Developing software to optimize organ doses depending on image quality for scanographic imaging

Abstract

Due to the significant rise of computed tomography (CT) exams in the past few years and the increase of the collective dose due to medical exams, dose estimation in CT imaging has become a major public health issue. However dose optimization cannot be considered without taking into account the image quality which has to be good enough for radiologists. In clinical practice, optimization is obtained through empirical index and image quality using measurements performed on specific phantoms like the CATPHAN. Based on this kind of information, it is thus difficult to correctly optimize protocols regarding organ doses and radiologist criteria. Therefore our goal is to develop a tool allowing the optimization of the patient dose while preserving the image quality needed for diagnosis.

The work is divided into two main parts: (i) the development of a Monte Carlo dose simulator based on the PENELOPE code, and (ii) the assessment of an objective image quality criterion. For that purpose, the GE Lightspeed VCT 64 CT tube was modelled with information provided by the manufacturer technical note and by adapting the method proposed by Turner et al (Med. Phys. 36: 2154-2164). The axial and helical movements of the X-ray tube were then implemented into the MC tool. To improve the efficiency of the simulation, two variance reduction techniques were used: a circular and a translational splitting. The splitting algorithms allow a uniform particle distribution along the gantry path to simulate the continuous gantry motion in a discrete way. Validations were performed in homogeneous conditions using a home-made phantom and the well-known CTDI phantoms. Then, dose values were measured in CIRS ATOM anthropomorphic phantom using both optically stimulated luminescence dosimeters for point doses and XR-QA Gafchromic films for relative dose maps. Comparisons between measured and simulated values enabled us to validate the MC tool used for dosimetric purposes. Finally, organ doses for several acquisition parameters into the ICRP 110 numerical female phantoms were simulated in order to build a dosimetric data base which could be used in clinical practice.

In parallel to this work, image quality was first studied using the CATPHAN 600. From the CTP 404 inserts, the signal-to-noise ratio (SNR) was then computed by using the classical Rose model (J. Opt. Soc. Am. A 16:633-645). An extensive number of images, linked to several acquisitions setups, were analyzed and SNR variations studied. Acquisitions with a SNR closed to the Rose criterion were selected. New acquisitions, based on those selected, were performed with a pre-clinical phantom containing suspect structures in PMMA. These images were presented to two senior radiologists. Both of them reviewed all images and indicated if they were able to locate the structures or not using a 5 confidence levels scale.

Two ROC curves were plotted to compare the detection ability if the bead was detectable ($SNR > 5$) or not. Results revealed a signi_cant di_erence between the two types of image and thus demonstrated the Rose criterion potential for image quality quantification in CT. Ultimately, organ dose estimations were linked to SNR values through acquisition parameters.

Preliminary results proved that an optimization can be performed using the Rose criterion and organ dose estimation, leading to a dose reduction by a factor up to 6.