4) A Comparison of CT Hounsfield Units of Medical Implants and Their Metallic and Electrical Components Determined by a Conventional and an Extended CT-scale

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Introduction: The number of patients with implanted electronic devices, such as pacemakers, cardioverter-defibrillators and neurostimulators is increasing. In addition, with the aging population the occurrence of malignancies is rising steadily. As a result, the probability of patients receiving radiotherapy as treatment modality due to malignancy and wearing an implant becomes higher [1-2]. The goal of radiotherapy is to achieve a well-defined homogenous dose delivery to the target volume while minimizing radiation dose to the surrounded healthy tissue. High-density materials like metallic implants can cause significant challenges in realizing an efficient radiotherapy treatment plan due to incorrect density assignment and determined dosimetric effects within treatment planning software (TPS) [3-5]. The purpose of this study is to investigate the CT Hounsfield units (HU) of metallic and electrical components of implantable electronic devices, since they are directly transferred as density values to the TPS.

Material and Methods: The scanning volume is composed of an acrylic water tank filled with water. A water equivalent solid state slab phantom, made of a white polystyrene material (RW3), was positioned within the water tank. The testing objects were embedded and fixed between two RW3 slabs, separated by two thin acrylic blocks. Four RW3 slabs were set under the object to account for the backscattering coming from the patient table.

The following objects were used for CT-acquisition: a cardioverter-defibrillator (IPG), common components of active implants, such as a lithium battery, an epoxy circuit board, a Shottky diode and a microprocessor made of carbon and silicon, metallic discs made of copper and an implant titanium case.

A conventional CT-value interval of -1024 to +3071 HU, which is used in CT-acquisition for treatment planning, allows the proper representation of the human body tissue. However, high-density materials, which exceed the conventional range, are often set to the highest HU thus limiting the accuracy of dose calculations within TPS. A SIEMENS SOMATOM Definition Flash Dual Source CT system with two selectable ranges; the conventional and an extended CT-scale ranging from -10240 to +30710 HU were used to obtain Hounsfield units. In order to distinguish between the different implant components defined by their densities each component was scanned separately by the two CT-scales.

Results: The HU values determined with a clinical DICOM viewer are summarized in Tab. 1. The HU values of implant materials are underestimated within a conventional CT scale, even though the values measured within an extended scale do not exceed its upper limit, as it is seen for the *titanium disc, case* and for the *circuit board*. If the density value exceeds the conventional range the value is set to the highest HU (e.g. *copper disc*).

Tab. 1: Materials of implantable electronic devices at a conventional and extended HU scale

Test objects	HU (conventional scale) [HU]	HU (extended scale) [HU]
titanium disc	1756 ± 31	2203 ± 313
titanium case	1507 ± 82	2321 ± 381
copper disc	3070 ± 1	5356 ± 413
battery	3066 ± 13	2617 ± 272
diode	3069 ± 18	3591 ± 416
microprocessor	2821 ± 217	3568 ± 585
circuit board	124 ± 20	550 ± 86

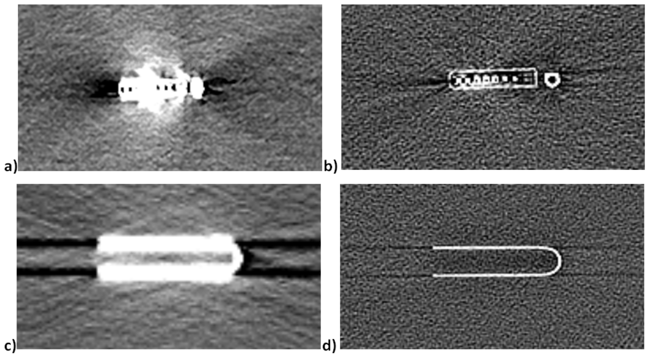

Fig. 1 CT image reconstructions of an IPG (top) and a titanium implant case (bellow) comparing CT acquisition with a conventional (left) and an extended HU scale (right)

Figure 1 compares two cross sectional images through an IPG and a titanium implant case. CT-acquisitions with the conventional HU scale are shown on the left hand side while acquisitions on the extended HU scale are shown on the right hand side. The inner part of the implant is well seen in picture in fig. 1b). The electrical components are distinguishable by HU values of the material and comparable to the values in Tab.1. Artefacts seen in fig. 1b) and d) are smaller compared to fig.1a) and c). In addition, the object geometry shows higher reconstruction accuracy in fig. 1b). and d).

Discussion and Conclusion: The material composition of some components such as the battery and diode can be well distinguished within an extended scale, while the CT-acquisition of these at a conventional HU scale are fully blended by the housing material with higher density. In conclusion, a CT-acquisition with an extended HU scale is a far more beneficial approach for dose calculations with a TPS in radiotherapy treatments.

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