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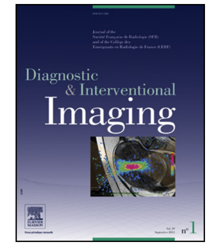

ORIGINAL ARTICLE/RESEARCH AND NEW DEVELOPMENTS

Ultra-low-dose chest CT with iterative reconstruction does not alter anatomical image quality

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KEYWORDS
Ultra-low-dose chest CT;
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Image quality;
Dose reduction;
Safire®

Abstract
Purpose: To evaluate the effect of dose reduction with iterative reconstruction (IR) on image quality of chest CT scan.
Materials and methods: Eighteen human cadavers had chest CT with one reference CT protocol (RP-CT; 120 kVp/200 mAs) and two protocols with dose reduction: low-dose-CT (LD-CT; 120 kVp/40 mAs) and ultra-low-dose CT (ULD-CT; 120 kVp/10 mAs). Data were reconstructed with filter-back-projection (FBP) for RP-CT and with FBP and IR (sinogram affirmed iterative reconstruction [SAFIRE®]) algorithm for LD-CT and ULD-CT. Volume CT dose index (CTDIvol) were recorded. The signal-to-noise (SNR), contrast-to-noise (CNR) ratios of LD-CT and ULD-CT and quantitative parameters were compared to RP-CT. Two radiologists reviewed the CT examinations assessed independently the quality of anatomical structures and expressed a confidence level using a 2-point scale (50% and 95%).
Results: CTDIvol was 2.69 mGy for LD-CT (−80%; $P < 0.01$) and 0.67 mGy for ULD-CT (−95%; $P < 0.01$) as compared to 13.42 mGy for RP-CT. SNR and CNR were significantly decreased ($P < 0.01$) for LD-CT and ULD-CT, but IR improved these values satisfactorily. No significant differences were observed for quantitative measurements. Radiologists rated excellent/good the RP-CT and LD-CT images, whereas good/fair the ULD-CT images. Confidence level for subjective anatomical analysis was 95% for all protocols.

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Conclusions: Dose reduction with a dose lower than 1 mGy, used in conjunction with IR allows performing chest CT examinations that provide a high quality of anatomical structures.

Computed tomography (CT) of the chest plays an important role in the diagnostic and therapeutic decisions in medical practice [1,2]. A major increase of the radiation dose delivered to the patients associated with all consecutive biological hazards was observed [3]. The chest is particularly sensitive to radiation [4]. Dose reduction should be one priority for every radiologist who performs CT examination [5,6]. However, because dose reduction alters image quality, it is crucial to find a proper balance between dose reduction and diagnostic performance. This technological challenge has been addressed and solved by manufacturers with multiple new approaches [7]. Tube voltage reduction, tube current (mAs) [8—10] and iterative reconstructions (IR) [11—16] are currently effective methods. In particular, the use of sinogram affirmed iterative reconstruction (Safire®, Siemens Healthcare, Erlangen, Germany) can improve image quality [17—30]. IR algorithms have an effect on the objective image quality represented by indices of image quality (IQI) (i. e., noise, signal-to-noise ratio [SNR], contrast-to-noise ratio [CNR]) and on the subjective visual image quality [28]. IR algorithms improve the IQI by reducing the noise for acquisitions obtained with the same dose, without altering signal parameters and transverse spatial resolution [27]. Thus, IR indirectly reduces patients radiation exposure. The use of IR algorithms counterbalances the degradation of raw data due to dose reduction so that useful applications have been developed in different clinical settings [31,32]. High strengths of IR maintain values of SNR and CNR similar to those of images obtained with high radiation doses, allowing a dose reduction from 50 to 75% [17,19]. However, by using high strengths of Safire®, changes in the visual appearance (smoothing effect) and image texture (changes in noise power spectrum) have been reported [13]. Initially, this modification impeded a rapid and wide diffusion of these techniques.

Several studies have demonstrated the possibility to reduce radiation exposure using low dose CT (LD-CT) protocols of the chest (effective dose [ED] < 1.5 mSv) [26,33]. Recently, some researchers have proposed interesting applications of ultra-low dose CT (ULD-CT) protocols for the chest (ED < 0.5 mSv) associated with IR in clinical practice [34—36]. Some of these ULD-CT protocols result in a radiation dose similar to that of a chest X-ray while achieving good image quality. These results opened a debate on the possibility of using ULD-CT protocols rather than conventional X-ray examinations in several selected indications even in an emergency setting [37]. However, these studies did not address the issue of repeatability or reproducibility. A comparison of anatomical image quality obtained at different dose CT protocols on the same individual is currently lacking. Such comparison is virtually impossible on living subjects because of ethical issues and unnecessary patient radiation exposure. Anthropomorphic phantoms are suitable to evaluate differences between CT scan protocols but with limitations regarding the number of evaluable tissues [15,38,39]. For this reason, human cadavers are a good alternative for this research of optimization of CT protocol.

The purpose of our study was to evaluate the image quality of anatomical structures using LD-CT and ULD-CT with Safire® compared to a reference chest CT protocol on the same human cadaver.

Materials and methods

Subjects

This prospective study was approved by our institutional review board and informed consent was obtained from the deceased's relatives. Adult human cadavers within a maximum post-mortem interval (PMI) of 48 hours, sent from the department of forensic pathology to the radiology department of our institution for post-mortem CT, were included from April to October 2015. A limited PMI was mandatory, in order to have tissue densities as similar as those of living subjects. Advanced tissue alterations (i. e., evident signs of putrefaction, charred or lacerated cadavers) served as exclusion criteria. Cadavers were scanned wrapped into two artifact-free body bags with the upper limbs placed along the thorax.

CT protocol and image reconstruction

CT images were acquired using a Somatom Definition AS+® (Siemens Healthcare). The detector acquisition configuration was 128×0.6 mm, which corresponds to a physical collimation of 64×0.6 mm. The use of z-flying focal spot technique allowed double sampling along the z-axis.

After CT acquisitions for virtual autopsy were obtained, only one chest scout view was performed and used for each cadaver prior to perform the protocols of the study. The scout view was acquired at 100 kVp and 20 mA. Consecutively, three different chest protocols were implemented on each cadaver covering from the first to the last thoracic vertebra without administration of intravenous contrast material. The first acquisition was the reference CT with a full radiation dose of 200 mAs, followed by other two at a dose reduced by 80% (40 mAs; LD-CT) and 95% (10 mAs; ULD-CT), respectively.