Monte Carlo algorithm impact on lung SBRT treatments

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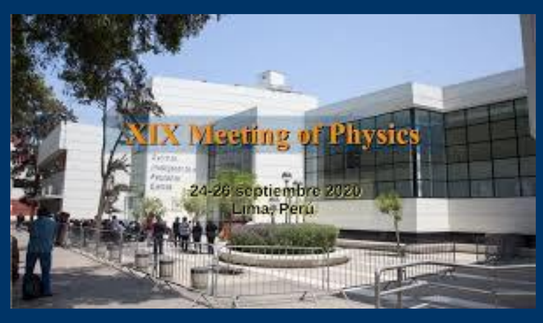

Introduction

SBRT (Stereotactic Body Radiation Therapy) irradiation technique requires a higher dose-calculation accuracy level than in common cases due to big amount of Dose per fraction; it is also known that Pencil Beam (PB) algorithm is widely used because of its short calculation time; however, its level of accuracy decreases with the presence of heterogeneities [1], [2], [3]. It is well established, including AAPM (American Association of Physicists in Medicine) recommendations [4], that lung SBRT requires a more robust algorithm that takes into account loss of Electronic equilibrium at the tumor/lung interface, within which current 'Gold Standard' is Monte Carlo (MC). So, the present work aims to quantify the calculation percentage difference between commented algorithms (PB and MC) at such interfaces.

Materials and Methods

A 6MV photon beam produced by a Primus Linear Accelerator (Siemens) equipped with MLC (multi-leaf collimator) Optifocus model was used, twenty patients with lung tumors were selected, treated with SBRT. Treatment plannings had been made with treatment planning system (TPS) iPlan v4.5.1 (BrainLAB), with MC calculation algorithm using 2mm and 2% for spatial resolution and variance respectively (Fig. 1), using a 12 beam arrangement (Fig. 2) as an average, some of them not coplanar. According to institutional protocol[2], all of these treatments were carried out with ExacTrac (BrainLAB) as IGRT (image guided radiation therapy) system, fixing bone marrow as the reference, immobilization was made with an abdominal compressor and a vaclock, delivering a total dose of 48Gy in 4 fractions with consecutive treatment days.

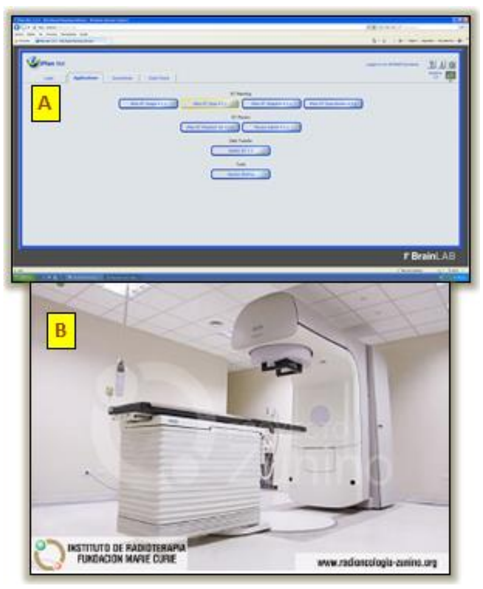

Figure 1. A: TPS used, B: Linear Accelerator employed for treatment delivery.

All plans were recalculated with PB algorithm obtaining the resulting distribution with the same normalization of MC calculation. The following values were recorded for planning target volumes (PTV) and internal target volume (ITV): D98%, D95%, D2% and D50%, which were evaluated from the dose-volume histogram (DVH, Fig. 3), obtained.

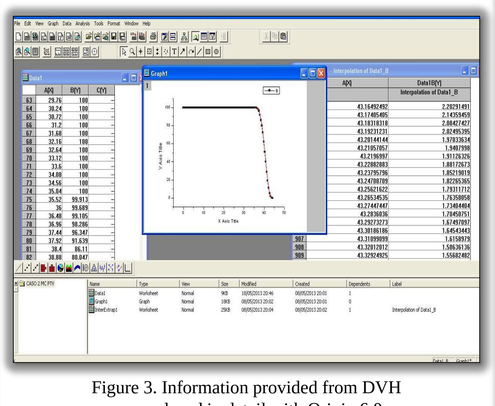

Figure 3. Information provided from DVH was analysed in detail with Origin 6.0.

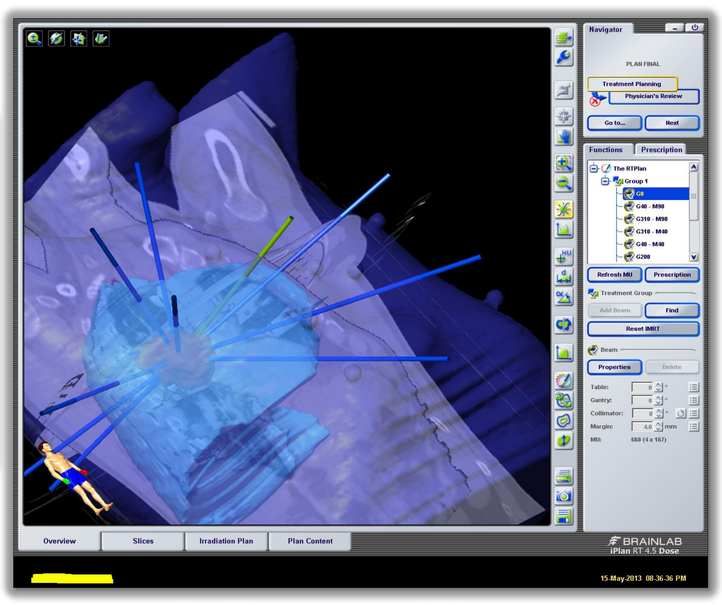

Figure 2. Beam arrangement for SBRT treatments.

Results

After recalculating all the treatment plannings, clear differences were observed in distributions and histograms that both algorithms produced after being executed (Fig. 4). The average percentage change between MC dose calculation and PB to D98%, D95%, D50% and D2% in PTV was: 12.4 +/- 6.1% [1.8%, 26.5%], 12.6 +/- 5.1% [5.8%, 24.7%], 9.8 +/- 4.4% [2.5%, 18.1%] and 7.0 +/- 4.2% [- 0.2%, 14.1%]. Analogously, in ITV: 9.4 +/- 3.9% [4.5%, 20.6%], 9.0 +/- 3.8% [4.3%, 19.1%], 7.6 +/- 4.4% [1.8%, 20.0%] and 6.3 +/- 3.6 % [- 0.3%, 12.7%], see detailed results in tables 1, 2 and 3.

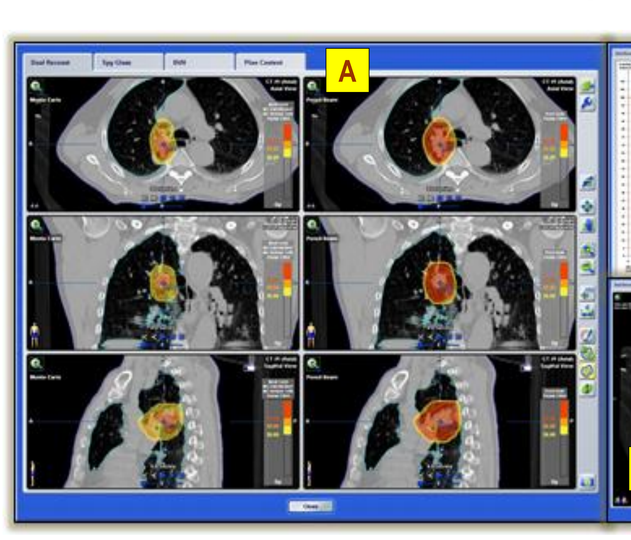

Figure 4. A: Dose distribution comparison for the same treatment planning worked with MC (left) and PB (right), since top to bottom can be seen axial, coronal and sagital views, distinguishing easily 'overheat' for PB column against MC one. B: DVH comparison for the same treatment planning, solid line corresponds to MC and the dashed one to PB, dose overestimation is clear. C: Chossing an axial slice and superposing both calculated distributions (PB and MC), it can be seen 1.5cm separation for 95% and 107% dose curves from one algorithm to the other.

PTV ANALYSIS

	VAR% D98%	VAR% D95%	VAR% D50%	VAR% D2%
1)	6.84	5.80	2.50	-0.17
2)	10.73	10.11	13.23	9.39
3)	18.66	17.07	12.63	11.72
4)	21.17	20.88	15.13	10.31
5)	4.20	8.47	10.92	6.14
6)	7.54	8.30	8.42	2.07
7)	26.48	24.74	16.96	10.85
8)	20.95	21.33	18.07	14.05
9)	10.44	9.38	6.89	7.73
10)	11.30	12.43	8.80	1.77
11)	14.80	15.95	11.27	12.58
12)	11.55	11.11	6.88	4.32
13)	10.28	13.09	13.92	10.36
14)	10.80	9.82	6.53	3.79
15)	14.99	13.73	10.28	8.93
16)	6.07	7.93	4.67	3.55
17)	1.76	6.92	4.24	1.74
18)	15.84	11.70	4.92	3.51
19)	14.31	13.29	11.37	7.97
20)	9.41	9.04	7.89	9.15

Table 1. PTV results.

ITV ANALYSIS

	VAR% D98%	VAR% D95%	VAR% D50%	VAR% D2%
1)	4.51	4.27	1.80	-0.29
2)	8.19	8.57	7.71	7.47
3)	12.73	12.27	10.33	11.11
4)	16.42	16.27	19.96	9.15
5)	6.54	8.48	7.89	5.33
6)	7.29	5.98	2.24	1.94
7)	20.59	19.14	12.26	9.91
8)	13.04	12.90	12.80	12.70
9)	6.87	6.68	5.93	6.82
10)	7.78	7.23	2.84	0.95
11)	11.82	10.95	8.94	8.63
12)	7.09	7.00	5.17	4.00
13)	9.84	8.93	11.24	9.68
14)	8.59	8.34	5.80	3.76
15)	9.81	9.21	8.57	8.79
16)	5.75	5.05	3.51	4.33
17)	6.41	5.22	3.53	2.07
18)	8.66	8.22	4.06	5.40
19)	9.98	9.50	9.75	7.65
20)	5.58	5.86	7.21	7.36

Table 2. ITV results.

PTV ANALYSIS			
VAR% average D98%	VAR% average D95%	VAR% average D50%	VAR% average D2%
12.4±6.1% [1.8%, 26.5%]	12.6±5.1% [5.8%, 24.7%]	9.8±4.4% [2.5%, 18.1%]	7.0±4.2% [-0.2%, 14.1%]
ITV ANALYSIS			
VAR% average D98%	VAR% average D95%	VAR% average D50%	VAR% average D2%
9.4±3.9% [4.5%, 20.6%]	9.0±3.8% [4.3%, 19.1%]	7.6±4.4% [1.8%, 20.0%]	6.3±3.6% [-0.3%, 12.7%]

Table 3: Overview results for 4 metrics selected as average, at PTV and ITV.

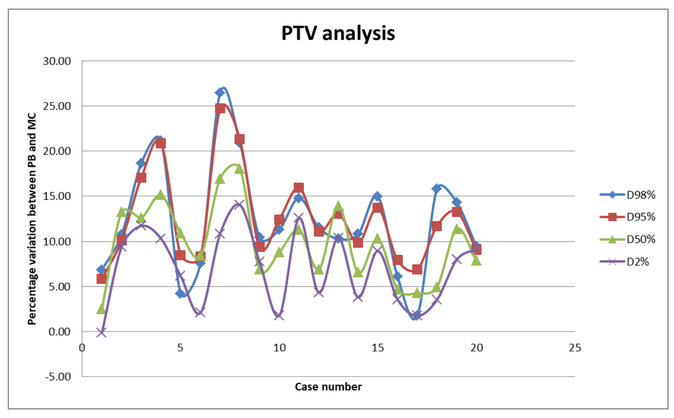

Figure 5. Four metrics graph for PTV.

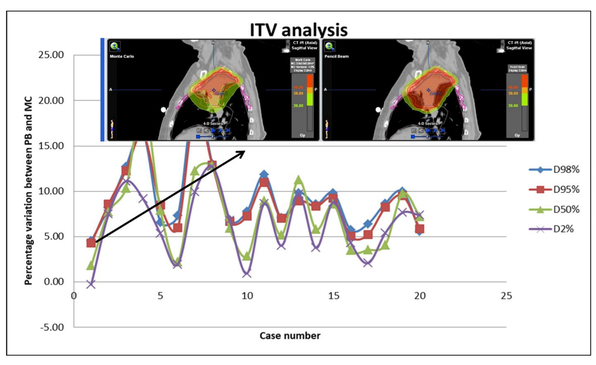

Figure 6. Four metrics graph for ITV, case 1. Percentage variation between PB and MC is just 4% for D95%, due to tumor location oriented to top of head-feet axis, thus a big tumor portion is not exposed to heterogeneities.

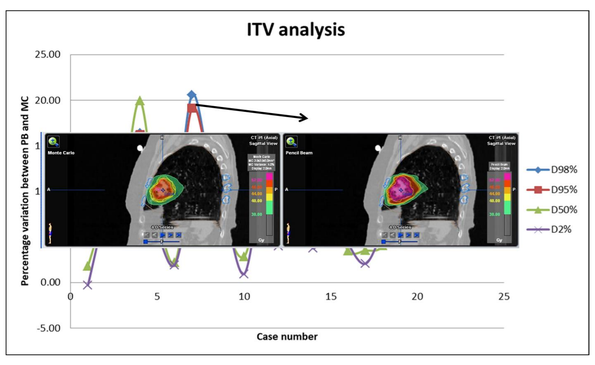

Figure 7. Four metrics graph for ITV, case 7. Percentage variation between PB and MC for D95% reach the highest value: 19%, tumor location is at middle of head-feet axis.

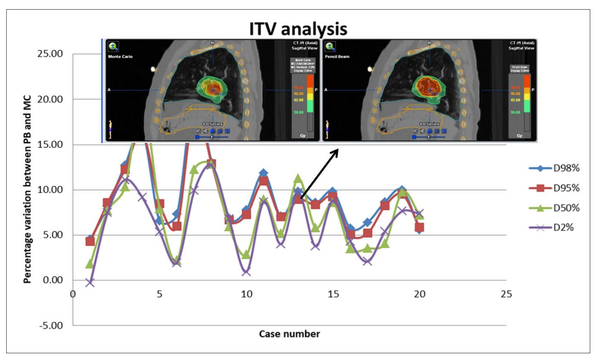

Figure 8. Four metrics graph for ITV, case 13. Percentage variation between PB and MC is 9% for D95%.

Conclusions

For these 20 cases, PB calculation algorithm overestimates the dose delivered in lung SBRT treatments in more than 10% for the PTV and less than 10% for ITV. If treatment delivery to patients would be made based on PB calculation, this will generate underdosing in the treatment volumes. PB is not a qualified algorithm to carry out accurate dose calculation for lung SBRT.

References

1. LAX Ingmar et al., "Dose distributions in SBRT of lung tumors comparison between two different treatment planning algorithms and MC simulation including breathing motions", *Acta Oncologica*, **45**, pp.978-988 (2006).
2. CASTRILLON FERNANDEZ Manuel et al., "SU-E-T-454: Dosimetric Comparison between Pencil Beam and Monte Carlo Algorithms for SBRT Lung Treatment Using iPlan V4.1 TPS and CIRS Thorax Phantom", *Med.Phys.*, **39(6):3809**, (2012).
3. OTTOSSON R.O., KARLSSON A., BEHRENS C.F., "Pareto front analysis of 6 and 15 MV dynamic IMRT for lung cancer using pencil beam, AAA and Monte Carlo", *Phys.Med.Biol*, **55**, pp.4521-4533 (2010).
4. STANLEY H. Benedict et al., "Stereotactic body radiation therapy: The report of AAPM Task Group 101", *Med.Phys.*, **Vol.37, No.8**, pp.4078-4101 (2010).