CBCT Dose distribution Calculation with GATE Monte Carlo Simulations for Lymphoma patients undergoing Radiation Therapy

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Background & Purpose

Council Directive 2013/59/EURATOM requires new medical radiodiagnostic equipment to provide relevant parameters for assessing patient dose. However, this is not the case for kV-CBCT equipment. This can increase the absorbed dose and thus the risk radiogenic cancer, as even if kV-CBCT involves lower doses compared radiation therapy (RT), patients undergo several scans.

The aim of this study is to calculate the organ-at-risk (OAR) dose distribution due to kV-CBCT scans throughout the RT procedure in lymphoma patients, as they are associated with long-term survivals, so the risk of radio-induced cancer is a greater concern.

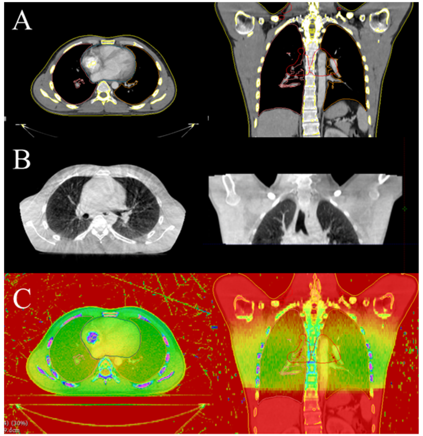

Figure 1. Axial and coronal views of the (A) planning CT with the PTV, (B) real CBCT, (C) Simulated CBCT dose map on top of the CT and structures

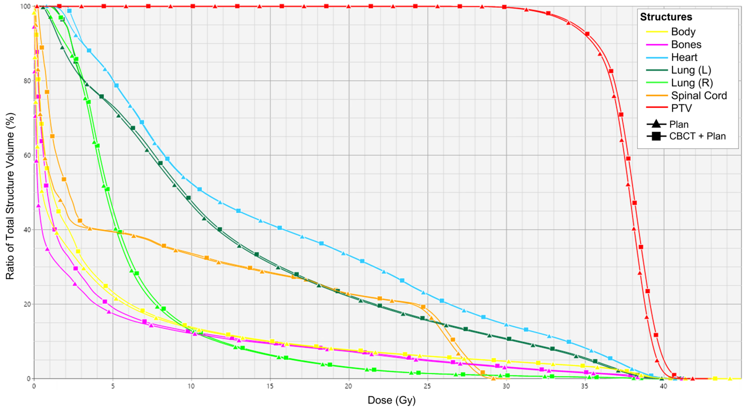

Figure 2. Example of DVH (Patient 4) from the original plan (Plan) and the sum with the CBCT (CBCT + Plan)

Methods

Simulated CBCT dose maps were calculated with Monte Carlo (MC) methods using Geant4 GATE software with an Elekta's Synergy model [1] on planning CT chest scans (Fig. 1A) from 5 lymphoma adult patients. The OARs were contoured in Aria (Varian Medical Systems, v 15.1). An open-source software (3D slicer, v 5.0.3) was used to calculate the mean absorbed dose (MD) in each OAR, which was verified in the TPS (Eclipse, v 15.6) and summed up to the original plan. The dose absorbed by each organ due to the overall treatment was obtained from the TPS.

Results

Results are shown in Table 1. The mean values were compared with the total dose delivered by the radiotherapy treatment (TPS) to calculate the relative dose increment (ΔD) due to the CBCTs. On average, the dose received by CBCT in OARs increases the absorbed dose by 5% over the treatment dose. The greatest increment was found for the heart (34.5%) followed by the bones (11.2%).

Conclusion

CBCT simulations in the pre-treatment planning CT scan are feasible and can account for additional doses absorbed by the patient for possible re-evaluation of treatment, especially in the case of young patients.

Table 1. Mean (range) of the absorbed dose (MD) for each structure and in total, the planned dose (TPS) and the dose increment due to CBCT with respect the TPS (ΔD)

	Patient	P1	P2	P3	P4	P5	Mean
	TPS dose (Gy) / f	36 /20	47 /22	36 / 12	36 / 20	45 / 20	
Body	MD (Gy)	0.2 (0.0 - 4.3)	0.4 (0.0 - 2.3)	0.2 (0.0 - 2.6)	0.2 (0.0 - 4.0)	0.3 (0.0 - 3.3)	
	TPS (Gy)	6.7	4.0	1.7	4.6	2.9	
	ΔD	3.7%	10.0%	10.7%	3.6%	9.5%	6.7%
Lung (L)	MD (Gy)	0.5 (0.0 - 2.0)	0.6 (0.1 - 1.9)	0.3 (0.0 - 1.0)	0.2 (0.0 - 1.3)	0.4 (0.2 - 1.6)	
	TPS (Gy)	11.2	9.5	4.5	12.5	8.0	
	ΔD	4.3%	6.2%	5.5%	1.3%	5.2%	4.5%
Lung (R)	MD (Gy)	0.5 (0.0 - 1.9)	0.6 (0.0 - 1.9)	0.3 (0.0 - 1.1)	0.2 (0.0 - 1.2)	0.4 (0.1 - 1.6)	
	TPS (Gy)	9.6	11.2	4.4	6.0	7.4	
	ΔD	4.9%	5.1%	5.9%	2.6%	5.7%	4.8%
Spinal Cord	MD (Gy)	0.2 (0.0 - 1.2)	0.3 (0.0 - 1.5)	0.2 (0.0 - 0.8)	0.2 (0.0 - 1.0)	0.2 (0.0 - 0.9)	
	TPS (Gy)	10.3	3.4	4.7	8.4	5.3	
	ΔD	1.7%	10.0%	3.8%	2.1%	4.3%	5.1%
Heart	MD (Gy)	0.5 (0.3 - 1.9)	0.6 (0.3 - 1.7)	0.3 (0.0 - 0.5)	0.04 (0.0 - 0.1)	0.5 (0.3 - 1.6)	
	TPS (Gy)	6.4	0.9	1.6	15.1	1.0	
	ΔD	7.9%	71.2%	18.7%	0.3%	47.9%	34.5%
Bones	MD (Gy)	0.5 (0.0 - 2.0)	0.6 (0.0 - 2.2)	0.5 (0.0 - 2.1)	0.3 (0.0 - 1.9)	0.4 (0.0 - 2.1)	
	TPS (Gy)	10.6	4.4	4.2	3.8	3.0	
	ΔD	5.0%	12.7%	12.3%	7.6%	12.3%	11.2%
Total	MD (Gy)	2.4	3.1	1.7	0.8	2.2	**5.0%**
	ΔD	6.7%	6.5%	4.7%	2.3%	4.8%	

Acknowledgments

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References

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