Effects of heterogeneities in dose distributions: Monte Carlo simulation vs dose calculation algorithms

Cristiano Reis; Laura E. Silva; Saulo S. Fortes; Leonardo Peres
Instituto Nacional de Câncer José Alencar Gomes da Silva (INCA)
Praça da Cruz Vermelha, 20230-130, Rio de Janeiro, RJ, Brasil

PURPOSE

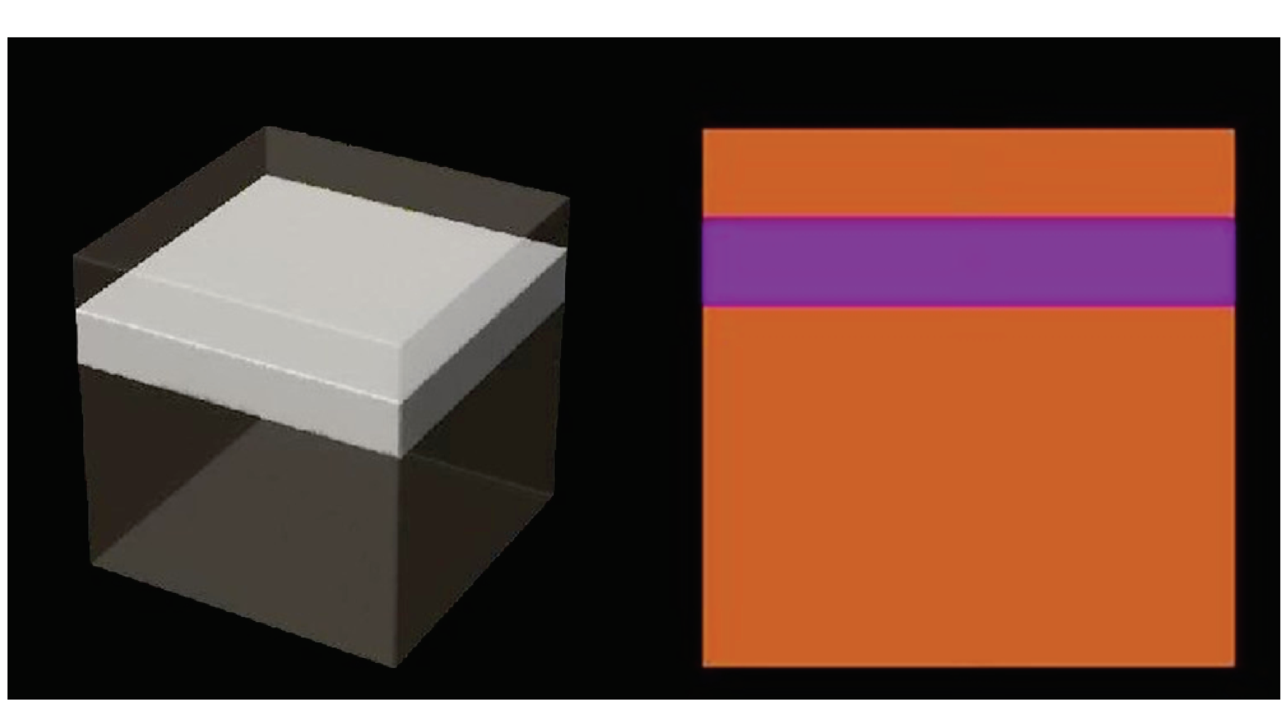
Evaluate the performance of dose calculation algorithms used in radiotherapy treatment planning systems (TPSs) in comparison to Mont Carlo (MC) simulations in regions of heterogeneities.

METHODS

Monte Carlo simulations with PENELOPE code were performed for either validation of a 6 MV spectrum of a VARIAN Trilogy linear accelerator and for comparison with dose calculated by Pencil Beam Convolution (PBC), Analytical Anisotropy Algorithm (AAA) and Acuros XB calculation algorithms from Eclipse TPS (Varian Medical System). Relative depth dose curves were calculated in heterogeneous water phantom with 5 cm thickness slab of lung-equivalent material with density of 0.3 g/cm^3 (-678 HU) placed at 5 cm depth (Fig.1) for fields of 1 x 1 cm^2, 2 x 2 cm^2, 3 x 3 cm^2 and 10 x 10 cm^2.

RESULTS

Comparison of Monte Carlo calculated percentage depth dose (%dd) curves are found to agree within 0.7% with measurements and it is shown figure 2. Maximum difference between our results and Monte Carlo data from the literature [1] are of 0.4% of maximum dose after the build up region. Results for the water phantom with lung-equivalent material interface are shown in figure 3 and table 1. In the water part of the phantom maximum difference between MC and TPS calculations was of 15.6% of maximum dose for the PBC algorithm in a 1 x 1 cm^2 field. The highest differences between MC and TPS algorithm calculations were obtained within lung for 1 x 1 cm^2 field. Maximum deviations were of 24.3% for PBC, 11.5% for AAA and 7.5% for Acuros.



Virtual heterogeneous water phantom with tissue-equivalent (lung) material interface modelled in the Eclipse treatment planning system (a). In (b) the same set-up is modeled with PENELOPE code and visualized using the gview geometry viewer. The tissue-equivalent material slab is 5 cm thickness and placed at 5 cm depth in the water phantom.

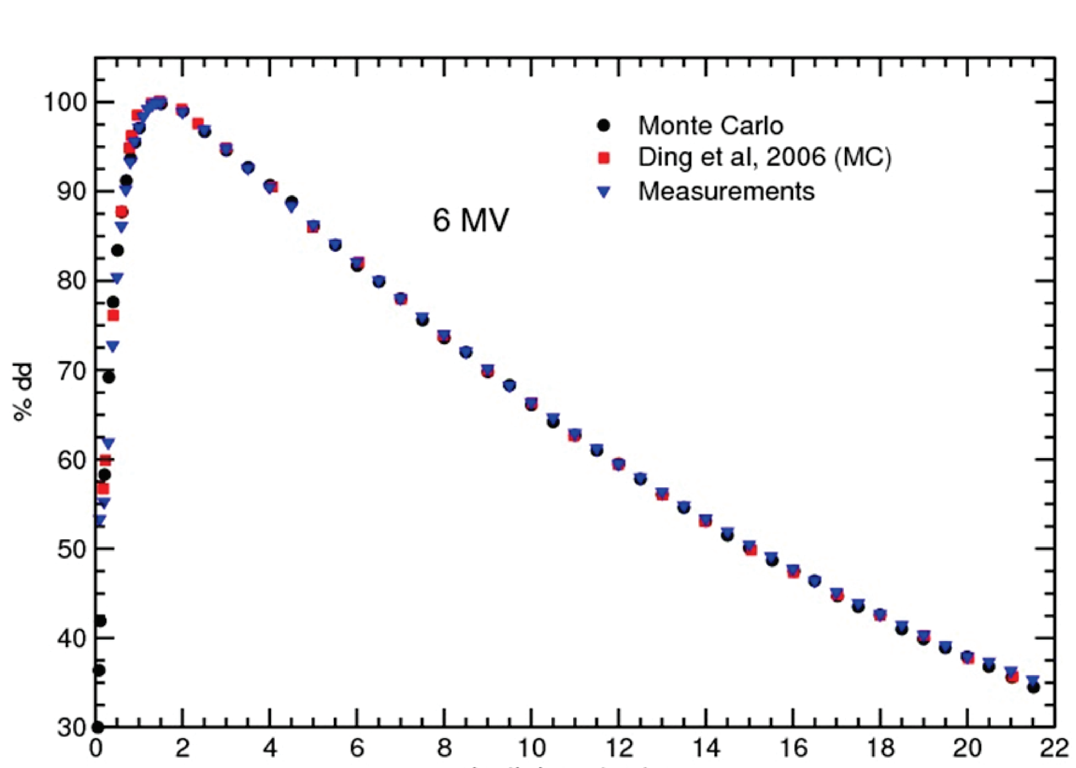


Figure 2: Percentage depth dose curves in water for a 6 MV photon beam with a 10 x 10 cm^2 field at an SSD = 100 cm. Monte Carlo simulated depth dose calculations are compared to data also obtained by simulation by Ding et al [1] and to experimental measurements with a Markus chamber.

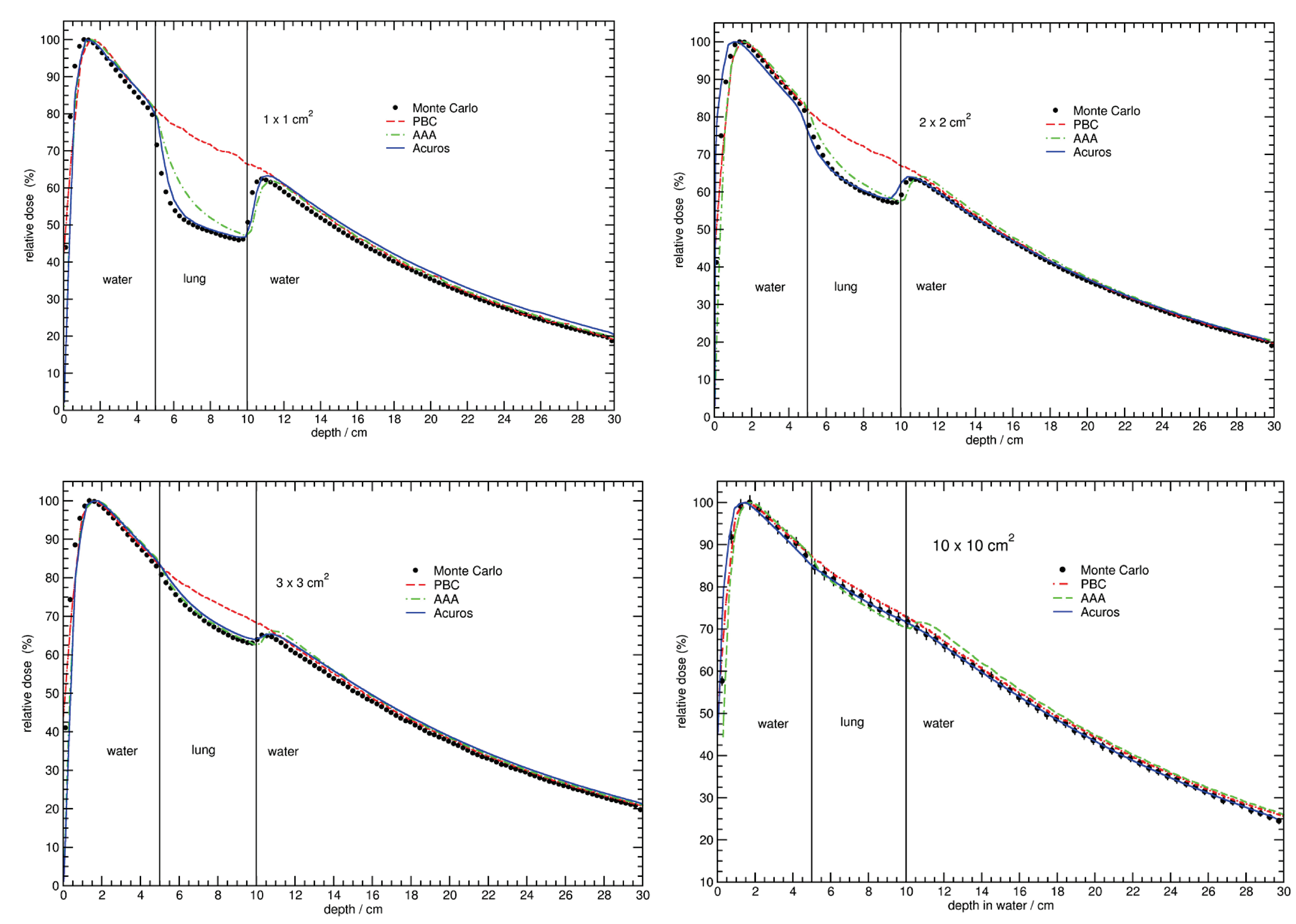


Figure 3: Comparison of 6MV relative dose curves in the heterogeneous water phantom with a water-lung interface for 1 x 1 cm^2 (a), 2 x 2 cm^2 (b), 3 x 3 cm^2 (c) and 10 x 10 cm^2 (d). Graphs show curves calculated with PENELOPE code and TPS algorithms

Table 1: Maximum percentage differences relative do D_{max} between MC and TPS algorithms dose calculations in the water (before and after the interface) and in the lung-equivalent material parts of the heterogeneous phantom.

Filed size (cm^2)	Water			Lung		
	PBC	AAA	Acuros	PBC	AAA	Acuros
1 x 1	15.6	8.7	5.7	24.3	11.5	7.5
2 x 2	7.7	3.3	4.3	12.2	3.5	3.0
3 x 3	4.3	3.0	2.1	6.9	2.0	2.2
10 x 10	1.3	2.7	1.4	2.0	1.8	0.6

CONCLUSION

The results presented in this study show that the dose calculation algorithm Acuros presents the best agreement with Monte Carlo simulation data with equivalent accuracy for modeling radiotherapy dose deposition especially in regions where electronic equilibrium does not hold such as that in the presence of inhomogeneities. However, both AAA and PBC algorithms can also exhibit reasonable agreement with MC results for standard fields (grater than 3 cm x 3 cm) used in radiotherapy.

REFERENCE

[1] Ding GX, Duggan DM, Coffey CW. Commissioning stereotactic radiosurgery beams using both experimental and theoretical methods. Phys. Med. Biol. 2006; 51: 2549 – 66.

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