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Research Article

# Feasibility of Using Iterative Reconstruction to Reduce Radiation Dose for Computed Tomography Pulmonary Angiograms

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## ABSTRACT

**Objective:** The purpose of this study was to assess the potential for iterative reconstruction algorithms to be used to reduce patient radiation dose for computed tomography pulmonary angiography examinations while maintaining diagnostic image quality.

**Materials and Methods:** This two-stage study first considered current computed tomography pulmonary angiography image quality through an audit of current practice. Secondly, an experimental design was adopted using an anthropomorphic phantom with the addition of contrast-enhanced tubes to mimic pulmonary arteries. The radiation dose was reduced by incrementally reducing the milliampere seconds value from the standard institutional protocol, and subjective and objective (contrast-to-noise ratio [CNR] and signal-to-noise ratio [SNR]) quality measures were recorded for each exposure and reconstruction.

**Results:** A sample of 10 patients met the inclusion criteria for the audit, and a mean CNR of 44.2 and an SNR of 47.9 were established as baseline quality. A clear positive correlation was identified between the number of iterations and objective quality measures (CNR [$r = 0.78$, $P < .001$] and SNR [$r = 0.78$, $P < .001$]). No relationship was identified between the subjective measures and either radiation exposure (milliampere seconds) or the number of iterations. Findings suggest that a potential reduction in effective dose of 1.46 mSv (57.0%) is possible with no associated loss of image quality with the use of iterative reconstruction.

**Conclusion:** Findings suggest that the potential dose reduction may be as great as 57%; however, further work is required to confirm this in a patient population.

## RESUMÈ

**But :** Évaluer la possibilité d'utiliser des algorithmes de reconstruction itérative (RI) afin de réduire la dore de rayonnement pour les patients lors des examens d'angiographie pulmonaire par tomodensitométrie (APTDM), tout en maintenant la qualité diagnostique des images.

**Matériel et méthode :** Cette étude en deux étapes a d'abord considéré la qualité diagnostique des images actuelles en APTDM par une vérification de la pratique actuelle. Dans un deuxième temps, une expérience a été conçue, faisant appel à un fantôme anthropomorphique avec ajout de tubes contenant des agents de contraste afin de simuler les artères pulmonaires. La dose de rayonnement a été réduite en diminuant graduellement les mA par rapport au protocole institutionnel standard; des mesures de qualité subjectives et objectives (rapport contraste-bruit (RCB) et rapport signal-bruit (RSB)) ont été relevées pour chaque exposition et reconstruction.

**Résultats :** Un échantillon de 10 patients a satisfait aux critères d'inclusion; un RCB moyen de 44,2 et un RSB moyen de 47,9 ont été établis comme mesure de base. Une corrélation positive nette a pu être établie entre le nombre d'itérations et les mesures de qualité objectives, RCB ($r=0,78$, $p<0,001$) et RSB ($r=0,78$, $p<0,001$). Aucun lien n'a été établi entre les mesures subjectives et l'exposition au rayonnement (mA) ou le nombre d'itérations. Les résultats suggèrent qu'une réduction potentielle de la dose effective de 1,46 mSv (57,0 %) est possible sans perte connexe de qualité de l'image avec l'utilisation de la reconstruction itérative.

**Conclusion :** Les résultats suggèrent que la réduction potentielle de la dose de rayonnement pourrait atteindre 57 %, cependant d'autres études seront nécessaires pour confirmer ces résultats dans une population de patients.

*Keywords:* CT; pulmonary angiography; iterative reconstruction; radiation dose; anthromorphic phantom

## Introduction

Computed tomography (CT) examinations contribute to nearly two thirds of the total radiation dose associated with medical imaging [1]. Therefore, it is essential that all efforts

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are made to reduce the radiation dose while maintaining diagnostic image quality [2] because of the greater overall lifetime risk within younger patients and the radiosensitivity of the developing fetus in pregnant patients [3]. CT is often the imaging method of choice for patients with suspected pulmonary embolus, and there is a relatively high prevalence of this condition within both young and pregnant patients.

Image reconstruction plays a critical role in CT and enables data to be displayed in cross-sectional planes. Fourier-based iterative reconstruction (IR) algorithms were initially used when CT was first developed in the 1970s, although filtered back projection (FBP) algorithms quickly replaced these methods because of the faster reconstruction times.

IR uses a method of image formation based on a succession of estimates in which comparisons are made with the original raw data at each stage. These comparisons inform subsequent refinements of the image in a cyclical process [4]. At each reconstruction cycle (iteration), image noise is reduced in more homogenous areas, thereby improving the contrast-to-noise ratio (CNR) [5]. Therefore, in theory, IR can provide optimal low-noise, high-contrast images by looping "iteratively" through image reconstruction cycles. Recently, statistical IR algorithms have been developed by major CT vendors that take into account the modelling of the x-ray photon electronic noise. With these IR algorithms, the information contained in the FBP image acts as the initial foundation of the reconstruction process instead of the raw data [6]. This results in the generation of images more consistent in texture to those reconstructed with FBP, and clinically acceptable reconstruction times.

The effective use of statistical IR has received much attention in the literature, and a number of studies have evaluated its use with a range of CT examinations, including the thorax. These studies have shown that statistical IR has the potential to lower the radiation dose to the patient when compared with FBP by up to 65% [7–13]. The two methods of dose reduction commonly evaluated are a reduction in tube potential (kV) [8, 9] and a reduction in tube current (milliampere seconds [mAs]) [7, 10, 11]. A low kV technique has already been routinely adopted at many institutions for CT pulmonary angiogram (CTPA) examinations without the use of IR, a practice supported by a wealth of evidence [2, 14–18]. Therefore, the scope for further reduction of tube potential in CTPA examinations is limited, although a small number of studies have considered this [19, 20].

Furthermore, the routine use of low kV CTPA parameters makes it difficult to directly translate the findings from studies in which CT scans were obtained at 120 kV [7, 11]. Despite this, only a limited number of studies have been identified that specifically considered the use of statistical IR within CTPA [21–24], and only a small number of these used a low kV technique [23, 24]. All of these studies acknowledge the huge potential for IR to contribute to dose reduction in CTPA examinations.

This article reports the results from a study that examined whether IR can be used to reduce patient dose for low kV CTPAs without compromising diagnostic image quality, with the aim of determining an approach to applying this within a practice setting.

## Materials and Methods

This was a single-centre study, and all images were acquired using a Siemens definition 128 scanner with statistical IR reconstructions undertaken using Sinogram-Affirmed Iterative Reconstruction (SAFIRE; Siemens Medical Solutions, Forchheim, Germany). SAFIRE offers 5 strengths of IR in which 1 has the fewest iterations and 5 the most. The study was conducted in two phases: an audit of current practice, followed by a phantom study. Both objective and subjective measures were considered to assess image quality. Local imaging protocols were used as the baseline; this protocol, developed in accordance with the evidence base [2, 14–18, 25], involved 100 kV, a quality reference mAs of 140 used alongside Siemens Care Dose 4D, and an acquired slice thickness of 3 mm (128 × 0.6). The quality and adequacy of this protocol had been confirmed and validated locally in a departmental audit conducted in 2010.

### *Stage 1*

Local institutional processes were followed and research and development approval sought; this stage was considered an audit, so full ethical review was not required. Participants gave verbal consent to participate after an explanation of the audit.

The aim of this stage was to determine a baseline for image quality. A convenience sample of 15 consecutive patients who were scheduled for a CTPA examination during the study period (March–April 2014) were invited to take part, and following consent, were weighed immediately before examination. Details regarding participant age, weight, and sex were recorded along with the dose-length product (DLP) of the scan. DLP is a comparable standard measure of dose in CT [2] and enables effective dose to be calculated, although there has been a suggestion that this may overestimate the real dose because of the effect of angular modulation [26]. Effective doses were calculated from DLP using a conversion factor of 0.014 as advocated by Shrimpton et al [27] for chest CT scans.

Inclusion within the sample was restricted to adult patients weighing between 70 and 80 kg. This weight range was applied to allow for comparison with the anthropomorphic phantom used in the second stage of this study. A minimum sample size of 10 was determined for this preliminary stage based on the method advocated by Eng [28] and the findings from previous studies [12, 13, 20].

Images were independently reviewed by an experienced radiologist using two subjective scales after the method adopted by Prakesh et al [12]. These included diagnostic acceptability rated on a four-point scale (1 = excellent fully acceptable, 2 = good probably acceptable, 3 = acceptable under limited circumstances, 4 = unacceptable) and image noise