

Monte Carlo evaluation of collapsed-cone convolution calculations in head and neck radiotherapy treatment plans

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Head and neck treatments

- Used MCDTK to evaluate CCC dose calculation in head and neck treatment plans

Treatment Plan	# of Beams	# of Segments	Mean X Jaw Separation (cm)	Mean Y Jaw Separation (cm)
1. Cervical node treatment	7	84	10.5	18.2
2. Infraclavicular node treatment	5	68	14.1	23.6
3. Retropharyngeal node treatment	9	120	13.9	21.9
4. Ethmoid paranasal treatment	9	119	14.0	26.7
5. Maxillary paranasal treatment	9	118	15.7	20.9
6. Oropharynx treatment	9	111	14.4	14.6

Head and neck treatments

- H&N region chosen due to heterogeneities
- Delivered using Varian 2100 CD operating at 6 MV
- TPS dose calculated using Eclipse CCC algorithm
 - ▣ KERMA is convolved with dose deposition kernels
 - ▣ kernels characterised using polar angles (cones)
 - ▣ kernels scaled according to density data

Simulation parameters

- 10^8 histories in BEAMnrc for each segment
 - ▣ segment phase space files ranged from 0.5 to 6 GB
 - ▣ 80 to 100 CPU hours each
 - ▣ phase spaces greater than 0.5GB probably excessive
- 10^{10} histories in DOSXYZnrc for treatment
 - ▣ mean of approximately 10^8 histories per segment
- Resolution of 1 to 3 mm voxels (chosen to minimise interpolation of CT data)
- Backscatter correction factor calculated from recorded chamber dose in BEAMnrc

Best agreement

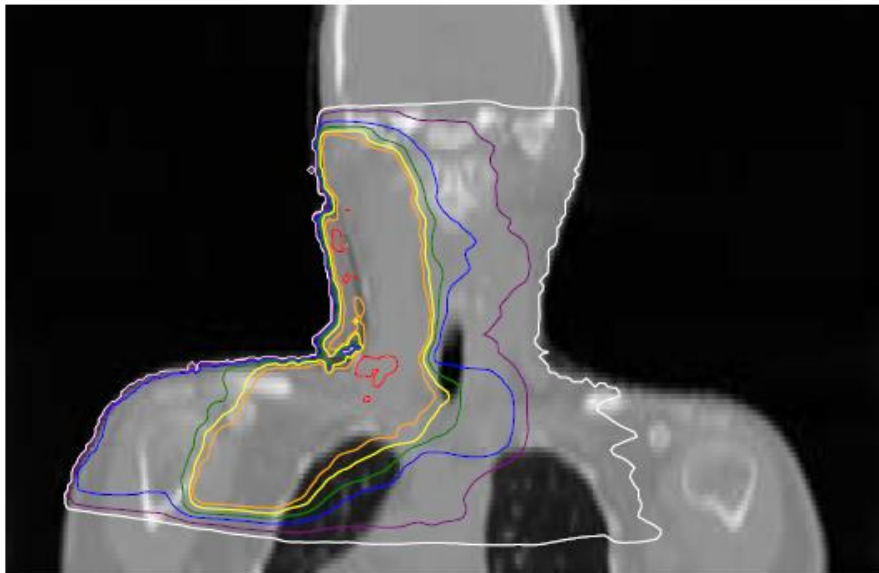
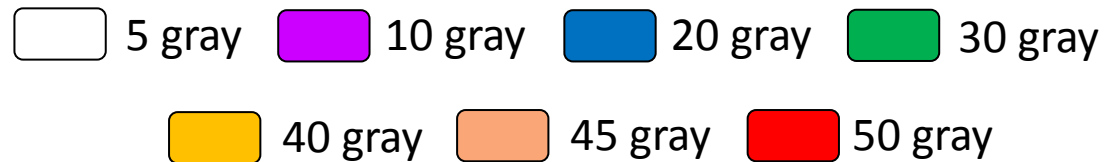
- Treatment where agreement was greatest:
 - ▣ 48 Gy prescription to the cervical, supraclavicular and infraclavicular nodes

Volume / Algorithm		D_{\min} (Gy)	$D_{V=95\%}$ (Gy)	$D_{V=50\%}$ (Gy)	D_{\max} (Gy)
Primary PTV (48 Gy prescription)	TPS	17.1	46.4	48.1	52.0
	MC	37.5	45.7	47.7	55.4
Entire Patient	TPS	0.0	1.3	9.3	52.0
	MC	0.2	1.3	9.0	55.4

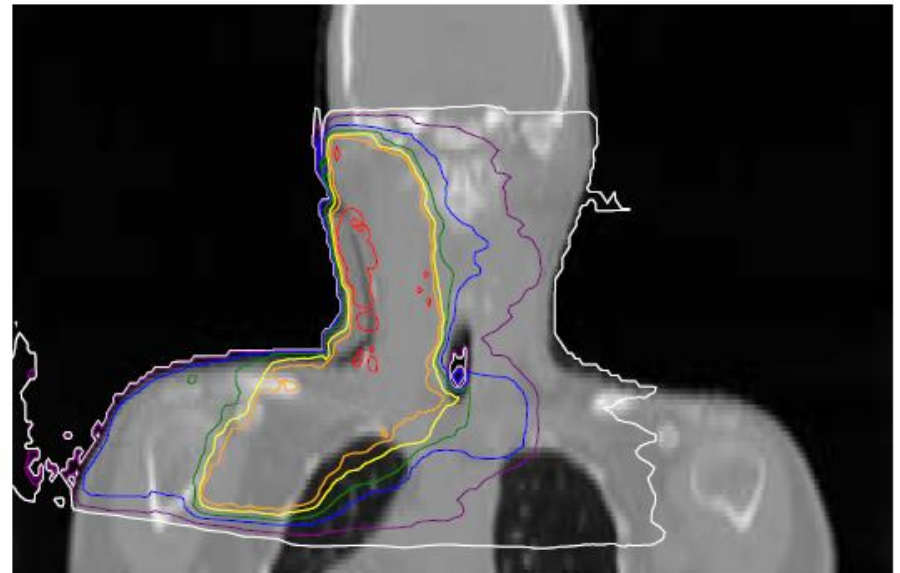
Volume / Dose (Gy)		TPS Volume	MC Volume
Glottic Larynx	22	32.9%	29.0%
Oesophagus	22	42.1%	41.1%
Trachea	22	49.4%	42.5%

22 Gy was the planning dose constraint for these organs

Best agreement



Treatment Planning system
isodose map

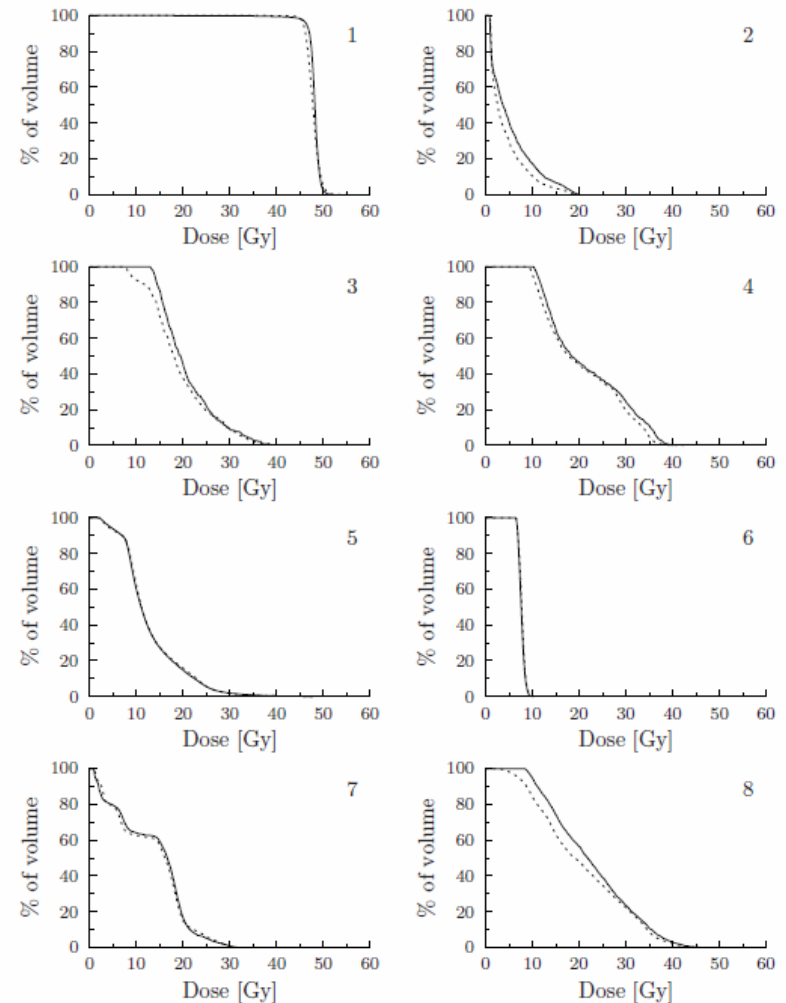


Monte Carlo simulation
isodose map

Best agreement

DVHs in

1. PTV (48 Gy)
2. brain stem
3. glottic larynx
4. oesophagus
5. oral cavity
6. right parotid gland
7. spinal cord
8. trachea



Best agreement

- MC simulation predicted a greater minimum and maximum dose in the PTV, smaller median dose
- CCC predicted a higher coverage of the organs at risk at the constraint dose
- 0.2% of CCC calculations fail 5% max dose / 5mm distance-to-agreement gamma evaluation when compared to reference MC predictions

Worst agreement

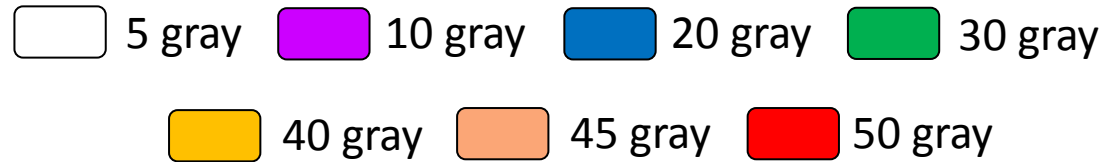
- Treatment where the agreement was worst
 - ▣ 50 Gy prescription to the cervical, supraclavicular and retropharyngeal nodes

Volume / Algorithm		D_{\min} (Gy)	$D_{V=95\%}$ (Gy)	$D_{V=50\%}$ (Gy)	D_{\max} (Gy)
Treatment Volume (50 Gy prescription)	TPS	14.3	46.4	50.2	55.5
	MC	5.2	43.6	47.9	55.3
Entire Patient	TPS	0.0	0.9	16.0	55.5
	MC	0.24	1.0	15.0	55.3

Volume / Dose (Gy)		TPS Volume	MC Volume
Left Parotid	30	54.9%	36.9%
	45	27.9%	20.2%
Right Parotid	30	47.6%	47.8%
	45	26.6%	28.7%

RTOG suggest keeping median dose in at least one parotid to below 30 Gy

Worst agreement



Treatment Planning system
isodose map

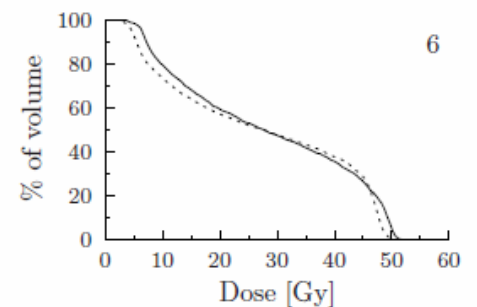
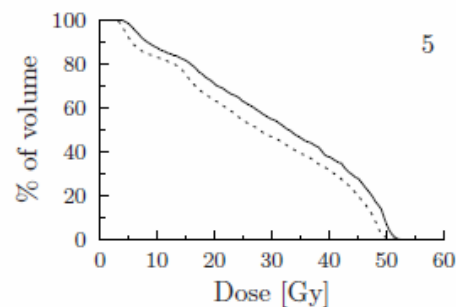
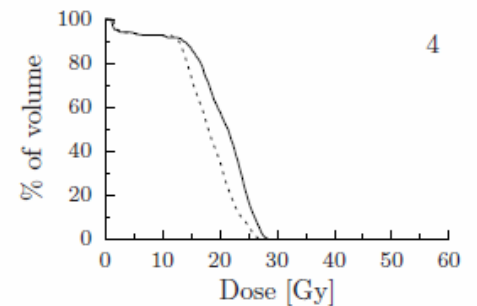
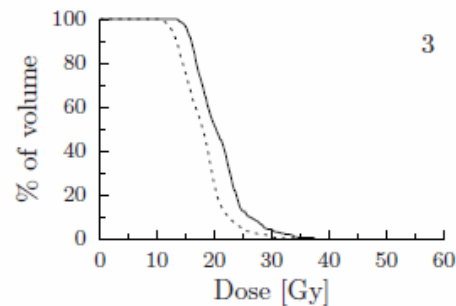
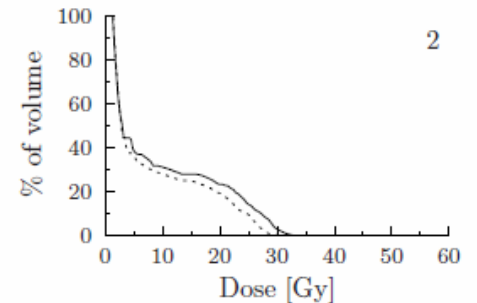
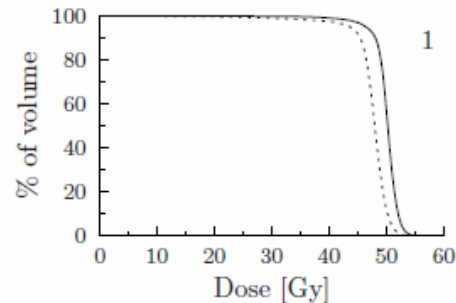


Monte Carlo simulation
isodose map

Worst agreement

DVHs in

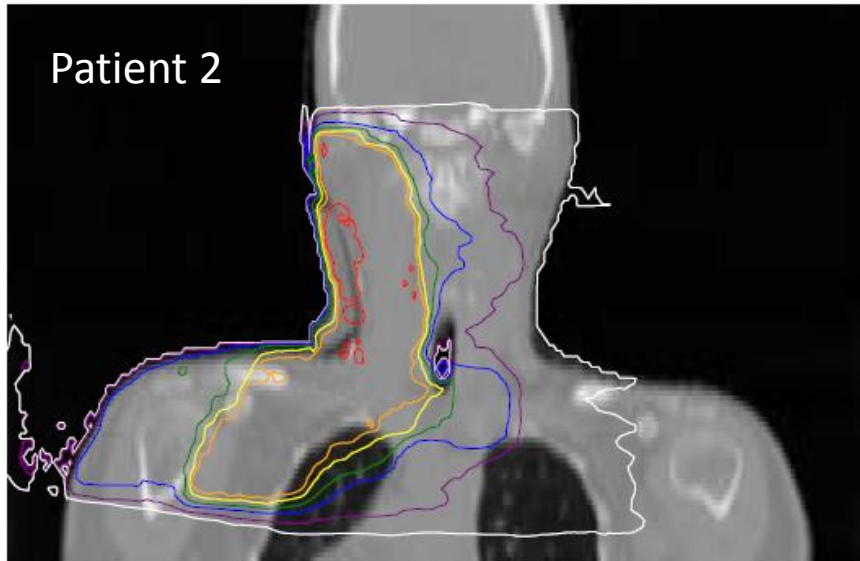
1. PTV (50 Gy)
2. brain stem
3. oesophagus
4. spinal cord
5. left parotid gland
6. right parotid gland



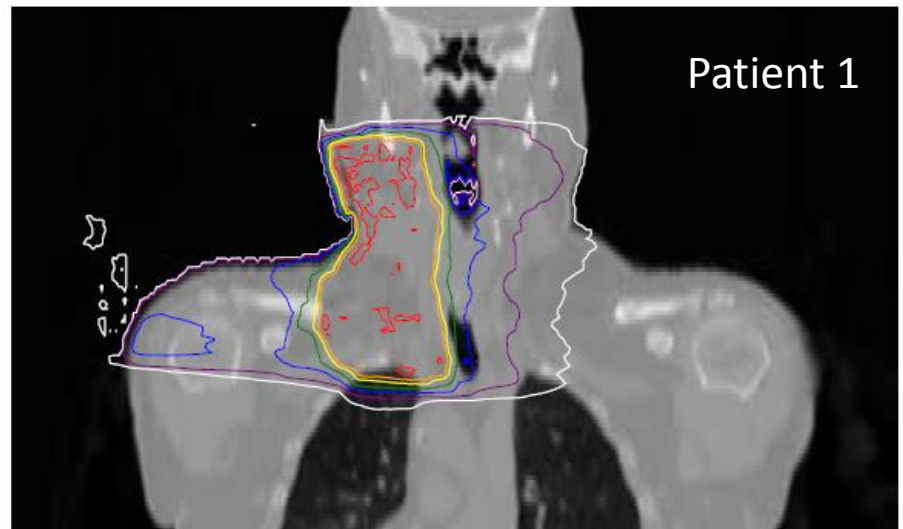
Worst agreement

- CCC predicted a higher dose in the treatment volume and most of the organs at risk
- 2% of CCC calculations fail 5% max dose / 5mm distance-to-agreement gamma evaluation when compared to reference MC predictions
- 12% of CCC calculations fail same conditions in the 50 Gy treatment volume

Summary: good agreement

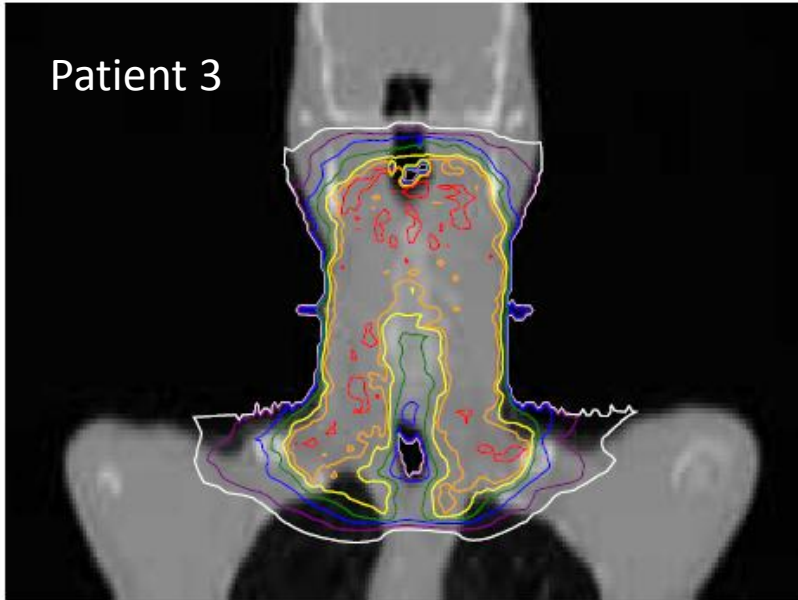


Monte Carlo isodose maps where agreement was found between Monte Carlo and collapsed cone convolution calculations



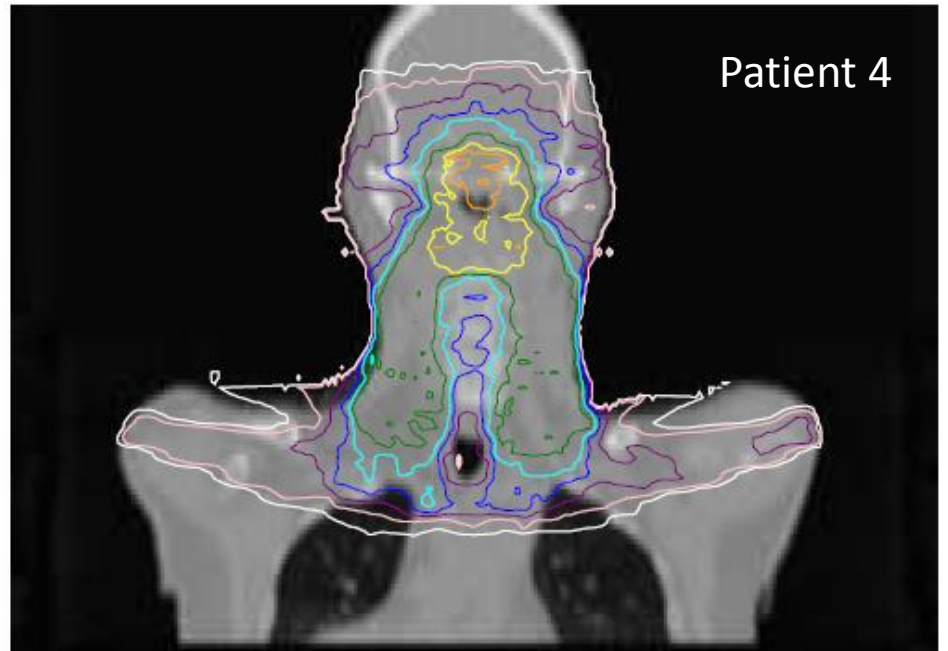
Summary: poor agreement

Patient 3



Monte Carlo isodose maps where disagreement was found between Monte Carlo and collapsed cone convolution calculations

Patient 4



Summary

- Strong agreement in “unilateral” treatments
- Poor agreement in “bilateral” treatments
- Reasoning:
 - dose kernels characterised for water and scaled
 - air cavities are treated as low density water cavities
 - overestimation of dose deposition beyond air cavity
- Treatments with largest deviations between MC and TPS dose distributions had treatment volumes encompassing tissue on both sides of air cavities

Other deviations

- There were other deviations:
 - ▣ backscatter of electrons at bone-tissue interfaces was more pronounced in MC simulation results (visible at clavicles)
 - ▣ out-of-field dose were higher in MC simulation
 - ▣ probably not clinically significant