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Value of ultra-low-dose chest CT with iterative reconstruction for selected emergency room patients with acute dyspnea

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ABSTRACT

Objective: To compare the diagnostic confidence between low-dose computed-tomography (LDCT) and ultra-low-dose CT (ULDCT) of the chest on a single source CT system (SSCT) for patients with acute dyspnoea.
Materials and methods: One hundred thirty-three consecutive dyspnoeic patients referred from the emergency room (ER) were selected to undergo two sequential non-enhanced chest CT acquisitions: LDCT first acquisition (100 kVp and 60 mAs), followed by ULDCT (100 kVp ± 20 and 10 mAs). Images were reconstructed with sinogram affirmed reconstruction (SAFIRE). Objective and subjective image quality assessments were made. Two radiologists evaluated subjective image quality and the level of diagnostic confidence as certain or uncertain.
Results: The mean effective doses (ED) were 1.164 ± 0.403 and 0.182 ± 0.028 mSv for LDCT and ULDCT, respectively. Objective image quality improved significantly on lung images of ULDCT compared with LDCT ($p < 0.05$). Subjective image quality was rated excellent/good in 90% of patients with BMI = 25 kg/m^2 for ULDCT. The level of diagnostic confidence was "certain" in all cases for both radiologists with excellent inter-observer agreement ($k = 1$).
Conclusion: Chest ULDCT with SAFIRE on a SSCT allows a high level diagnostic confidence for the evaluation of selected acute dyspnoeic patients.

1. Introduction

Although chest X-ray (CXR) is the most commonly used diagnostic tool in Emergency Room (ER), Computed Tomography (CT) is becoming increasingly determinant for patient's care, but with the drawback of non-negligible radiation doses [1,2]. The risk to develop radiation-induced cancer increases especially in patients of young age with a long life expectancy [3–5]. In addition, the chest is the most radiation sensitive region compared to the other parts of the body [6,7], therefore an inappropriate irradiation of this anatomic region raises concerns.

To reduce the radiation-induced cancer risk, the European Atomic Energy Community (EURATOM) issued a directive that required the European Community member States to optimise the dose for ionizing imaging while maintaining a diagnostic quality of Image [8]. Based on this directive, the French government established the Diagnostic Reference Levels (DRLs) for chest CT imaging [9]. Such DRLs limit the dose length product (DLP) to 475 mGy cm, which is equivalent to the effective dose (ED) of 6.65 mSv (conversion factor: 0.014 mSv mGy^{-1} cm^{-1}) [10].

Several tools were suggested to reduce the dose in CT but often resulted in a degradation of the image quality with difficulties for diagnosis [11–13].

The Iterative reconstruction (IR) is a method that improves the quality of the image decreasing the image noise in comparison to filtered back projection (FBP) for a protocol with the same dose [14]. Moreover, IR permits to maintain a good image quality while

Abbreviations: BMI, Body Mass Index; CNR, contrast-to-noise ratio; CT, Computed Tomography; DLP, dose length product; DRLs, Diagnostic Reference Levels; DSCT, dual source computed tomography; ED, effective dose; ER, Emergency Room; LDCT, low dose computed tomography; ROI, region of interest; SAFIRE, Sinogram Affirmed Iterative Reconstruction; SNR, signal-to-noise ratio; SSCT, single source computed tomography; ULDCT, ultra low dose computed tomography.

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reducing the dose [15]. Sinogram Affirmed Iterative Reconstruction (SAFIRE; Siemens) is one of IR methods whose applications are widely used for clinical purposes [16,17].

Since SAFIRE is available at our institution, a routine low-dose chest CT (LDCT) protocol was established with effective dose (ED) lower than 1.5 mSv [18].

Previous studies demonstrated that ultra-low-dose chest CT (ULDCT) imaging associated with IR can provide satisfactory outcomes in clinical practice. These studies compared chest ULDCT with IR and LDCT or standard dose protocols reconstructed either with IR or with FBP [19–22]. Such comparisons were performed using a dual-source CT system (DSCT), but no evidences of clinical application have already been published using a single-source CT system (SSCT).

With the present study we aimed to evaluate the image quality and the level of diagnostic confidence of a ULDCT protocol, delivering a dose similar to that of a double projection CXR, in comparison with an LDCT protocol for the study of the chest in selected acute dyspnoeic patients coming from ER.

2. Materials and methods

2.1. Patients

This prospective monocentric study was approved by the Institutional Review Board. Patients were duly informed and they signed an informed consent before examinations. The study was carried out from October 1st to December 31st 2015 and the CT indication was the assessment of acute dyspnoeic patients, whom have had preliminarily a CXR and for whom a non-enhanced chest CT was requested as additional study. Specifically, as causes of acute dyspnoea were considered infectious pneumonia, non-traumatic pneumothorax and the exacerbation of known chronic obstructive pulmonary diseases (COPD) or idiopathic interstitial pneumonia (IIP). Dyspnoeic patients with suspected cardio-vascular disease (e.g. myocardial infarct, pulmonary embolism, aortic dissection), cancer, sustained a trauma or any other indications deserving an enhanced chest CT were not considered for this study.

3. CT examination

3.1. Image acquisition

Chest CT images were obtained on a 64 slices SSCT (Somatom, Definition AS+, Siemens, Erlangen, Germany) with z-flying focal spot for simultaneous acquisition with 128 overlapping and 0.6-mm thick sections with both measurement systems.

Patients lied in supine position during a non-enhanced two consecutive acquisitions CT protocol. The first acquisition was the routinely used institutional chest LDCT and the second the ULDCT study acquisition, which was performed immediately after.

Overall, both acquisitions were conceived to do not exceed the National DRLs for chest CT for standard patient care. LDCT dataset was obtained with 0.33 s rotation time, tube voltage of 100 kVp (with actived Care kV), tube current of 60 mAs reference (with activated CareDose 4D), collimation of 128×0.6 mm (slice thickness 1 mm) and pitch 1.2. Subsequently, ULDCT dataset was obtained with 0,33 s rotation time with, tube voltage of 100 kVp (no activated Care kV; 120 kVp for BMI > 25 kg/m^2), tube current of 10 mAs reference (without CareDose 4D), collimation of 128×0.6 mm (slice thickness 1 mm) and pitch 1.5.

3.2. Image reconstruction

LDCT protocol consisted of 1-mm thick overlapped 0.7 mm images reconstructed with raw data-based iterative reconstruction (SAFIRE), as implemented on the CT scanner with a high-spatial-resolution reconstruction kernel (I70, lung images) and a soft-tissue reconstruction kernel (I30, mediastinal images). SAFIRE strength was set at 3 and 2 for lung and mediastinal images, respectively.

ULDCT protocol consisted of 1-mm-thick overlapped 0.7 mm images reconstructed with SAFIRE. ULDCT images were reconstructed by using a high-spatial-resolution reconstruction kernel (I50, lung images) and a soft-tissue-resolution reconstruction kernel (I30, mediastinal images). SAFIRE strength was set at 4 and 3 for lung and mediastinal images, respectively.

4. Images analysis

4.1. Objective image quality

Objective assessments were obtained by measuring the mean (signal) and the standard deviation (noise) of pixel values in six regions of interest (ROI [cm^2]) on mediastinal (I30) images at three anatomic levels: axillary fat (0.51 ± 0.01 cm^2), in subscapular muscle (0.71 ± 0.01 cm^2) and into the trachea (0.71 ± 0.01 cm^2); on lung (I50 or I70) images, at three anatomic levels, in the pulmonary parenchyma (1.01 ± 0.01 cm^2), in a vertebral body (0.71 ± 0.01 cm^2) and into the trachea (0.71 ± 0.01 cm^2). Altogether, these ROIs covered the greatest part of the chest structures.

The signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) were calculated according the method previously described by Mieville et al. [14]. The signal and the noise measured within the ROI of trachea, both in the mediastinal and in lung images, were used as reference to calculate the CNR.

4.2. Subjective image quality

Two radiologists (F.M. [R1] and A.C.R. [R2] with nine and six years of experience, respectively) read the images on clinical workstations with Centricity PACS viewer system (General Electric, Healthcare, Wisconsin, USA). R1 had a three-year experience with ULDCT images, whereas R2 was trained to interpret ULDCT images only for this study. This different expertise was voluntarily sought in order to evaluate whether any interpretation difference subsisted between an experienced radiologist in ULDCT images and a radiologist less experienced.

Radiologists viewed LDCT and ULDCT anonymised images by using standard mediastinal (window width, 450 HU; window centre, 50 HU) and lung parenchymal (window width, 1600 HU; window centre, −600 HU) window settings.

For each patient, the clinical data and the reason of the examination were not available. Radiologists interpreted by consensus ten cases randomly chosen, which were excluded from the study. The remaining cases were read independently.

LDCT and ULDCT images were presented in a random fashion to the readers. The image quality of anatomical structures was rated according to the five-point scale proposed by Neroladaki as follows [19]: 1 point: anatomical structures visible at 100% (excellent), 2 points: anatomical structures visible at > 75% (good), 3 points: anatomical structures visible between 25% and 75% (fair), 4 points: anatomical structures visible < 25% (poor), 5 points: landmarks were not visible at all (unacceptable).

The image quality of diagnostic findings was rated according to an other five-point Likert scale proposed by Neroladaki scale [19]: 1 point: abnormal structures clearly visible with good demarcation (Excellent), 2 points: structures visible with blurring but without