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Dose reduction with iterative reconstruction: Optimization of CT protocols in clinical practice

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KEYWORDS
Multidetector CT;
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Dose reduction;
Image quality;
Patient safety

Abstract
Objectives: To create an adaptable and global approach for optimizing MDCT protocols by evaluating the influence of acquisition parameters and Iterative Reconstruction (IR) on dose reduction and image quality.
Materials and methods: MDCT acquisitions were performed on quality image phantom by varying kVp, mAs, and pitch for the same collimation. The raw data were reconstructed by FBP and Sinogram Affirmed Iterative Reconstruction (SAFIRE) with different reconstruction kernel and thickness. A total of 4032 combinations of parameters were obtained. Indices of quality image (image noise, NCT, CNR, SNR, NPS and MTF) were analyzed. We developed a software in order to facilitate the optimization between dose reduction and image quality. Its outcomes were verified on an adult anthropomorphic phantom.
Results: Dose reduction resulted in the increase of image noise and the decrease of SNR and CNR. The use of IR improved these indices for the same dose without affecting NCT and MTF.

Abbreviations: CNR, Contrast-to-Noise Ratio; CTDI, Computed Tomography Dose Index; DRL, Diagnostic Reference Levels; FBP, Filtered Back Projection; FOV, Field-Of-View; IR, Iterative Reconstruction; LDPE, Low-Density PolyEthylene; LSF, Line Spread Function; MDCT, Multi-Detector Computed Tomography; MTF, Modulation Transfer Function; NCT, CT Number; NPS, Noise Power Spectrum; PSF, Point Spread Function; ROI, Region Of Interest; SAFIRE, Sinogram Affirmed Iterative Reconstruction; SNR, Signal-to-Noise Ratio; VBA, Visual Basic Application.

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The image validation was performed by the anthropomorphic phantom. The software proposed combinations of parameters to reduce doses while keeping indices of the image quality adequate. We observed a CTDIvol reduction between −44% and −83% as compared to the French diagnostic reference levels (DRL) for different anatomical localization.
Conclusion: The software developed in this study may help radiologists in selecting adequate combinations of parameters that allows to obtain an appropriate image with dose reduction.

Introduction

Due to a growing demand of computed tomography (CT) examinations, patients are being exposed more frequently to ionizing radiation [1]. To address this increasing medical/clinical requirement, health care professionals are asked to strengthen the rationale for examinations and to optimize practices and procedures. The optimization is achieved by simultaneously managing the dose level and the image quality [2,3]. Changes in the parameters of the image acquisitions can be arranged to reduce the dose delivered to patients but this causes a deterioration of the image quality [4].

Recent advances in iterative reconstruction (IR) methods of MDCT images have provided a reliable and alternative method for optimizing the ratio between the dose and the image quality. These methods consist in post-processing mathematical approaches that allow us to correct raw data by reducing image noise without changing the transverse spatial resolution [5,6]. Several studies have demonstrated that it is possible to maintain satisfactory image quality with dose reduction [7—19]. However, the dose reduction is usually a medical judgment and the gain in the image quality obtained by IR needs to be quantified. Those studies evaluated intra-group comparison with optionally chosen acquisition and reconstruction parameters. Moreover, dosimetric and qualitative analyses were made a posteriori.

The purpose of this work was to define an adaptable and global approach for optimizing MDCT protocols by evaluating the influence of acquisition parameters, SAFIRE on dose reduction and image quality by using the phantom Catphan 500 and an anthropomorphic phantom. We developed a software in order to facilitate the optimization between dose reduction and image quality.

Materials and methods

MDCT protocol

Images were acquired on a MDCT SOMATOM Definition AS + (Siemens, Erlangen, Germany) with floating diaphragm on the 3 axes allowing to obtain a collimation of 128 × 0.6 mm from an array of 64 detectors 0.6 mm. Raw data were reconstructed using two procedures: Filtered Back Projection (FBP) and Sinogram Affirmed Iterative Reconstruction (SAFIRE). The latter uses two corrections loops, which are applied on the raw data and on the image data with five iteration levels (S1 to S5) respectively [16,20].

Phantom Quality Image

A Catphan 500 phantom (The Phantom Laboratory, Salem, USA) was used to assess the quality of image based on the acquisition parameter and the levels of SAFIRE. Three sections of the phantom (CTP 401, CTP 486 and CTP 528a) were studied. The CTP 401 section is composed of four inserts of distinct densities. Each section aims to assess both signal (CT Number (NCT)) and image noise in the Air (−1000 HU), in Low-Density PolyEthylene (LDPE, −100 HU), in Acrylic (120 HU) and in Teflon (950 HU).

The CTP 486 section consists of a uniform section for measuring NCT and image noise of a material that owns density close to the water, (20 HU). Finally, the CTP 528a section is used to assess the transverse spatial resolution by the computing the Modulation Transfer Function (MTF).

Standardized method for acquisition and reconstruction parameters

Raw data were collected and reconstructed according to the parameters presented in Table 1. These parameters are available on the MCDT and include five levels of iteration in SAFIRE (S1 to S5). Overall, 4032 combinations of parameters were obtained.

Dosimetry

For each acquisition Computerized Tomography Dose Index volume (CTDIvol) was measured with the dosimetry phantom body (The Phantom Laboratory, Salem, USA) with 32 cm of diameter and a pencil ionization chamber of 10 cm. The ionization chamber and the multimeter were calibrated according to an accredited laboratory (Swedish Board for Conformity Assessment and Accreditation 2035 ISO/IEC/17025).

Physical metrics

Except for Noise Power Spectrum (NSP), data were analyzed with the CTP module software Qualimagiq (QUALIFORMED,