Development of CT Scanner Models for Patient Organ Dose Calculations Using Monte Carlo Methods

by

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ABSTRACT

There is a serious and growing concern about the CT dose delivered by diagnostic CT examinations or image-guided radiation therapy imaging procedures. To better understand and to accurately quantify radiation dose due to CT imaging, Monte Carlo based CT scanner models are needed. This dissertation describes the development, validation, and application of detailed CT scanner models including a GE LightSpeed 16 MDCT scanner and two image guided radiation therapy (IGRT) cone beam CT (CBCT) scanners, kV CBCT and MV CBCT. The modeling process considered the energy spectrum, beam geometry and movement, and bowtie filter (BTF). The methodology of validating the scanner models using reported CTDI values was also developed and implemented. Finally, the organ doses to different patients undergoing CT scan were obtained by integrating the CT scanner models with anatomically-realistic patient phantoms. The tube current modulation (TCM) technique was also investigated for dose reduction. It was found that for RPI-AM, thyroid, kidneys and thymus received largest dose of 13.05, 11.41 and 11.56 mGy/100 mAs from chest scan, abdomen-pelvis scan and CAP scan, respectively using 120 kVp protocols. For RPI-AF, thymus, small intestine and kidneys received largest dose of 10.28, 12.08 and 11.35 mGy/100 mAs from chest scan, abdomen-pelvis scan and CAP scan, respectively using 120 kVp protocols. The dose to the fetus of the 3 month pregnant patient phantom was 0.13 mGy/100 mAs and 0.57 mGy/100 mAs from the chest and kidney scan, respectively. For the chest scan of the 6 month patient phantom and the 9 month patient phantom, the fetal doses were 0.21 mGy/100 mAs and 0.26 mGy/100 mAs, respectively. For MDCT with TCM schemas, the fetal dose can be reduced with 14%-25%. To demonstrate the applicability of the method proposed in this dissertation for modeling the CT scanner, additional MDCT scanner was modeled and validated by using the measured CTDI values. These results demonstrated that the CT scanner models in this dissertation were versatile and accurate tools for estimating dose to different patient phantoms undergoing various CT procedures. The organ doses from kV and MV CBCT were also calculated. This dissertation finally summarizes areas where future research can be performed including MV CBCT further validation and application, dose reporting software and image and dose correlation study.