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# Dose reduction with iterative reconstruction in multi-detector CT: What is the impact on deformation of circular structures in phantom study?

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Computed tomography;
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Image quality;
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Noise power spectrum

**Abstract**
*Objectives:* To evaluate the distortion of circular structures induced by the increased image noise related to dose reduction and to assess the effect of iterative reconstruction (IR).
*Methods:* MDCT acquisitions were performed with 120 kVp for 200/100/60/40/20 mAs with 100%/50%/30%/20%/10% of dose. Raw data were reconstructed by filtered back projection (FBP) and with two IR strengths. Image quality indices referred to water and acrylic were measured on a quality image phantom. Areas, perimeters, circularity were measured on the circular inserts of 4.8, 7.9 and 11.1 mm on a morphological phantom.
*Results:* Dose reduction resulted in increased image noise and in decreased signal to noise ratio and contrast to noise ratio. IR improved these indices for the same dose without affecting the signal (number CT) and spatial resolution (modulation transfer function). The values of area, perimeter and circularity were altered compared to the actual value and the inserts were visually deformed with the dose reduction. IR improved these three parameters. Image quality indices, areas, perimeters and circularity of inserts were similar between the acquisition at

*Abbreviations:* CNR, contrast to noise ratio; CTDI, computed tomography dose index; FBP, filtered back projection; FOV, field of view; IR, iterative reconstruction; MDCT, multi-detector computed tomography; MTF, modulation transfer function; NPS, noise power spectrum; PSF, point spread function; ROI, region of interest; SAFIRE, sinogram affirmed iterative reconstruction; SNR, signal to noise ratio; TTF, Target Transfer Function.

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100% of the dose in FBP, 50% in strength-3 and 30% in strength-5 with different curves of noise power spectrum.
*Conclusion:* IR associated to 70% of dose reduction modifies the images smooth (NPS) but maintains adequate image quality indices without causing distortions of circular structures.



The increasing number of multi-detector computed tomography (MDCT) studies and the exposure of patients to ionizing radiation have required a dose optimization which has been applied in routine [1—3]. These steps are resulted from a compromise between dose and image quality. Many tools [4,5] were developed to reduce the dose directly such as the tube current modulation, or indirectly, e.g. iterative reconstruction (IR) algorithms, such procedure aim to keep the satisfactory image quality for diagnosis purposes.

IR algorithms [6—8] improve image quality by reducing noise without changing significantly the signal parameters and the transverse spatial resolution. Indirectly, these techniques can reduce the dose delivered to the patients by changing the usual methods to dose optimization.

These methods compensate the degradation of raw data caused by dose reduction and it is frequently applied in different clinical studies (cardiac imaging, liver, chest and spine). Most of studies [9—18] have highlighted the interest of IR algorithm in dose reduction by using Sinogram AFfirmed Iterative REconstruction (SAFIRE) tool on Siemens CT scan. For instance, high strength of IR algorithm allows that signal to noise ratio (SNR) and contrast to noise ratio (CNR) values remains similar to the images produced with high dose permitting a dose reduction ranging from 50 to 75% [9—18]. Thus, high strengths of IR algorithm modify the visual appearance (image smoothing) and the texture (changes in noise power spectrum [NPS]) of the images [8,19—21]. These changes were originally an obstacle for a wide spreading use of the fore-mentioned techniques.

A major challenge in clinical practice [22] is to handle radiologist subjectivity. Indeed, image quality analysis should consider individual interpretations in additional to several other parameters while diagnosing.

Several abnormal lesions such as nodular ones are usually circular in living tissues and can be easier diagnosed by using a proper imaging enhanced. Due that, the impact of circular structures deformations on the visualization of lesions must be firstly studied in phantoms before being applied to clinical studies.

The objective of this study was to evaluate the distortion of circular structures induced by the increased image noise related to dose reduction and to assess the effect of IR algorithm.

## Materials and methods

### Phantom used

Catphan 500 (Phantom Laboratory, Salem, USA) was composed of four sections but three sections CTP 401, 486 and 528b were used in this study to evaluate the effect of IR algorithm on the image quality indices (SNR, NPS, CNR, modulation transfer function [MTF]). Deluxe Jaszczak phantom (Date Spectrum Corporation, Durham, USA), a morphological phantom, was used to evaluate deformations due to dose reduction and the effect of IR algorithm. This phantom, more often used in nuclear medicine, consists of a unit in a water cylinder (20 HU) with six sectors of Plexiglas cold rods (125 HU) of 8.8 cm height and different diameters. The study was performed on the sector 1 with 56 rods of 4.8 mm in diameter; sector 3 and 5 with 21 rods of 7.9 mm and 10 rods of 11.1 mm of diameter respectively. These diameters were the most relevant for clinical practice on parenchymal organ.

### CT scan

Images were acquired on a MDCT SOMATOM Definition AS+ (Siemens, Erlangen, Germany). The detector acquisition mode was $128 \times 0.6$ mm$^2$, which corresponds to a physical collimation of $64 \times 0.6$ mm$^2$ and use of a z-flying focal spot technique that allowed for double sampling along the z-direction. Raw data were reconstructed using the traditional filtered back projection (FBP) algorithm and with an IR algorithm available on the mentioned CT scan (SAFIRE). This method represents the particular usage of two corrections loops, one in the raw data especially and the other in the image data [23,24] with five iteration strengths (S1 to S5). On a scale of 1 to 5, 1 indicates the least amount of noise reduction while 5 refers to the most one.

### Acquisition and reconstruction parameters

Images of both phantoms were obtained with the following parameters: date collection diameter 500 mm, 1.2 helical pitch, 0.33 s rotation time, $128 \times 0.6$ mm$^2$ collimation; 1 mm acquisition thickness. Images were acquired at five quality reference of mAs: 20, 40, 60, 100 and 200 mAs, these levels of mAs correspond to 10%, 20%, 30%, 50% and 100% of the reference dose. Regarding to volume Computed Tomography dose index (CTDIvol), the values were 1.35, 2.7, 4.04, 6.74 and 13.44 mGy. All images were reconstructed axially with 1 mm image thickness and an interval of 0.7 mm; field of view (FOV) was set to $260 \times 260$ mm$^2$ (voxel size: 0.51x0.51x0.7mm); the traditional FBP algorithm with a medium sharp kernel (B30) and the IR algorithm SAFIRE using the kernel with the same sharpness as that FBP algorithm (I30).

Although five strengths are available in SAFIRE in the present work only explored two of them; strengths 3 and 5. On one hand, the strength of 3 (S3) is commonly used in