ESTRO MOBILITY GRANT (TTG) REPORT

Title of the report: Dual energy perfusion CT development

HOST INSTITUTE: ,
MAASTRO Clinic, Maastricht, The Netherlands

DATE OF VISIT:

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Computed tomography (CT) perfusion assesses temporal changes in attenuation tissue material by acquiring a series of rapid scans following the administration of an iodinated contrast agent. There has been a rising interest in the use of CT perfusion as a prognostic imaging biomarker(1)(1). Despite the recent advances in CT detector and reconstruction methods, the iodine signal enhancement range in tissues remains relatively small due to the inherent low sensitivity of single energy CT (SECT) in differentiating between iodine, bone, and other materials. Dual energy CT's (DECT) material decomposition capabilities allow for better differentiation between iodine and other materials. Furthermore, parameterizing the response of the CT scanner specifically to iodine can improve the dynamic signal range hence improving detectability. By combining DECT's material differentiation, iodine parameterization, and CT perfusion, it is possible to develop a Dual Energy Perfusion CT (DEPCT) scanning technique to overcome the current limitations and improve the accuracy of imaging-derived pharmacokinetic parameters.

At the Princess Margaret Cancer Centre, we acquired static dual and single energy scans of a phantom containing various concentrations of iodinated contrast agent (2) to calculate stoichiometric parameters for derivation of Z_{eff} (effective atomic number) for each concentration. Following this, I headed over to MAASTRO Clinic at the start of this summer, where I was kindly hosted by Prof. Frank Verhaegen and his team, to learn more about their spectral modelling and dual energy material decomposition methods. This group has widely published on DECT for brachytherapy and proton planning purposes. We investigated the possibility of treating different levels of contrast enhancement at different time points during perfusion scanning as different "tissues" and applied Landry's fitting algorithms. Additionally, we discussed possible ways of improving and optimizing stoichiometric calibration to improve its response to iodine concentrations.

SpekCalc software, developed by the MAASTRO group models the scanner's x-ray spectra. Using this software allows for a spectral approach to calculating Z_{eff} and relative electron density, leading to more accurate estimates of iodine concentrations in phantoms. Moreover, the fitting method for calculating Z_{eff}, developed by Landry *et al.* from Prof. Verhaegen's lab, takes into account the contributions from different interaction cross-sections, an important feature when considering high atomic number elements such as iodine in contrast agents (3). Additionally, spectral modelling can lead to improved stoichiometric calibration methodology through the introduction of appropriate spectral weighting functions.

Based on these concepts, the goal of this grant was to enable modeling of our intra-operative Siemens Somatom FLASH dual energy scanner and use different material decomposition and calibration methods to derive Z_{eff} and ρ_e (relative electron density) maps of iodine concentrations. These goals were successfully met and more. We found that incorporating these methods in the development of the dual energy perfusion CT protocol results in more accurate iodine quantification, thus significantly decreasing the uncertainty in estimations of iodine concentrations compared to the uncertainty observed in single energy CT. This reduction was highest in lower concentrations of iodine, which are especially relevant in clinical settings. In addition, it was shown that incorporating the high- and low-energy x-ray spectra in stoichiometric calibration process leads to scanner-specific parametrization, resulting in a more robust methodology and subsequently more reliable stoichiometric parameters. These maps of Z_{eff} for clinically relevant iodine concentrations will now be used to redefine the contrast enhancement curves with respect to Z_{eff} with the goal of obtaining statistically significant improvement in dynamic range compared to ρ_e.

1. Coolens C, Driscoll B, Moseley J, et al. Feasibility of 4D perfusion CT imaging for the assessment of liver treatment response following SBRT and sorafenib. Adv Radiat Oncol. 2016;1(3):194-203.

2. Driscoll B, Keller H, Coolens C**.** Development of a dynamic flow imaging phantom for dynamic contrast-enhanced CT. Med Phys. 2011;38(8):4866-80.

3. Landry G, Reniers B, Granton PV, et al. Extracting atomic numbers and electron densities from a dual source dual energy CT scanner: experiments and a simulation model. Radiother Oncol. 2011;100(3):375-9.