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Dosimetric comparison of IMRT plan using different electron density calibration

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Abstract

The precised electron density calibration curve of Computed tomography (CT) used for radiotherapy treatment plan in TPS is playing a major role for the calculation of accurate dose to deliver the patients. Radiotherapy dosimetric procedures are depends on the physical differences between the biological molecules present in the body. In addition, some cases required foreign objects implant inside the body to improve the treatment. In order to get accurate dose calculation, Hounsfield unit (HU) versus electron density (ED) curve used in TPS is playing an important role in radiotherapy. From in this study, we were analysed the dosimetric comparison for head and neck patient for Intensity Modulated radiation therapy (IMRT) plan in treatment planning system (TPS) using the Rocsboard02 standard ED curve given by Elekta vendor and Catphan® phantom (CTP) calibrated ED curve. The CTP phantom having limitation for relative electron density (RED) from 0.001 to 1.868 and HU range from -1046 to +1060. The comparison of total MU for IMRT plan having a significant difference between the rocsboard02 and CTP phantom in the range from 2.2% to 6.7%. Based on the obtained results, we concluded that for radiotherapy treatment planning, the CTP phantom and rocsboard02 ED calibration curve are not recommended for implanted patient. The rockboard02 ED and CTP phantom ED calibration curves are suitable for treatment planning of without implanted patient.

Keywords:

Conformity index, Catphan® phantom, Electron density, Homogeneity index, Hounsfield unit, Intensity Modulated Radiation Therapy and Rocsboard02.

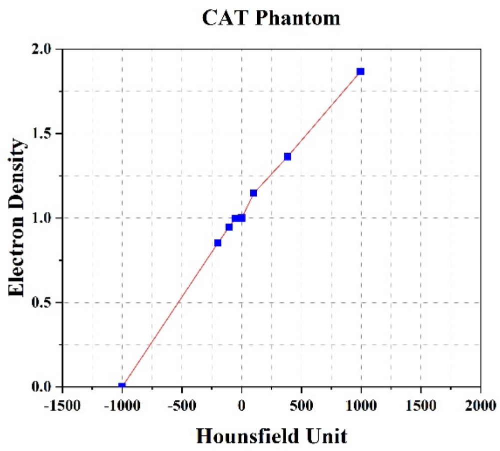
1. Introduction

Accurate calculation of dose distribution is affected by the inhomogeneity of tissue in radiotherapy planning [1]**.** Radiotherapy (RT) dosimetry is based on the physical differences between the tissues and cavities in the body, such as lung, oral cavity, teeth, nose, sinuses, and bones, etc [2]. Some RT cases, even foreign objects deliberately implanted in the human body, such as metal prostheses[3-4].The absorbed dose was planned and irradiated to the entire tissues must be corrected by tissues inhomogeneity as predicted [5].The efficiency of RT treatment with medical implants is reduced, owing to the limitations of computed tomography (CT) [5]. The treatment planning system (TPS) is calculating dose based on the CT data, providing tissue dependent information about their radiological properties, such as mass and electron density (ED) [6]. The majority of CT scanners used in the radiology department provides a conventional hounsfield unit (CHU) scale, which suffices to properly represent human body tissues [7]. The Hounsfield unit (HU) values of high-Z materials like metallic implants, considerably exceed the maximum CHU scale, because these materials usually saturate at CHU's maximum [8]. The extended hounsfield unit (EHU) scale better reproduces the HU values of high-Z materials thus rendering itself appropriate for the purpose of dose calculations with TPS [9].

The most important steps in RT planning are the acquisition of patient data needed to define the target volume and an accurate calculation of the dose distribution [9-10]. These data are mostly derived from the patient's radiology images which are usually obtained from a scanning by CT, which contains all the important information, for an example to see the density distribution of organs and tissues. This information's are then used for an accurate dose calculation, especially when the radiation beam passes through non-homogeneous tissues such as lungs, cavity and bones where the attenuation coefficient is very different with soft tissue's attenuation coefficient [11]. So an accurately calibrated HU versus electron density (ED) curve used in TPS is playing an important role to calculate accurate dose [12]. RT planning are performed to get the optimal therapeutic ratio that provides sufficient dose distribution in target (Tumour) and minimal dose to normal tissue. In this present study, dosimetric comparison was analysed between the Rocsboard02 standard ED curve given by Elekta vendor and Catphan® phantom (CTP) calibrated ED curve for head and neck patient for IMRT plan in Monaco TPS (Version 5.11.02).

2. Materials and methods

The Catphan® phantom (CTP503) was used for this study given by The Phantom Laboratory (Incorporated 2727 State Route 29 PO Box 511 Greenwich, NY12834). The CTP phantom was scanned by 1.25 mm slice thickness at 120 kV and 260 mA parameter on CT-simulator GE Health Care Optima CT520. Calibration CT number curves was the early step in this research. Initially, the calibration curve of CT number was obtained by scanning CTP phantom by CT-simulator and then transferred to the TPS Monaco. Afterwards, we inserted CT electron density calibration curve were obtained by entering density (ρ) of each plug as the y-axis, and the number of CT as the x-axis in Monaco TPS. In this RT plan we were used two electron density (ED) calibration curve of CT number from CTP Phantom and Rocsboard02 standard ED curve given by Elekta vendor. The CT number and ED calibration tables were imported into the Monaco TPS (Elekta Medical Systems Pvt Ltd,Sweden) and were used to investigate its impact on dose calculations. Figure 1 and 2 shown CTP Phantom ED calibration curve and Rocsboard02 standard ED curve Given by Elekta vendor. Total 10 head and neck case were chosen for this study. Treatment planning was performed by the Monte Carlo calculation algorithms that provide superior inhomogeneity correction as reported by many investigators [5]. To investigate the dosimetric impact of different density tissues in patients body, IMRT plan were generated using 6 MV photon beam to achieve optimum coverage to the tumour of patients. In each RT plans, a different CT number - ED calibration table were used for inhomogeneity correction. The remaining parameters, for example, beam arrangements, IMRT dose calculation parameter and prescription dose were kept as same. The difference in dose coverage of the planning target volume (PTV), conformity index (CI) and homogeneity index (HI) were compared by evaluating the dose-volume histograms (DVHs).



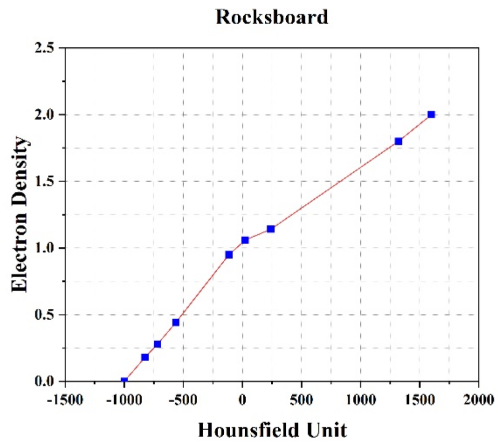


Figure.1 CTP Phantom ED calibration curve **Figure.2** Rocsboard02 standard ED curve Given by Elekta vendor

Owing to the head and neck cancer patients were chosen for this study, some beams passed through the mandible, soft tissue, larynx, and oral cavity to account inhomogeneity correction. Patients CT images were taken for this study. The PTV and OAR (Organ at risk) were drawn by radiation oncologist. Then, IMRT treatment plan were generated using different ED calibration curve. The dose differences in PTV, CI and HI with various ED curve were evaluated.

In order to evaluate the RT planning, the calculation of homogeneity index (HI) [6] and conformity index (CI) [13] had been taken from following equation [5,9].The evaluation of RT planning were also performed, the organ at risk by referring to the Quantitative Analysis of Normal Tissue Effects in the Clinic (Quantec).

HI and CI were calculated using the following equations:

$$\mathrm{HI} = \frac{(\mathrm{D\ 5} - \mathrm{D\ 95})}{\mathrm{Dp}} \quad (1)$$

$$CI = \frac{\mathrm{Tvri}\ {}^{*}\mathrm{Tvri}}{\mathrm{Tvri}\ {}^{*}\mathrm{Tri}} \quad (2)$$

where,

D5 and D95 refer to the maximum dose encompassing 5%, 95%, and Dp refer prescribed dose of PTV, respectively. Tri is the volume of the target and Vvri is the volume of the PTV covered by the prescribed dose.

3. Results and discussions

The maximum tissue inhomogeneity correction for mega voltage photon beam is +4.00% per cm shown in table 1. TPS calculation uncertainty is 2%. If we added 2% of the TPS calculated uncertainty [14], and then the total uncertainty can be almost reached to 6%, this value is far beyond the ICRU recommended that the accepted total uncertainty in the whole radiotherapy process amounts to 5% [15].The human body consists of a variety of tissues and cavities with different physical and radiological properties. The most important for radiation dosimetry perspective, the density of tissues and cavities those are different from water, including lungs, oral cavities, teeth, nasal passages, sinuses and bones. In some instances, foreign materials, such as metallic prostheses are also present. To maximize the therapeutic benefit of RT, it is essential that the absorbed dose delivered to all irradiated tissues in the presence of such inhomogeneity to be predicted accurately.

Table 1. Simple correction (percent per cm) of the dose according to photon energy and tissue density [5].

Energy	%/cm correction	
	Lung	Bone
Co-60	+4.00%	-2.50%
4-6MV	+3.00%	-2.00%
10 MV	+2.50%	-1.50%
18-25 MV	+1.50%	-1.00%

The plan was made by CTP phantom in Monaco TPS which phantom having different electron density property [16]. Dose distribution for field size 20x20cm^2 and depth at centre of phantom by different ED curve shown in figure 3 and 4. Dose colour wash for 107% is brown colour, 95% is orange colour and 90% is yellow colour shown in figure 3 and 4. The variations of dose distribution were shown in those images, the plan made by different ED calibration curve.

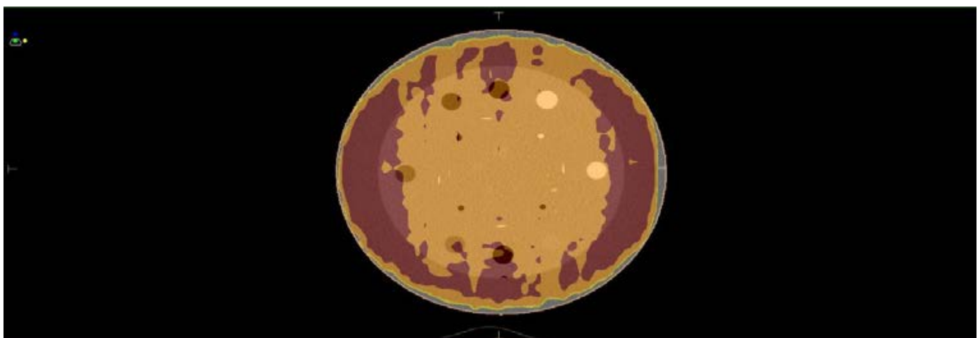


Figure 3. Dose distribution for field size 20x20 cm^2 and depth at centre of phantom by Rocsboard02 standard ED curve

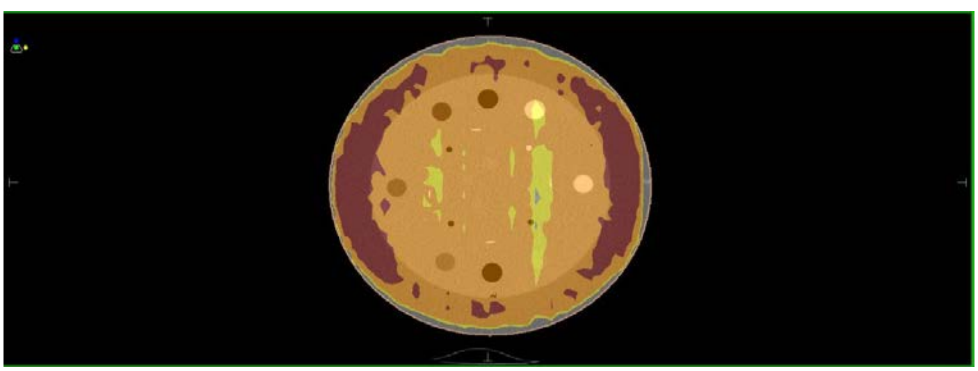
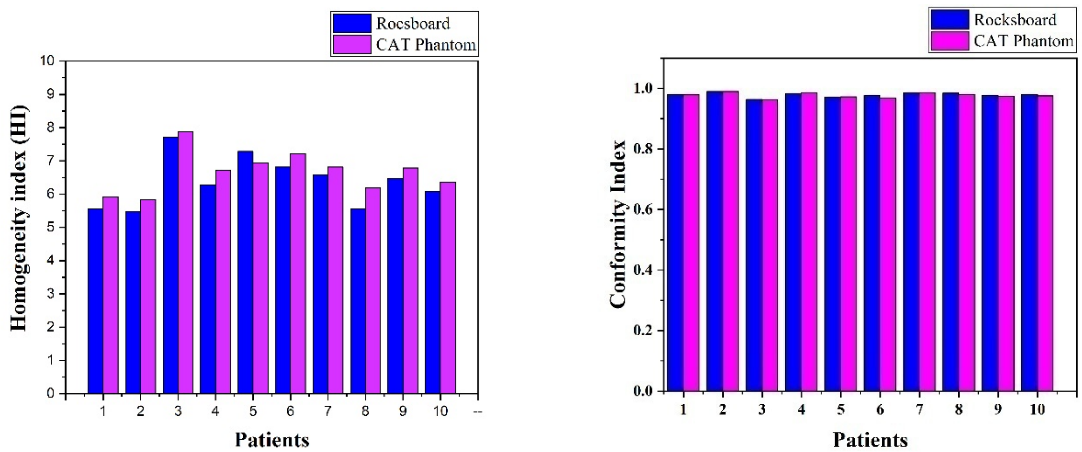


Figure 4. Dose distribution for field size 20x20 cm^2 and depth at the centre of phantom by CTP phantom ED curve

IMRT results were more homogeneous because optimization was performed in TPS. Different calibration of electron density curves would make the different planning result, because the electron density curve contributing major role while dose calculation. A phantom that had more mass density would deliver dose calculation accurately than phantom that had less mass density. In our study homogeneity index and conformity index obtained from planning of radiotherapy by different ED calibration curve did not significantly differ as shown in figure 5.



(a) (b)

Figure 5. Comparison of (a) HI and (b) CI from radiotherapy planning result by different electron density calibration curve.

Comparison of total MU for IMRT plan using different ED calibration curve shown in table 2. The IMRT plan dose calculated by CTP phantom ED calibration curve are having maximum percentage of deviation 6.7% and average 3.8% compare with rocsboard02 ED calibration curve.

Table 2. Comparison of total MU using different ED calibration curve

Patients	Rocsboard02	CTP Phantom	% deviation
1	716	764	6.7
2	703	743	5.7
3	724	753	4.0
4	1252	1282	2.4
5	1108	1169	5.5
6	1192	1229	3.1
7	1288	1316	2.2
8	1091	1138	4.3
9	1082	1115	3.0
10	1138	1175	3.3
Average	1029.4	1068.4	3.8

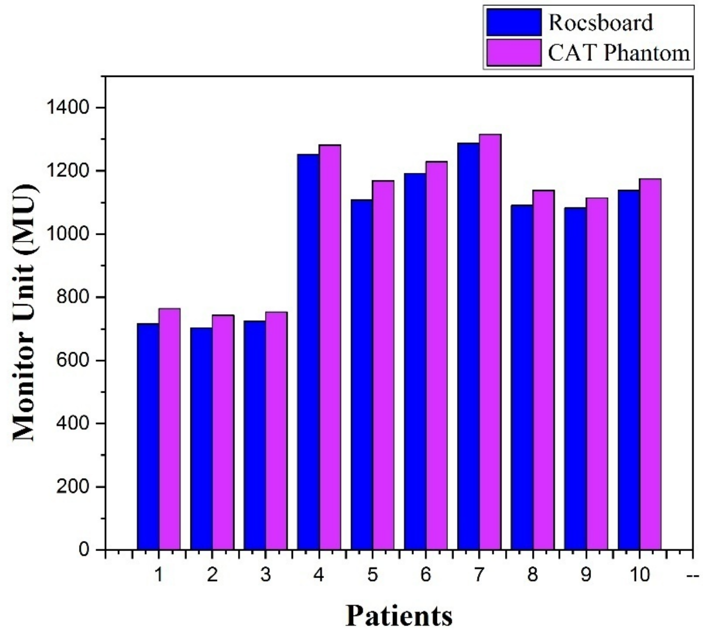


Figure 5. Comparison of total MU from radiotherapy planning result by different ED calibration curve

4. Conclusion

In our study, no significant differences were found in homogeneity index and conformity index obtained from IMRT planning of radiotherapy by different ED calibration curve. But the comparison of total MU for IMRT plan having a significant difference between the rocsboard02 and CTP phantom in the range from 2.2% to 6.7%. Elekta recommend rocsboard02 ED calibration curve for treatment plan in monaco TPS. The CTP phantom having limitation for relative electron density (RED) from 0.001 to 1.868 and HU range from -1046 to +1060. Based on the obtained results, we concluded that the CTP phantom and rocsboard02 ED calibration curves are not recommended for treatment plan of implanted patient. The rockboard02 ED and CTP phantom ED calibration curves are suitable for treatment plan of without implanted patient.

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