COMPENSATOR-BASED INTENSITY MODULATED RADIOTHERAPY WITH TELECOBALT MACHINE USING MISSING TISSUE APPROACH

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Abstract— **Background:** Dose distribution within a patient has been found to be the most reliable and verifiable quantity that links treatment parameters of any radiotherapy treatment technique to treatment outcome. It is therefore imperative to chose irradiation geometries that will maximise radiation dose to the tumour volume while concurrently minimizing doses to normal tissues in close proximity to tumour volume during external beam radiation therapy (EBRT) to achieve favourable treatment outcome. Spatial distribution of radiation dose within a patient is influenced by skin topography at the point of beam entrance and tissue inhomogeneity within the irradiated region. The aforementioned factors coupled with the often complex shapes of tumours will require the modulation of the fluence distribution across beams from conventional teletherapy machines. This has culminated in the introduction of Intensity Modulated Radiotherapy (IMRT). Pre-requirements for modern day IMRT are capital intensity and may be out of reach of many developing countries.
Alternative approach of implementing IMRT with customized compensators with forward planning treatment planning system (TPS) and telecobalt machine to minimise cost is being presented.

Methods: Medium density materials such as: wax, Perspex, Alumimium, Brass and Copper were selected for the construction of compensators. Bolus with varying thicknesses placed on the surfaces of a tissue equivalent phantom were used to achieve beam intensity modulation during treatment simulation processes with the TPS (refer to fig. 1). The treatment plans generated with the TPS were replicated on the telecobalt machine with compensators placed on block trays and held at the accessory holder of the telecobalt machine to represent the bolus. Semi-empirical algorithm incorporating influences of treatment parameters (field size, treatment depth and applied bolus thickness) was developed and proposed for the conversion of an applied bolus thickness to a compensator material thickness such that the dose at any point within the phantom will be the same for the two irradiation geometries (with bolus and with compensator respectively). The semi-empirical algorithm was derived from the analyses of empirical data obtained through the implementation processes of a bolus and a compensator. A compensator sheet with grid lines was designed for recording bolus/compensator thicknesses across a radiation field, and this was utilized to account for beam divergence. Once the required shape of a compensator had been determined, the compensator was constructed from well known methods such as: cubic pile approach for compensators made from Perspex, Alumimium, Brass and Copper, and negative mould approach for a compensator constructed from wax. The efficacy of the proposed approach was verified to ensure clinical implementation.

Results: The semi-empirical algorithm derived for the convention of an applied bolus thickness, $\boldsymbol{X_b}$, along a particular ray line (or within a grid) to a compensator material thickness, $\boldsymbol{X_c}$, is given by:

$$\boldsymbol{X_c = X_b \times T \times f_r \times f_d} \qquad \textbf{(1)},$$

where, $\boldsymbol{f_r}$ and $\boldsymbol{f_d}$ are correction factors introduced to account for the influences of field size and treatment depth respectively, and $\boldsymbol{T}$, is a thickness density ratio of a compensator material relative to that of the bolus (presumed to be water). Verification of the output of the proposed approach in a solid water with calibrated Gafchromic EBT2 films for compensators constructed from the various selected materials is presented in Table 1.

Correction factors for the stipulated treatment parameters in equation (1) were found through regression analyses of empirical data to be a fifth and a sixth degrees polynomial equations in terms of treatment depth and field size, respectively. The thickness density ratio for a particular compensator material could also be expressed as a fifth degree polynomial equation in terms of applied bolus thickness. The coefficients and the degrees of the polynomial equations were found to be dependent on the selected compensator material and the stipulated treatment parameters, respectively.
However, there were issues with abutting radiation fields, due to the fact that the TPS used does not allowed creation of bolus for an individual radiation field .
Dosimetric verifications of dose profiles measured in a solid water phantom with calibrated Gafchromic EBT2 films for various irradiation geometries having

compensators constructed based on the developed and proposed method were found to be comparable to that of the treatment planning system with deviations within ±3.00% (mean of ±(2.22 ± 0.68)%) (expressed as a percentage of the respective measured dose). This is within the tolerance of ± 5% recommended for dose delivery in external beam radiotherapy.

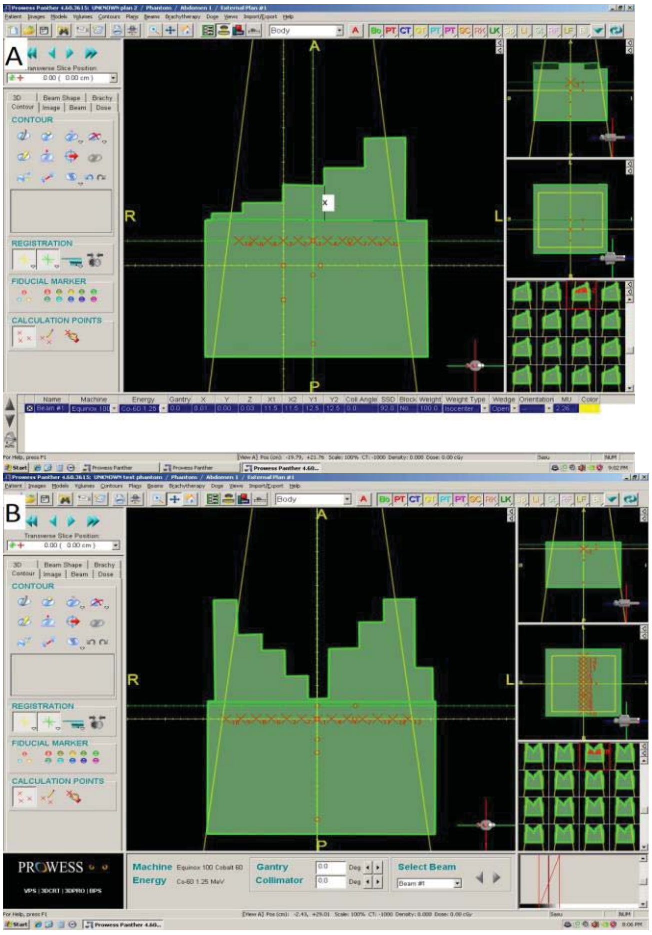

Fig. 1. TPS treatment planning window showing samples of bolus used to provide beam intensity modulations on the surface of a tissue equivalent phantom; A , for case scenario 1 and B, for case scenario 2 .

Table 1. Comparison of outputs of proposed and developed approach for selected compensator materials with those of the TPS .

Case scenario	**Compensator material**	**Range of % Diff. between meas. and Calc. doses (%)**	**Mean of % Diff. (%)**
1			
	Paraffin wax	-2.89 to 3.00	1.87 ± 0.87
	Perspex	-1.78 to 3.00	1.89 ± 0.76
	Alumimium	1.30 to 3.00	2.12 ± 0.74
	Copper	-2.14 to 3.00	2.32 ± 0.63
	Brass	-3.00 to 3.00	2.40 ± 0.54
2			
	Paraffin wax	-2.86 to 2.96	1.98 ± 0.67
	Perspex	-2.80 to 3.00	2.09 ± 0.50
	Alumimium	-3.00 to 3.00	2.52 ± 0.58
	Copper	-3.00 to 3.00	2.52 ± 0.50
	Brass	-3.00 to 3.00	2.51 ± 0.40

Conclusion: This signifies that the developed and proposed approach can be used to achieve beam intensity modulations with limited resources rendering encouraging results. This approach can be used for missing tissue compensation in the treatment of head and neck cancers, tangential breast irradiation, and total body irradiation with photon beams. It can also be used to account for tissue heterogeneities, especially in the treatment of lung cancers. The developed and proposed approach is therefore recommended for clinical application.

Keywords — Bolus. Compensator. Semi-empirical algorithm. Intensity modutaled radiotherapy. treatment parameters. treatment planning system.