ORIGINAL ARTICLE

COMPARISON OF PENCIL BEAM AND COLLAPSED CONE ALGORITHMS, IN RADIOTHERAPY TREATMENT PLANNING FOR 6 AND 10 MV PHOTON

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Background: In radiotherapy treatment, the calculation of radiation dose distribution in target volume lead to an optimum set of planning parameters. This worked has been aimed to compare two photon beam dose calculation algorithms in the Oncentra Treatment Planning system for Varian Linear Accelerator, to assure the quality of treatment planning. **Methods:** Monitor Units to be delivered on normalization depth in patient has been calculated using the pencil beam and collapsed cone algorithms for two photon energies 6 and 10 MV. The percentage depth dose and beam profiles for 21 treatment fields, for both the calculation systems have been compared for both photon energies. **Results:** The percentage depth doses and beam profiles for both calculation systems are comparable in large field sizes as well as central axis field settings. The doses at normalization depth deviate for some field settings, but in central axis large field sizes the difference in within tolerance limits. **Conclusion:** Both calculation algorithms are in close agreement in most of the field settings (mainly in central axis fields), within tolerance level. The difference is relatively greater in small field sizes and off-axis field settings.

Keywords: Radiotherapy, treatment planning, dose distribution, pencil beam, collapsed cone

INTRODUCTION

Radiotherapy physics needs vast consideration of clinical response of tumors and normal tissues exposed to high-energy photon beams, so that dose distribution and delivery is calculated accurately.

The treatment planning systems use computation methods to determine dose distribution in patients from external photon beams. Advance algorithm is needed in order to achieve quick and accurate calculation of dose distribution for radiation beams. Depending on treatment modality an optimum algorithm should be selected. Dose calculation algorithms are the most critical software component in a computerized Treatment Planning System. These modules are responsible for the correct representation of dose in the patient, and may be linked to beam time or monitor unit (MU) calculations.[1] Dose calculations involving convolution and superposition principles have been the subject of many research works.[2–6]

In pencil beam (PB) techniques the energy spread or dose kernel at a point is summed along a line in a phantom to obtain a pencil type beam or dose distribution. By integrating the pencil beam over the patient's surface to account for changes in primary intensity and by modifying the shape of the pencil beam with depth and tissue density, a dose distribution can be generated.[1] Pencil beam calculates the dose distribution around an infinitely small beam in water using a convolution technique. The convolution is performed between polyenergetic pencil beams and the planar photon energy fluence distribution. The pencil beam algorithm does not take the changes of lateral scattering effects into consideration.

The Collapsed Cone Convolution Superposition (CCCS) dose model is a true three-dimensional dose computation that intrinsically handles the effects of patient heterogeneities on both primary and secondary scattered radiation. This computation method is inherently able to account for dose distributions in areas where the electronic equilibrium is perturbed, such as tissue-air interfaces and tissue bone interfaces. Collapsed Cone (CC) uses a convolution technique between TERMA and a dose deposition kernel. The algorithm uses an approximation where all energy inside a specified solid angle will be transported along a line. The choice of dose calculation algorithm can have a large influence on a treatment plan for certain case of treatment.[7–10]

MATERIAL AND METHODS

This study has been carried out on Oncentra Masterplan treatment planning system, for two photon energies 6 and 10 MV. There were 21 treatment fields have been analysed, in which some were off-axis, and some central axis. Treatment dose has been calculated by normalising 100% dose on a depth of 5 Cm for 16 fields, however for five field sizes the same was done for a normalisation depth of 10 Cm. doses have been calculated by pencil beam algorithm first, and then by collapsed cone. The dose grid matrix of central slice of every field has been taken to obtain beam profile and percentage depth dose.

RESULTS

The treatment dose, for delivering 100 Monitor units on the normalisation depth has been calculated for two photon energies, and is tabulated below. In conjunction with the treatment dose, we have also obtained the percent depth dose (PDD) and beam profile for each beam and field size. Table-1 to 6 represents the data of treatment dose for a number of field sizes, for each photon energy, both by pencil beam and collapsed cone algorithms. There is a Diversity in the field sizes to investigate the comparison of the two dose calculation systems, on central axis as well as off-axis regions.

Table-1: Monitor Units Calculated by Pencil Beam and Collapsed Cone Algorithms, For 6 MV Photon, Normalization Depth= 5 Cm

Field Size (Cm^2)	Monitor Units		Percentage
	PB	CC	Difference
4×4	109.76	109.51	0.23%
10×10	100.04	99.73	0.31%
20×20	92.89	93.79	-0.97%
4×4 EDW (60^0)	126.65	126.37	0.22%
10×10 EDW (60^0)	151.45	151.03	0.28%
20x20 EDW (60^0)	217.32	219.82	-1.15%
2×2 cm^2 centered in a 20×20 Cm^2	111.13	114.46	-3.00%
4×4 cm^2 centred in a 20×20 Cm^2	95.6	96.11	-0.53%
10x10 cm^2 centred in a 20×20 Cm^2	100.01	100.16	-0.15%
5×20 Cm^2 in 20×20 Cm^2 centered at X= 0	99.9	100.29	-0.39%
2×20 Cm^2 in 20×20 Cm^2 centered at X= 0	106.66	108.26	-1.50%
2×2 corner	109.94	114.67	-4.30%
4×4 corner	105.83	105.9	-0.07%
2×20 Cm^2 in 20×20 Cm^2 off-axis at +X=5 Cm	105.74	107.76	-1.91%
2×20 Cm^2 in 10×20 Cm^2 off-axis at X=9 Cm	106.77	108.96	-2.05%
5×20 Cm^2 in 20×20 Cm^2 off-axis at +X=5 Cm	99.17	99.18	-0.01%

Table-2: Monitor Units Calculated by Pencil Beam and Collapsed Cone Algorithms, For 6 MV Photon, Normalization Depth= 10 Cm

Field Size (Cm^2)	Monitor Units		Percentage
	PB	CC	Difference
2×2 corner	139.08	147.42	-6.00%
4×4 corner	130.74	133.67	-2.24%
2×20 Cm^2 in 20×20 Cm^2 **off-axis at +X=5 Cm**	130.64	133.86	-2.46%
2×20 Cm^2 in 10×20 Cm^2 **off-axis at X=9 Cm**	132.13	136.68	-3.44%
5×20 Cm^2 in 20×20 Cm^2 **off-axis at +X=5 Cm**	118.9	119.65	-0.63%

Table-3: Monitor Units Calculated by Pencil Beam and Collapsed Cone Algorithms, For 10 MV Photon, Normalization Depth= 5 Cm

Field Size (Cm^2)	Monitor Units		Percentage
	PB	CC	Difference
4×4	108.46	108.69	-0.21%
10×10	100.08	99.8	0.28%
20×20	94.24	94.79	-0.58%
4×4 EDW (60^0)	122.53	122.78	-0.20%
10×10 EDW (60^0)	142.57	142.19	0.27%
20×20 EDW (60^0)	194.84	196.19	-0.69%
2×2 Cm^2 **centered** in a 20×20 Cm^2	113.49	117.43	-3.47%
4×4 Cm^2 **centered** in a 20×20 Cm^2	104.28	105.74	-1.40%
10×10 Cm^2 **centered** in a 20×20 Cm^2	99.99	100.76	-0.77%
5×20 Cm^2 in 20×20 Cm^2 **centered at X= 0**	99.39	100.42	-1.04%
2×20 Cm^2 in 20×20 Cm^2 **centered at X= 0**	107.49	109.45	-1.82%
2x2 corner	113.35	118.72	-4.74%
4×4 corner	105.03	106.42	-1.32%
2×20 Cm^2 in 20×20 Cm^2 **off-axis at +X= 5 Cm**	106.74	109.44	-2.53%
2×20 Cm^2 in 10×20 Cm^2 **off-axis at X = 9 Cm**	107.99	110.8	-2.60%
5×20 Cm^2 in 20×20 Cm^2 **off-axis at +X = 5 Cm**	98.85	99.37	-0.53%

Table-4: Monitor Units Calculated by Pencil Beam and Collapsed Cone Algorithms, For 10 MV Photon, Normalization Depth= 10 Cm

Field Size (Cm^2)	Monitor Units		Percentage
	PB	CC	Difference
2×2 corner	135.03	143.58	-6.33%
4×4 corner	123.25	126.8	-2.88%
2×20 Cm^2 in 20×20 Cm^2 **off-axis at +X= 5 Cm**	125.09	128.88	-3.03%
2×20 Cm^2 in 10×20 Cm^2 **off-axis at X= 9 Cm**	126.75	131.53	-3.77%
5×20 Cm^2 in 20×20 Cm^2 **off-axis at +X= 5 Cm**	113.5	114.66	-1.02%

DISCUSSION

Here we can see the percentage difference between the dose values, calculated from two different calculation systems. Optimisation of radiotherapy treatment planning demands to select the most appropriate and accurate set of treatment planning parameters. The calculation of dose distribution in the patient is vital parameter. The two calculation systems do not differ significantly in large fields and central axis fields. On the other hand, in small as well as off-axis fields a deviation can be noted. The pencil beam calculations, seems to be matched with the standard Percent Depth Dose and beam profile curves for both 6 and 10 MV. Collapsed cone calculations have been declared to be equally useful for brachytherapy with the same efficiency as for external beams.[11] Pencil beam calculations too, have been affirmed of significant importance in case of electron beam therapy.[12] Our exploration indicates some special field settings where collapsed cone calculations reveal considerable deviation not only in percentage depth dose but also in beam profile curves.

CONCLUSION

The comparison of two algorithms has been analyzed and it has been noted that pencil beam and collapsed cone algorithm do not vary significantly in central axis fields as well as large field sizes, but in the case of off-axis fields and small field size they show notable variation. For the large field sizes as well as off-axis fields where two algorithms show some variation with each other, the pencil beam calculation results seem to be more close to measured and standard percentage depth dose and beam profile curves.

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