.

Table 1 Comparison of TPS calculated and chamber measured dose at measurement points obtained for the anterior-posterior techniques

Mate-rials	AP (cGy)		PA (cGy)		AP/PA (cGy)	
	TPS	**Meas-urement**	**TPS**	**Meas-urement**	**TPS**	**Meas-urement**
Tissue	122.30	120.69	81.90	86.62	203.10	207.00
Lung	109.40	120.59	94.60	100.15	203.70	220.99
Bone	82.50	75.187	116.80	111.32	200.10	188.23

Table 2 Comparison of TPS calculated and chamber measured dose at measurement points obtained for the oblique medial-lateral techniques

Materials	ML (cGy)		LM (cGy)		ML/LM (cGy)	
	TPS	**Meas-urement**	**TPS**	**Meas-urement**	**TPS**	**Meas-urement**
Tissue	116.00	116.75	89.70	103.38	204.90	218.65
Lung	96.20	97.75	110.20	116.23	206.50	213.54
Bone	85.30	80.40	117.10	113.86	202.90	194.04

The results indicated that TPS calculation is not accurate without heterogeneity correction as predicted, because low density materials are more penetrating for radiation beams and causing less scattered radiation [7]. The radiation dose should consist of primary and scattered components, in this case both components were not properly accounted for by the TPS without heterogeneity correction.

IV. Conclusion

Our experiment with anthropomorphic phantom shows that dose calculation with TPS uncorrected for tissue heterogeneity can have an error up to 8% especially for low density materials and that the calculation is accurate in tissue equivalent materials. Treatment planning and dose calculation without correction for tissue inhomogeneity should be avoided.

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