Absolute and Radiobiological Comparison of Collapsed Cone Convolution and Monte Carlo Dose Calculation Algorithms in Small Lung Tumors

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Introduction

- Collapsed Cone Convolution (CCC) and Monte Carlo (MC) are common dose calculation algorithms used when treating lung SBRT tumors
- Since CCC and MC use different methods to create a dose distribution, the resulting dose distributions from each algorithm might yield a difference in calculated dose being delivered to the target volume and organs at risk[1] (OARs)
- This difference can sometimes cause clinical confusion and concern for increased toxicity risk[1]

Purpose

The purpose of this study is to determine whether there is a clinically relevant difference between Collapsed Cone Convolution and Monte Carlo dose algorithms in lung tumors treated with SBRT

Methods

- Twenty previous lung SBRT treatment plans that were planned using CCC dose algorithm at UMMC were used
- All patients had a prescription of 55 Gy/5 fx except two patients that had a prescription of 60 Gy/8 fx and 52.5 Gy/15 fx
- Treatment plans were created on RayStation 2023b using 6 MV FFF energy with a final isocenter placed near or at the center of the PTV with 1-2 partial arcs
- All plans were optimized to obtain 95% coverage of the target volume while meeting organ at risk (OAR) constrains and maintaining conformality of the R100 and R50
- These same 20 plans were then re-calculated using fast MC set at 1% uncertainty and differences in coverage and OAR dose were examined

Technique

- Differences between GTV, ITV, and PTV coverage, GTV mean dose, R100, R50, Lungs-GTV V20, rib max point dose, skin max point dose of CCC and MC plans were examined using a two-tailed paired t-test ($\alpha = 0.05$)
- Percent differences between the OAR doses were also compared
- Biological evaluation via tumor control probability (TCP) and normal tissue complication probability (NTCP) for CCC and MC plans were calculated then compared using a two-tailed paired t-test ($\alpha = 0.05$)

Results

- No statistically significant difference was found between the GTV coverage when switching from CCC to MC, p= 0.131 (**Table 1**).
- GTV mean dose decreased by 2% when switching from CCC to MC, p= 5.227E-5 (**Table 1**).

	CCC GTV Coverage	MC GTV Coverage	CCC GTV Mean Dose (cGy)	MC GTV Mean Dose (cGy)
1	100%	100%	6354.47	6269.00
2	100%	100%	7198.90	6930.91
3	100%	99.54%	5921.57	5870.34
4	100%	98.17%	5824.95	5758.96
5	100%	100%	6629.58	6472.37
6	100%	100%	6462.80	6307.42
7	100%	100%	7094.39	6934.69
8	100%	100%	7329.67	7251.67
9	100%	100%	6521.22	6376.25
10	100%	100%	8101.82	7715.89
11*	N/A	N/A	N/A	N/A
12	100%	100%	7637.10	7359.30
13	100%	100%	6905.94	6744.07
14	100%	100%	6518.88	6288.49
15	100%	100%	6380.57	6286.81
16	100%	99.11%	5849.57	5743.00
17	100%	100%	6729.38	6895.36
18	100%	100%	6940.45	6728.86
19	100%	100%	7031.87	6993.89
20	100%	100%	8087.23	7881.43
Mean	N/A	N/A	6815.91	6674.14
Percent Difference	N/A	N/A	-2.08%(p=5.23E-5)	

Table 1. Differences in GTV coverage and GTV mean dose when switching from CCC to MC dose calculation algorithms.
* Patient did not have a GTV and was excluded from GTV coverage and mean dose comparison

- No statistically significant difference was found in ITV coverage when switching from CCC to MC, p= 0.298 (**Table 2**)
- A statistically significant decrease in PTV coverage was found when switching from CCC to MC, p=3.546E-6 (**Table 2**)

	CCC ITV Coverage	MC ITV Coverage	CCC PTV Coverage	MC PTV Coverage
1	100%	100%	95.00%	90.19%
2*	N/A	N/A	95.67%	84.06%
3	100%	99.57%	96.27%	87.09%
4*	N/A	N/A	98.05%	93.81%
5*	N/A	N/A	96.22%	85.60%
6	100%	99.92%	95.60%	80.71%
7	100%	100%	95.43%	89.69%
8	100%	100%	95.13%	85.30%
9	100%	100%	95.35%	86.72%
10	100%	100%	95.92%	89.55%
11	99.83%	93.18%	97.29%	88.23%
12	100%	100%	95.37%	89.01%
13	100%	100%	95.57%	89.27%
14*	N/A	N/A	95.30%	75.80%
15	100%	100%	95.29%	90.87%
16*	N/A	N/A	95.43%	70.95%
17	100%	100%	95.66%	95.93%
18	100%	100%	95.84%	84.55%
19	100%	100%	95.59%	93.19%
20	100%	100%	96.59%	94.84%

Table 2. Differences in ITV coverage and PTV coverage when switching from CCC to MC
*Five patients that did not have an ITV due to being treated with breath hold were excluded from the ITV coverage comparison

- Statistically significant differences were seen in the R100, p= 1.083E-5, and the R50, p= 0.003, when switching from CCC to MC (**Table 3**)

	CCC R100	MC R100	CCC R50	MC R50
1	1.13	1.02	4.57	4.48
2	1.16	0.88	5.86	5.56
3	1.01	0.89	3.81	3.90
4	1.07	0.99	3.67	3.70
5	1.07	0.88	5.46	5.38
6	1.05	0.82	5.01	4.89
7	1.07	0.96	4.30	4.26
8	1.06	0.9	5.34	5.26
9	1.08	0.92	4.71	4.59
10	1.14	0.95	4.42	4.15
11	1.09	0.97	4.74	4.82
12	1.14	0.97	4.78	4.46
13	1.13	0.96	4.84	4.66
14	1.1	0.77	6.18	5.85
15	1.1	0.98	5.01	4.92
16	1.12	0.72	5.74	5.58
17	1.09	1.25	10.35	10.47
18	1.14	0.89	5.66	5.50
19	1.02	0.98	4.81	4.80
20	1.04	1	3.90	3.91

Table 3. Differences in the conformality indexes of the 100% isodose line (R100) and the 50% isodose line (R50) when switching from CCC to MC.

- Lung-GTV V20 dose increased by 0.05% when switching from CCC to MC, p= 0.026 (**Table 4**)
- Rib max point dose decreased by 3.02% when switching from CCC to MC, p= 0.004 (**Table 4**)
- Skin max point dose decreased by 1.32% when switching from CCC to MC, p=0.017 (**Table 4**)

	CCC Lungs-GTV V20 dose	MC Lungs-GTV V20 dose	CCC Rib Max Dose (cGy)	MC Rib Max Dose (cGy)	CCC Skin Max Dose (cGy)	MC Skin Max Dose (cGy)
1	3.30%	3.31%	6195.28	5907.27	1177.07	1164.77
2	1.11%	1.09%	5287.33	4877.38	1319.64	1284.68
3	4.80%	4.98%	4979.77	4899.53	2045.82	2071.75
4	6.32%	6.54%	1933.45	1971.33	1500.29	1510.19
5	2.42%	2.44%	4190.35	3960.81	1385.49	1298.33
6	5.24%	5.30%	4761.44	4353.09	1385.40	1355.57
7	2.74%	2.79%	6384.65	6265.65	1877.52	1847.41
8	1.62%	1.65%	2456.14	2513.11	1939.48	1923.28
9	6.40%	6.36%	2198.96	2185.71	946.81	940.14
10	2.91%	2.83%	6314.23	5751.12	1547.64	1481.28
11	5.58%	5.75%	3499.14	3441.08	1795.79	1760.82
12	1.02%	0.99%	2500.92	2372.38	1039.42	1017.86
13	1.01%	0.98%	6645.06	6505.14	1618.91	1616.71
14	1.31%	1.26%	3717.87	3623.25	1448.63	1394.80
15	2.76%	2.76%	5668.35	5742.07	988.83	1020.74
16	1.86%	1.85%	5699.01	5591.38	2480.41	2721.95
17	3.41%	3.35%	5149.68	5283.52	1561.73	1548.32
18	3.45%	3.73%	2665.17	2605.95	1298.23	1278.59
19	3.65%	3.72%	3523.15	3542.04	1240.33	1242.19
20	5.09%	5.28%	1637.72	1631.58	927.26	932.99
Mean	3.30%	3.35%	4270.38	4141.57	1490.24	1470.63
Percent Difference	0.05%(p=0.026)		-3.02%(p=0.004)		-1.32%(p=0.017)	

Table 4. Differences in the organ at risk dose for lungs-GTV V20, rib max point dose, and skin max point dose when switching from CCC to MC

- No statistically significant difference was seen in GTV TCP, p= 0.331; tumor response to treatment and the likelihood of treatment success remains unchanged when switching from CCC to MC (**Table 5**)
- No differences were seen in in the Lungs-GTV NTCP when switching from CCC to MC; likelihood of side effects of treatment due to normal tissue damage remains unchanged (**Table 5**)

	CCC GTV TCP	MC GTV TCP	CCC Lungs-GTV NTCP	MC Lungs-GTV NTCP
1	0.99	0.99	0	0
2	1	1	0	0
3	0.98	0.98	0	0
4	0.98	0.98	0	0
5	0.99	0.99	0	0
6	0.99	0.99	0	0
7	1	1	0	0
8	0.99	0.99	0	0
9	0.89	0.87	0	0
10	1	1	0	0
11*	N/A	N/A	0	0
12	1	1	0	0
13	1	1	0	0
14	0.99	0.99	0	0
15	0.99	0.99	0	0
16	0.98	0.98	0	0
17	1	1	0	0
18	1	1	0	0
19	1	1	0	0
20	1	1	0	0

Table 5. Difference between GTV TCP and Lungs-GTV NTCP when switching between dose algorithms

Conclusion

- 0.05% lung dose increase when switching from CCC to MC was statistically significant but not meaningfully significant
- ~1% decrease in skin dose and 3% decrease rib max point dose when switching from CCC to MC align with known discrepancies that occur when switching dose calculation algorithms[1,2]
- Overall, little difference in clinical outcomes between the CCC and MC dose calculation algorithm, and therefore the use of either algorithms is likely appropriate
- Further investigation into the 2% decrease in GTV mean dose may be necessary as GTV prescription dose coverage was found to be equivalent

References

1. Lee BI, Boss MK, LaRue SM, Martin T, Leary D. Comparative study of the collapsed cone convolution and Monte Carlo algorithms for radiation therapy planning of canine sinonasal tumors reveals significant dosimetric differences. *Vet Radiol Ultrasound*. 2022;63(1):91-101. doi:10.1111/vru.13039

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