The Impact of CT-density conversion curve for VMAT plans in Monaco Monte Carlo TPS: case of head and neck cancers

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***Abstract*— Purpose: Inaccurate CT-to-density conversion curve (CDCC) information may introduce errors in dose calculation. The aim of this study is to investigate the sensitivity of volumetric modulated arc radiotherapy (VMAT) plans for head and neck cancer (HNC) with Monaco treatment planning system (TPS) to the CDCC. To obtain this goal, a comparison between dosimetric parameters obtained by VMAT plans using 3 different CDCCs was established.**

Method: A CIRS phantom was scanned on 3 different CT-Scan. data from 10 previously treated patients were selected randomly from the list of patients with head and neck cancer that have received VMAT with Monaco planning system at our institution. Plans were evaluated using DVH for PTVs and OARs, the planning DVH objectives used to access plan quality for all plans included: minimum dose, D5%, D95%, V<95%, V>107% target, homogeneity index HI95% and conformity index CI95%. Paired t-test analysis was used to analyse the results. The number of UM of each arc, the total number of UM, the conformity and the heterogeneity indexes, were compared.

Results: A serious variation in the DVHs of the PTVs and the OARs were observed, a variation up to 6% for the OARs, and up to 6% for the PTVs were found. The number of UM of each arc and the total number of UM were found invariable. The conformity index (CI) and homogeneity index (HI) were acceptable.

Conclusion: It is important to consider the use of a specific (CDCC) for planning each VMAT treatment, A wrong (CDCC) will lead to a serious difference in delivering the wanted dose. The need to use the appropriate CT-to-density conversion curve through the treatment planning system is very clear.

***Keywords*— VMAT, MONACO MONTE CARLO, head and neck cancer, Ct-to-density conversion curve.**

I. Introduction

In radiotherapy, precise calculation of the dose is only possible when precise data are obtained from the patient. These data include body contour, shape and density of internal organs, location and spread of tumour volume, etc. The best way to obtain this data is to use three-dimensional imaging systems, including computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET)

In radiotherapy treatment planning systems (TPS), dose calculations are performed on the CT image data. These images are imported into the treatment planning systems as input data in the planning process. CT images are used to contour different target treatment volumes and surrounding normal tissues or organs at risk (OAR). In addition, CT images contain quantitative data (CT values) that can be used to correct tissue heterogeneity in radiotherapy treatment plans. For accurate dose calculations, it is necessary to provide a correct relationship between CT numbers expressed in Hounsfield units (HU) and electron density in treatment planning systems. CT number values represent tissue electron densities and are directly related to the linear attenuation coefficients of tissues in the path length of the photon beam [1].

II. Materials and Methods

In this study, we evaluate The Impact of CT-density conversion curve for VMAT plans using Monaco TPS version 5.10 (Elekta CMS, Maryland Heights, MO, USA) on an Elekta Synergy linac (Elekta, Crawley, England).

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A CIRS phantom (CIRS model 062 Tissue Simulation Technologie, Norfolk, VA) was scanned on 3 different CT-Scan using: NEUSOFT CT (Neusoft Medical System Co, China), OPTIMA CT 16 slice (GE Healthcare, Japan Corporation), OPTIMA CT 64 slice. After the scan, CT images of the CIRS phantom were downloaded into to the TPS, the HU values were used to establish the relationship between the different Physical Densities, electron densities and their corresponding CT number in Hounsfield units. Curves obtained from these 3 CT scanners are plotted in Fig 1.

Data from 10 previously treated patients were selected randomly from the list of patients with head and neck cancer that have received VMAT with Monaco TPS at our institution.

Two PTVs (PTV1 and PTV2) were defined from respective clinical target volumes (CTVs) by adding 3mm margin with 3D expansion. They were treated with two dose levels giving high dose to primary tumour (PTV1) and low dose to nodal disease (PTV2). Prescription to PTV1 were 66.6 in 30 fractions (#) and PTV2 WERE 54Gy in 30#. The PTVs were reduced to 3mm under skin surface to avoid optimization problem in the build-up region.

The VMAT plans consist of two full arcs (clockwise and counter clockwise) from 178° to 182°. Gantry spacing between two control points was 30° and optimization was made on cost functions parameters.

To identify the impact of changing a CDCC on the distribution of the dose, a recalculation of the treatment plan of the 10 patients was performed using each CDCC.

For each plan, a set of DVH parameters was analysed. For PTV, mean dose, D95%, D98% (near-minimum dose), and D2% (near-maximum dose) were taken into account, whereas, for OAR's, the maximum point and PTV2 were 54Gy in dose and the mean dose to the spinal cord (SC) and the mean dose to the left and right parotid (LP and RP) glands were considered.

To assess the homogeneity of dose distribution in the PTV, an homogeneity index was defined as HI = (D2% - D98%)/mean dose. The lower (closer to 0) the HI, the better is the dose homogeneity. Also, to facilitate the comparison of various treatment plans, the RTOG conformity index (CI) was calculated: CI = VRI/TV, where VRI = 95% − isodose volume and TV = target volume. A CI = 1 corresponds to ideal conformation. A CI > 1 indicates that the irradiated volume is greater than the target volume and includes healthy tissues. A CI < 1 indicates that the target volume is only partially irradiated.[2]

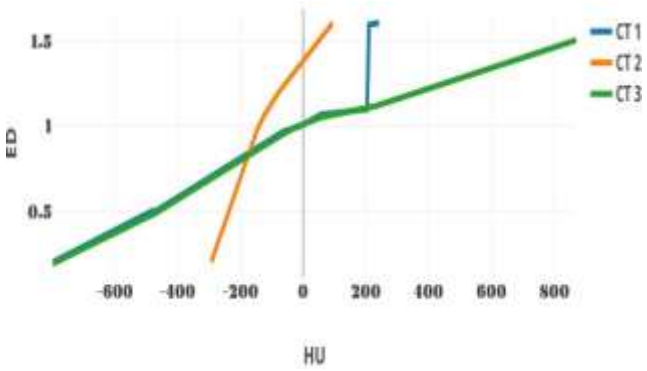

Figure 1 CT to ED conversion curves for the tree CTs

III. Results and Discussion

The overall results in terms of target dose homogeneity, Conformity Index and OARs statistics from DVH and plan analysis are displayed in Table 1. Figure 2 and 3 shows cumulative DVHs using the 3 CDCCs for one representative case. Paired t-test analysis was reported to determine the significance of the results (p<=0.05) for CDCC1 vs CDCC2 (P+) and CDCC1 VS CDCC3 (P-).

In terms of PTV1 homogeneity CDCC2 plans achieved best homogeneity followed by CDCC1.CDCC1 plans achieved very conformal plans with a mean of 0,312. However, difference was not statistically significant. D95% for CDCC1 plans that use a correct calibrated CDCC for TPS is significantly highest.

As shown in Table2. The number of UM of each arc and the total number of UM were found invariable.

As for the OAR's, CDCC2 plans allowed the largest sparing of spinal cord (SC), SC5mm in terms of maximum dose with statistical significance observed. Overall CDCC2 plans also allowed reduced parotid involvement compared to other CDCCs. CDCC1 plans spares SC5mm better then CDCC3 plans but difference is rather small. Mean dose to right parotid when using CDCC2 instead of CDCC1 resulted of a dose difference up to 5%, and 2% when using CDCC3. For left parotid the dose difference is 6% when using CDCC2 and 0.8% when using CDCC3.

Finally, difference dose for maximum doses to the spinal cord and SC5mm are 5% when using CDCC2 ,0.5% and 3 % respectively when using CDCC3.

	CDCC1	**CDCC2**	**P+**	**CDCC3**	**P+**
PTV1 H	1,093 (0,0035)	1,081	0,2216	1,098 (0,012)	6,79E-08
PTV1 CI	0,312 (0,084)	0,431	0,20	0,396 (0,05)	0,153
PTV95 %	65,48 (2,51)	61,92	0,0004	67,31(1,29)	0,0002
SC max dose	44,86 (1,63)	42,55	1,66E-10	44,62 (0,16)	5,98E-10
SC5mm max	50,77 (2,04)	47,88	1,15E-05	52,50 (1,22)	5,21E-06

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dose					
Right parotid mean dose	25,58 (0,94)	24,24	2,53 E-08	26,09 (0,36)	1,05E-09
Left parotid mean dose	26 ,23 (1,02)	24,78	1,38E-08	26,45 (0,15)	1,28E-09

Table 1 CDCCS TARGET Homogeneity, Conformity Index, Coverage and OAR statistics

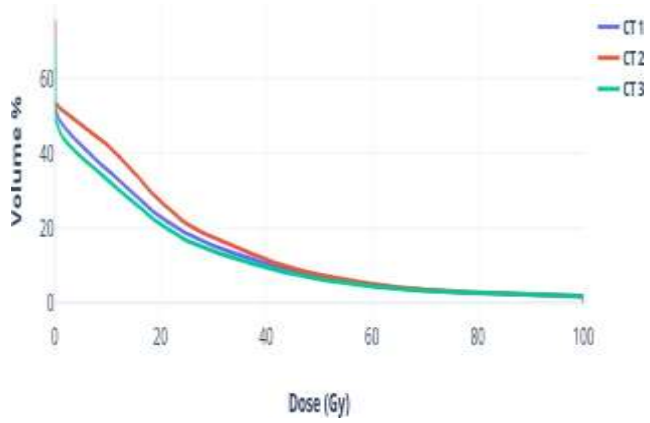

Figure 2 Right parotid DVH calculated with the 3 CDCC

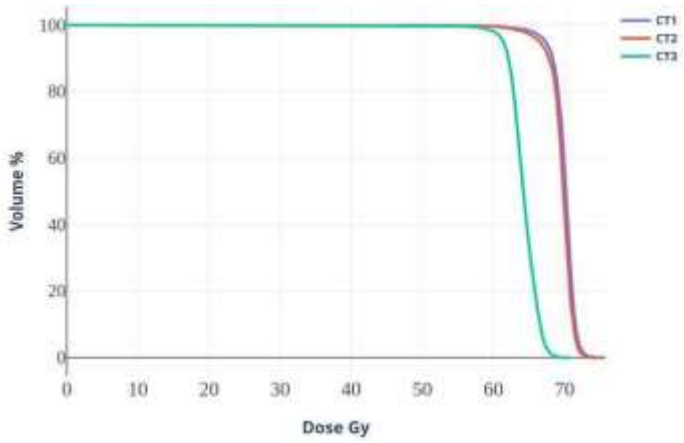

Figure 3 PTV1 DVH calculated with the 3 CDCC

Cases	CDCC	ARC1(UM)	ARC2(UM)	TOTAL(UM)
1	CDCC1	433,61	431,55	865,16
	CDCC2	464,9	378,83	843,73
	CDCC3	464,9	378,83	843,73
2	CDCC1	430,9	346,77	777,67
	CDCC2	430,9	346,77	777,67
	CDCC3	430,9	346,77	777,67
3	CDCC1	362,82	393,44	756,26
	CDCC2	362,82	393,44	756,26
	CDCC3	362,82	393,44	756,26
4	CDCC1	488,58	545,71	1034,29
	CDCC2	488,58	545,71	1034,29
	CDCC3	488,58	545,71	1034,29
5	CDCC1	547,63	387,3	934,93
	CDCC2	547,63	387,3	934,93
	CDCC3	547,63	387,3	934,93
6	CDCC1	407,2	389,92	797,12
	CDCC2	407,2	389,92	797,12
	CDCC3	407,2	389,92	797,12
7	CDCC1	623,9	566,77	1190,67
	CDCC2	623,9	566,77	1190,67
	CDCC3	623,9	566,77	1190,67
8	CDCC1	497,65	439,29	936,94
	CDCC2	497,65	439,29	936,94
	CDCC3	497,65	439,29	936,94
9	CDCC1	697,84	627,38	627,38
	CDCC2	697,84	627,38	627,38
	CDCC3	697,84	627,38	627,38
10	CDCC1	656,33	554,50	1210,83
	CDCC2	656,33	554,50	1210,83
	CDCC3	656,33	554,50	1210,83

Table 2 Monitor units for different CDCCs

IV. Conclusions

This study compared the dosimetric parameters obtained by VMAT plans for head and neck cancer using 3 different CDCCs and calculated by Monaco TPS, which to the best of our knowledge, has not been previously investigated.

the Monte Carlo method allows human tissues to be characterized by elemental composition and mass density, and hence allows the accurate consideration of all relevant electromagnetic and nuclear interactions [3].

The accuracy of Monte Carlo dose calculations is affected by the ability to precisely define materials based on the Hounsfield number information. Thus, in addition to electron or mass density, composing elements and their relative weights need to be known as well.

If there is a mismatch between the TPS calibration curve and Hounsfield unit values in the CT image for particular tissue types, it will lead to discrepancies in the dosimetric calculations performed by the TPS [4, 5].

In this study we present the impact of mismatching the CT images with the appropriate CDDCS for head and neck cancer. A serious variation in the DVHs of the PTVs and the OARs were observed, a variation up to 6% for the OARs, and the PTV were found.

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