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ORIGINAL PAPER

Evaluation of a commercial Model Based Iterative reconstruction algorithm in computed tomography

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ABSTRACT

Introduction: Iterative reconstruction algorithms have been introduced in clinical practice to obtain dose reduction without compromising the diagnostic performance.
Purpose: To investigate the commercial Model Based IMR algorithm by means of patient dose and image quality, with standard Fourier and alternative metrics.
Materials and methods: A Catphan phantom, a commercial density phantom and a cylindrical water filled phantom were scanned both varying $CTDI_{vol}$ and reconstruction thickness. Images were then reconstructed with Filtered Back Projection and both statistical (iDose) and Model Based (IMR) Iterative reconstruction algorithms.

Spatial resolution was evaluated with Modulation Transfer Function and Target Transfer Function. Noise reduction was investigated with Standard Deviation. Furthermore, its behaviour was analysed with 3D and 2D Noise Power Spectrum. Blur and Low Contrast Detectability were investigated.

Patient dose indexes were collected and analysed.
Results: All results, related to image quality, have been compared to FBP standard reconstructions.

Model Based IMR significantly improves Modulation Transfer Function with an increase between 12% and 64%. Target Transfer Function curves confirm this trend for high density objects, while Blur presents a sharpness reduction for low density details.

Model Based IMR underlines a noise reduction between 44% and 66% and a variation in noise power spectrum behaviour. Low Contrast Detectability curves underline an averaged improvement of 35–45%; these results are compatible with an achievable reduction of 50% of $CTDI_{vol}$.

A dose reduction between 25% and 35% is confirmed by median values of $CTDI_{vol}$.
Conclusion: IMR produces an improvement in image quality and dose reduction.

1. Introduction

Currently different typologies of iterative reconstruction (IR) techniques are used in computed tomography (CT). CT vendors propose IR technology to reduce image noise, thus improving the image quality at lower dose levels. So far, regarding the use of IR no exhaustive guidelines have been published. Several papers have presented the physical characterization of CT images, reconstructed with classical Filtered Back Projection (FBP), statistical iterative (SIR) and Model Based Iterative (MBIR) methods [1].

SIR iterative processing is performed, generally, in both projection and image domains. The reconstruction algorithm starts with the projection data, where it identifies and corrects the noisiest CT measurements. Each projection is examined using a model that includes the true photons statistics. Thus, noisy data is penalized and edges are retained, both ensuring a significant noise reduction and preserving spatial resolution.

MBIR reconstruction is an optimization process that takes into account data statistics, image statistics, and detailed CT system geometry. The system model deals with the nonlinear, polychromatic nature of X-ray spectrum by modelling the photons in the measured data set. The statistical noise model considers the size of an X-ray tube focal spot and the shape of detectors.

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Both SIR and MBIR can be used with different reconstruction levels of strength. Images obtained with these algorithms are produced combining a pure iterative reconstruction with a standard filtered back projection. Reconstruction level represents the proportion of iterative used to obtain the final images.

Nowadays radiologists' approach in evaluating the image quality improvements mainly consists in measuring the Hounsfield number and the standard deviation (SD) of a Region of Interest (ROI) in quite uniform anatomical region; Nevertheless, in using the SD as a figure of merit, with filters the SD can be reduced at the cost of a spatial resolution degradation.

The easiest way to estimate image noise is by measuring the standard deviation (SD) of a Region of Interest (ROI) in a slice of a uniform phantom. This approach provides no information regarding the spectral noise distribution and does not account for the observer perception of noisy images. Fourier analysis was applied to noise characterization and spatial resolution, calculating both the Noise Power Spectrum (NPS) and the Modulation Transfer Function (MTF) [2]. Unfortunately, IR algorithms generally involve operations resulting in nonlinear processing. Because of the correlation involved in the reconstruction process, noise is texture and non-stationary [3], thus NPS metric should be applied cautiously.

Furthermore, the non-linearity of these algorithms leads to a dependency of resolution from contrast [3]. The standard MTF metric, based on an MTF estimation with a high Z metal pin object, yields to an overestimation of IR images resolution properties [4]. Therefore, Target Transfer Function (TTF) analysis for different contrast objects may be adopted to study IR algorithms [4].

In this paper IR image quality features are evaluated with both standard and modified Fourier metric. A Blur metric [5] was applied to estimate the spatial resolution properties. To evaluate Low Contrast Detectability (LCD) a statistical method was employed to characterize noise amount and texture [6].

The aim of the present study is to find an easy way to quantify the radiologist feeling with IR images, in terms of perception of texture noise and blurring.

Dosimetric indexes and dose reduction percentage are also reported.

2. Materials and methods

A 256 slices Philips Brilliance Elite iCT was employed in this study. Images were reconstructed by means of FBP, statistical IR algorithm such as iDose4 and IMR, i.e. the MBIR algorithm by Philips Medical System.iDose4 algorithm may be applied with all the reconstruction filters commonly employed for FBP and choosing seven different reconstruction levels.

FBP standard body (FBP B) filter has been investigated for body examinations while Standard Brain UB filter (FBP UB) have been considered for brain CTs. Different levels of iDose IR have been analysed too.

Considering body exams, IMR reconstruction algorithm can be used with three different filters: SoftTissue, Routine and SharpPlus; they are suggested for parenchyma, iodine contrast media examination and bone reconstruction, respectively.

For brain investigations, BrainRoutine, BrainSharp and BrainSharpPlus were employed. BrainRoutine is designed for brain examinations, BrainSharpPlus for bone and high resolution examination while BrainSharp is a good compromise for parenchyma and bone investigations.

Each IMR filter can be used with three reconstruction levels.

The effect of this new class of reconstruction algorithm was evaluated in terms of image quality and patient dose.

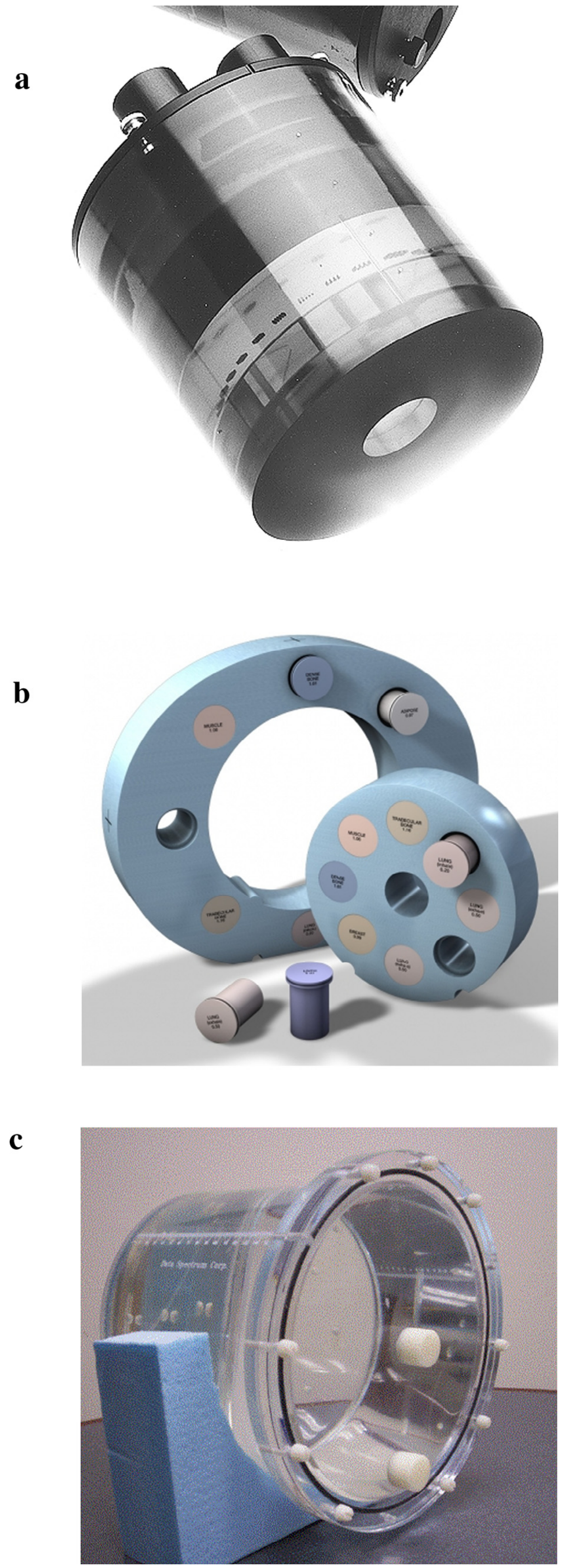

Fig. 1. Three phantoms were used: a Catphan phantom (a), a commercial density phantom (b) and the water filled phantom (c).

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