The influence of CT tube current and voltage on extended Hounsfield unit values

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Abstract – The precision of radiotherapy treatment planning (RTP) is restricted for medical implants, among others due to limitations of computed tomography (CT) imaging. Radiological CT imaging is an essential part of radiotherapy as it provides important information about the physical characteristics of the tumor and the differentiation from normal tissue. CT imaging uses Hounsfield Unit values (HU) in order to describe the attenuation of X-rays in tissue. Clinical systems use a conventional HU (CHU) scale [-1024 HU; +3071 HU], which is suited for the representation of human body tissues but is limited for high-density materials such as implants. The underestimation of implant material in RTP can lead to errors in dose calculation, which might cause an overexposure of the implant [1]. Uncontrolled irradiation of an electronic implant can lead to malfunction or even a functional loss [2]. In a previous study we have shown, that an extended HU (EHU) scale allows a proper representation of materials with a high atomic mass [3]. In this study, we quantify the influence of CT tube current and voltage on extended Hounsfield unit values.

Material and Methods: The CT systems GE LightSpeed RT (CT1), SIEMENS Somatom Definition Flash (CT2), SIEMENS Somatom Force (CT3) were used to investigate the voltage and current dependence of EHU values. Objects made from aluminium ($ED_{rel}(Al) = 2.34$), titanium ($ED_{rel}(Ti) = 3.73$), chromium ($ED_{rel}(Cr) = 5.94$) and copper ($ED_{rel}(Cu) = 7.33$) were placed in a water phantom for CT acquisition. The metallic objects were coin shaped with a diameter of $20\ \mathrm{mm}$ and a thickness of $5\ \mathrm{mm}$. All CT scans were acquired with the convolution kernel Br40 (standard). The images were reconstructed with filtered backprojection technique. The variable CT settings are shown in Tab.1.

Tab.1: CT acquisition protocols for the analysis of tube voltage (U) and current (I) dependence of EHU values.

Protocol	CT system	CT setting	
		constant	variable
(1)	CT2, CT3	$U_{1,const}$= 120 kV	$I_{2,var}$= 100 mA - 600 mA, increments of 100mA
(2)	CT1, CT2, CT3	$I_{2,const}$= 230 mA	$U_{2,var}$= 80 kV - 140 kV, increments of 20 kV

The CT images were reconstructed using extended HU scale. The EHU scale of SIEMENS CT scanners with $[-10240\ \mathrm{HU}; +30710\ \mathrm{HU}]$ is implemented using 12-bit storage, however GE use 16-bit imaging with a scale of $[-32768\ \mathrm{HU}; +32768\ \mathrm{HU}]$. In order to allow a larger HU value range at 12-bits, SIEMENS scanners increase the rescale slope from $1\ \mathrm{HU}$ to $10\ \mathrm{HU}$. In this way the standard HU scale is spread by the factor 10. For the evaluation of the HU values of the metals, a region of interest (ROI) was placed on the central part of each metal on the CT images. The mean HU value and the mean error of the ROI was quantified with a self-developed MATLAB program.

Results: The EHU values at variable current acquired with CT2 and CT3 are shown in Fig. 1 (left). The results at variable voltage for all three CT systems are shown in Fig. 1 (right). The EHU values of metal objects acquired and determined on SIEMENS CT scanners show no change at variable tube current. However, the EHU values show differences by changing tube voltage. The EHU value

of the metals decreases with increasing voltage. The mean error increase with increasing EHU value. The EHU values for all materials, regardless of voltage, result in lower values for GE scanners than for SIEMENS scanners.

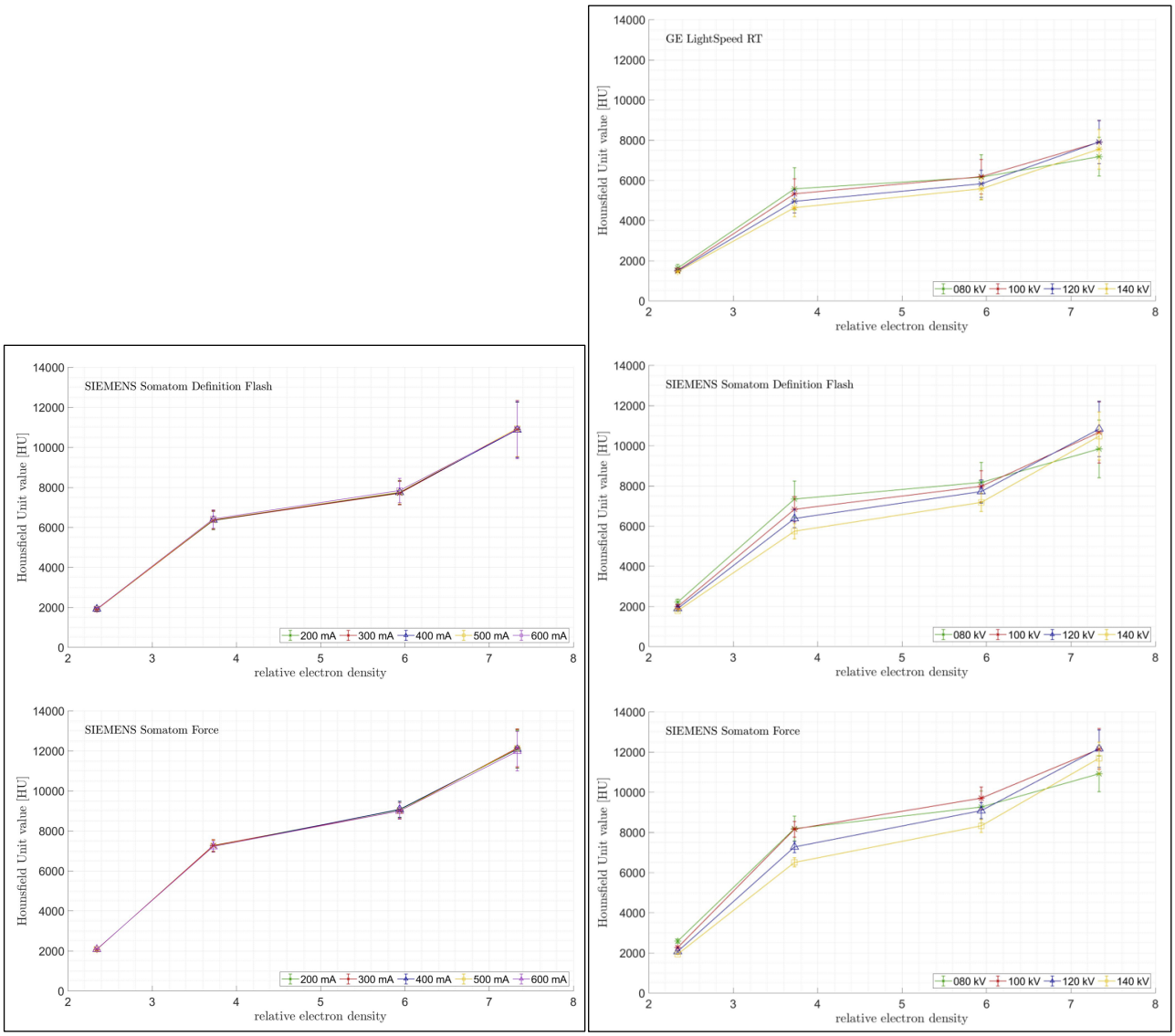

Fig.1: EHU values of metals determined on CT images acquired with variable tube current (left) and voltage (right)

Discussion and Conclusion: The EHU values are stable and independent of the tube current magnitude. However, they depend strongly on tube voltage. Small changes in HU values can lead to bigger errors in dose calculation. In order to quantify the effect of slightly changing HU values in RTP calculations, further investigations are proceeding.

References

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