Design and Testing of the VirtualDose Software under the Software as a Service (SaaS) Platform for Tracking and Reporting CT Doses

Introduction and Innovation

The potential health risk to patients undergoing computed tomography (CT) examinations has led to an increasing level of attention from the radiology and regulatory communities [1,2]. An accurate and easy-to-use dose reporting software is an essential tool in managing CT exposures. However, most existing packages, such as ImPACT, ImpactDose, CT-Dose and CT Expo are based on crude patient anatomy and ignore pediatric, obese and pregnant patients. When compared with advanced voxel, NURBS and mesh phantoms, the stylized phantoms result in significantly dose discrepancies up to 100% in certain cases [3]. Many existing software needs to be updated for tissue weighting factors in effective dose calculations using the recent ICRP 103 recommendations [4] or for the latest multi-detector CT (MDCT) scanners. Finally, all these said software packages are based on very old programming features, including one package that is entirely based on spreadsheet. This paper describes the efforts to develop a modern VirtualDose Software as a Service (SaaS) platform for tracking and reporting the organ doses and effective doses to patients undergoing CT examinations. **Innovation:** a comprehensive library of patient phantoms of different ages, genders, and body weights; SaaS software mode for maximum user access and easy software update.

Material and Methods

A detailed database of organ doses was established from a large number of Monte Carlo simulations involving CT scanner models and anatomically realistic patient phantoms using the MCNPX v2.6 code [5]. CT scanners by the GE, Philips, Siemens and Toshiba operated at different tube voltages (80kVp, 100kVp, 120kVp and 140kVp) have been systematically taken into consideration. Detailed CT scanner X-ray sources and bowtie filter geometry are also modeled by an iterative method in the Monte Carlo simulations. A set of previously developed BREP- or mesh-based phantoms is included, covering 50th percentile of adults and children at different ages as well as a pregnant female at three gestational stages. A new set of BMI-adjustable obese patient phantoms was also included. These BREP-based phantoms were adjusted to match ICRP parameters before being converted to voxel geometry in the MCNPX code for organ dose calculations.

To estimate the effective dose easily, all the related organ doses are incorporated into a database compiled using Microsoft SQL server 2008. Combined with the additional knowledge of the scanner parameters, including the axial scan range, the scan pitch, the tube current and scanning time in milliamp-seconds (mAs), the tube voltage in the kilovolt peak (kVp), the software package embedded with this dataset would be a helpful and comprehensive tool for evaluating the radiation risk to which the patient is subject. All these information can be used directly to roughly estimate the effective dose patients received from the CT exams. The patient and scan parameter information stored in the DICOM file can be automatically retrieved and imported into “VirtualDose” to calculate the organ dose and effective dose for specific patients. “VirtualDose” is designed as a Software as a Service (SaaS) platform to allow as many users as possible to access it at the same time via Internet, as shown in Figure 1. SaaS is a new software distribution mode and typically provides a web-based software application to a big account of client users. Unlike the traditional software, SaaS does not require the installation of the software on user’s personal computers. A new “Service-Orientated Architecture (SOA)” software developing pattern is adopted in designing and building the whole software architecture, as shown in figure1. The entire software framework was developed using Microsoft .NET platform. Windows Communication Foundation (WCF) technology is used in the software development. C# was used as the primary programming language in the development of the graphical user interface (GUI) and all the WCF service were implemented in C#. The GUI is designed to allow a user to specify the patient type, body scanning region, and various scanner operating parameters. Using the object-oriented programming technology, 3D phantoms are displayed interactively to improve the user interaction with the software functions. Organ and effective doses are rapidly archived and reported in the GUI according to the user-specified protocols.

Results

Figure 2 summarizes the software features. The software program offers a modern GUI through which a phantom is chosen by a user and is displayed in an interactive 3D rendering mode. A user can also specify the scanner type and scanning parameters. The following default scanning protocols can be selected from a pull-down menu: head, neck, chest, abdominal, kidney and pelvis. Alternatively, the scanning range can be manually specified on the phantom using object-oriented programming. This new
software is able to interactively display the organ of interest using object-oriented programming and 3D surface rendering. Dosimetry capabilities for tube current modulation (TCM) protocols are included in the current version of the software by integrating a dose information extraction function module. This function module could automatically connect the DICOM server and extract dose (e.g., CTDI, DLP, etc.), CT scanner (e.g., scanner style, kVp, mAs, scan region, scan protocol, etc.) and patient (Weight, age, gender, etc.) information from the DICOM files. These patient and scan parameter information can then automatically be imported into “VirtualDose” to calculate the organ dose and effective dose for the specific patients. The GUIs are considerably better than those in the existing packages. Furthermore, the biggest improvement is in the comprehensive organ and effective dose database that can be rapidly archived and reported. Effective dose values were calculated using both the ICRP-60 and ICRP-103 tissue-weighting coefficients for easy comparison. The organ dose estimates can be different by a ratio ranging from 0.77 to 1.24 for the organ or tissue covered in the scan range, and 0.13 for the organ out of the scan region between our calculations using the anatomically realistic phantoms and those derived from the stylized MIRD-type phantoms. The Tube Current Modulation schemes can reduce the dose by around 20% for pregnant patient phantoms. The new developed morbidly obese phantom was found to have CT organ doses on average a factor of 0.76 times smaller than that of the normal weight phantom for the same tube current setting because of shielding by the extra fat.

**Conclusion**

VirtualDose is a new software platform for tracking and reporting CT dose that improves upon existing software. The preliminary results show a number of attractive GUI design and reporting features. The SaaS design allows as many users as possible to access it simultaneously via Internet without having to install the software locally. A user can interactively and visually specify a number of parameters for the arbitrary scan protocols. Accurate organ dose data afforded by anatomically realistic phantoms are expected to improve both the accuracy and usability in CT dose reporting in the future.

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**References**