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A Comprehensive Clinical Decision Support Application Software for dose Optimisation Procedure in CT

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ABSTRACT

CT images are the most common imaging modality after conventional X-ray imaging. There are used in order to determine organ position, location and size in relation to treatment area for treatment planning and for diagnoses of diseases. The general aims of the study is to design a comprehensive clinical decision support application software for patients' dose optimization. The design of the GUI involve the use of mathematical modeling procedure where the modeled equations reduces the data from empirical measurements to real clinical application process for implementation. The final component of the modeling process is the GUI applications. This was done in two different process and procedures. The first was the coding process where a software was developed with written C++ code and integrated on the data capturing application platform for clinical application. The second was the visual indicators where the shape and size were modeled to represent the variation in age and gender that exist between the various model equations. The GUI are then used by radiographers to predict and plan the choice of input parameters for effective managements of doses to patient undergoing abdominal CT examination. Finally, a GUI and CAD models were designed to adequately reflect the comfortable working process of all the mathematical model equations. Reference effective abdominal and renal dose parameters have been established and developed in a data base for clinical application. In addition, the displayed interface on the DICOM interface enable the prediction of CTDI and DLP parameters with known kVp and mAs parameters before imaging.

Keywords: kVp, mAs, Renal Dose, Effective Dose, CTDI, DLP and DICOM

I. INTRODUCTION

Medical imaging is described as the method for noninvasive assessment of physiological and anatomical information about human tissues or organ [1]. For this reason medical imaging is used to accurately and timely diagnose health problems, allowing for a more effective treatment of patients. It can thus be used to test the effective remedies and evaluate the effects of treatments for specific diseases [2]. Due to its effective use it gradually replacing most laboratory chemical assessment of human body for clinical pathological condition. This is because, over the past 20 years the world has seen the emergence of several medical imaging modalities like, Fluoroscopy, CT, SPECT and PET [3, 4].

Furthermore, apart from the most widely diagnostic use, medical imaging also plays a crucial role in cancer control and management process. Without medical imaging tools such as CT, and wherever affordable in combination with PET (PET-CT) or SPECT (SPECT-CT), the implementation of cancer control programs will not meet the standard of practice of clinical oncology. This is essential for successful treatment of patients' which are based on CT images in order to determine organ position, location and size in relation to treatment area for treatment planning. Indeed, CT is an imaging modality that is part of many current projects in radiotherapy and nuclear medicine, which make use of various reference organ model design as part of treatment planning application software [5]. Unfortunately however, the measurements, analysis and diagnostic assessments of these organ models varied base on race, gender and age variations. Therefore, there is the need to design a local based organ models and CT dose reference levels in order to address clinical diagnostic challenges and radiation protection issues caused by the increasing use of CT in Ghana.

Even though the beneficiary of these increase use of CT are mainly the patients, there is the need to establish a tradeoff between these benefits and the high potential biological effects due to exposure to ionizing radiation with high prognostic challenges [5, 6, 7]. This is because based on the BEIR VII report, which states that cancer is the primary risk associated with exposure to ionizing radiation [8]. In addition, approximately 1 in 1,000 individuals will develop cancer from an exposure of 10 mSv [8]. Even though, this risk level is relatively small in comparison to approximately 420 out of 1,000 individuals expected to develop cancer from all other causes combined [8]. There is the need to create awareness and provide enough information for clinicians and patients for all form of ionizing radiation imaging procedure, including CT. This is essential because of the stochastic nature of cancer development from low dose radiation, regardless of the etiological process, with a latent period of 10-20 years or more [8]. Hence, the need to improve dose optimization procedures of patients' exposure parameters in relation to recommended exposure and DRLs set up by the various institutions [5, 6]. Through the design and implementation of comprehensive optimization procedures, which would protect patients, clinicians and the general public.

A. Objectives

The general aims of the study is to design a comprehensive clinical decision support application software for patients dose optimization procedures without loss of acceptable and allowable image quality during abdominal CT scan. This will provide a baseline for radiographers and technologist during their decision making processes in setting up acquisition parameters (kVp, mAs) for dose optimisation. In addition, the study also make available processes and procedures that will improve radiation protection requirements through effective use of kVp, mAs and the resultant exposure parameters ($CTDI_{VOL}$ and DLP) for dose and dose optimization of patient protection in clinical environment during abdominal CT examination.

B. Basic Principles

In clinical environment working process is made easier and comfortable using a design **GUI.** This enable an adequate graphical display of a design model, in order to develop a final product of user interactions. The aim of this is to demonstrate the functionality of the developed model and the applicability of the user interface in clinical environment. For instance the **GUI** of a modeled input parameters like kVp and mAs will enable better assessment and prediction of dose parameters before imaging. Where in the clinical environment only the input parameters are required to be determined by radiographers and estimated the output parameters such and DLP values before imaging as generated by the user interface as shown. This is to demonstrate the functionality of the developed model and the applicability of the **GUI** in clinical environment [9].

A major part of clinical decision-making involves the analysis of a finite set of alternatives described in terms of evaluative criteria. Then the task might be to rank these alternatives in terms of how attractive they are to the decision-maker(s) when all the criteria are considered simultaneously. Another task might be to find the best alternative or to determine the relative total priority of each alternative (for instance, if alternatives represent projects competing for funds) when all the criteria are considered simultaneously. Solving such problems is the focus of multiple-criteria decision analysis (MCDA). This area of decision-making, although very old, has attracted the interest of many researchers and practitioners and is still highly debated as there are many MCDA methods which may yield very different results when they are applied on exactly the same data [2]. This leads to the formulation of a decision-making paradox.

Logical decision-making is an important part of all science-based professions, where specialists apply their knowledge in a given area to make informed decisions. For example, medical decision-making often involves a diagnosis and the selection of appropriate treatment. But naturalistic decision-making research shows that in situations with higher time pressure, higher stakes, or increased ambiguities, experts may use intuitive decision-making rather than structured approaches. They may follow a recognition primed decision that fits their experience and arrive at a course of action without weighing alternatives. Based on these analysis the availability of decision support software is essential in minimising errors and maximising accuracy.

II. METHODS AND MATERIAL

A. Material

Figure 1. CT Scanner

Figure 3. Imaging Procedure

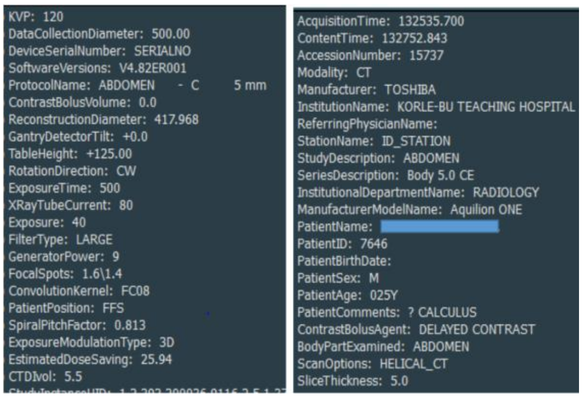

Figure 3. Image data

B. Methodology

The design of the GUI involve the use of mathematical modeling procedure where the modeled equations reduces the data from empirical measurements to real clinical application process for implementation [10]. These were done using two modeling techniques including: experimental analytical modeling technique where the equations were design and the CAD modeling technique, where the established equations were converted into int GUI for clinical application. Both models were designed from the acquired data of kVp and mAs with the resultant CTDI and DLP. The effect of these parameters on abdominal tissues especial the renal tissues has been modeled to predict future dose parameters. That is with careful chosen values of kVp and mAs CTDI and DLP. In addition, the experimental analytical modeling technique was used to model the relationship between these parameters and internal organ parameters for initial clinical assessment for further action.

Furthermore, the procedure involve the use of mathematical regression analysis to determine the mathematical relationship between kVp and mAs as input parameters and CTDI and DLP as the output parameters. Furthermore, the idea of linear regression equation predictor was use to modeled the relationship between CTDI and DLP as input parameters and renal and effective dose as output parameters in the form of the model equation predictor.

C. Computer Aided Design Model

The final component of the modeling process is the GUI applications. This was done in two different process and procedures. The first was the coding process where a software was developed with written C++ code and integrated on the data capturing application platform for clinical application. The second was the visual indicators where the shape and size were modeled to represent the variation in age and gender that exist between the various model equations.

The codification process involve written codes with C++ and then integrate the code on the capturing application platform. This was done by converting the mathematical representation into GUI in a text-based user interface which is applicable in clinical environment. This serve as an input interface for the nurses as appropriate input parameters for initial control measure). The visual indicators was done on the application platform to assist visualized the deviation or otherwise of the m4asured parameters. This allowed direct manipulation of the data during clinical application.

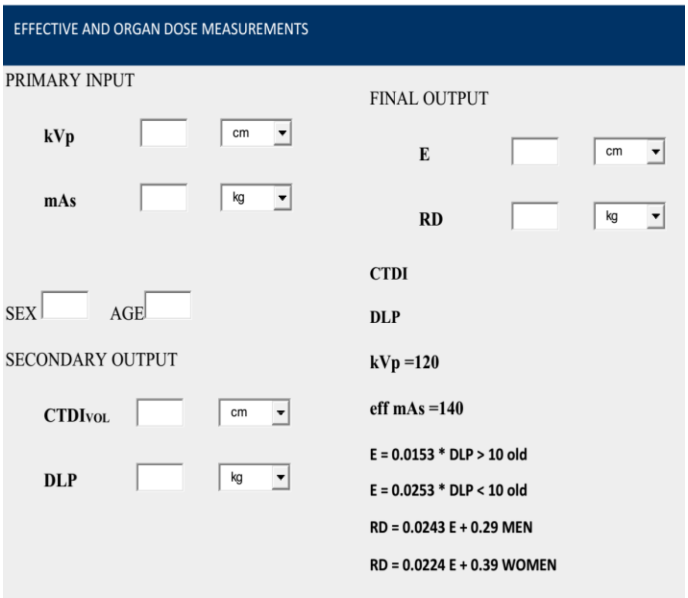

Figure 4. Application software

Modeled Equations

kVp =120

eff mAs =140

$CTDI_{VOL} = \frac{1}{P} CTDI_W$

$DLP = CTDI_{VOL} * L$

E = 0.0153 * DLP > 10 old

E = 0.0253 * DLP < 10 old

RD = 0.0243 E + 0.29 MEN

RD = 0.0224 E + 0.39 WOMEN

III. ANALYSIS AND DISCUSIONS

The Radiology Information System GUI is use to assess all general patients information while a more specific GUI written with specific object-oriented programming language was designed to assess specific information about individual patients dose management. This interface are displayed using C++ on MVL application platform and integrated on the DICOM reader for use by the radiologist and radiographers during the decision making process [11].

Finally, a GUI and CAD models were designed to adequately reflect the comfortable working process of all the mathematical model equations. Reference effective abdominal and renal dose parameters have been established and developed in a data base for clinical application. In addition, the displayed interface on the DICOM interface enable the prediction of CTDI and DLP parameters with known kVp and mAs parameters before imaging. That, the radiographers input display interface are also design to capture dose parameters in relation to mAs and kVp and the expected CTDI and DLP values. These parameters were used to estimate renal and effective dose. The design display interface enable the prediction of renal dose together with effective dose as shown in equation 4.8M for male and 4.8F for females. This method is intended to be used to predict the expected estimate of radiation dose to patients and to optimize the radiation dose in relation to image quality before imaging. This has become extremely useful as the study shows that approximately 1 in 1,000 patients will develop cancer from an average exposure of 14.09 mSv. This is based on the BEIR VII report [5] which put the development of cancer from an average exposure to approximately 10 mSv. This developed software will help reduced dose to patients undergoing abdominal CT imaging.

IV. CONCLUSION

The developed software from the modeled equations can adequately and accurately be used to predict individual renal and effective dose parameters for clinical application. With confident level of 95% for dose optimisation procedures. The software has been made available for use during abdominal CT examination. These equations has been converted to text-based graphic user interface and visual indicator for use by radiologist and radiographers. To address image optimisation processes and improve accuracy in image analysis and reporting.

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