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Clinical utility of ultra high pitch dual source thoracic CT imaging of acute pulmonary embolism in the emergency department: Are we one step closer towards a non-gated triple rule out?

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ABSTRACT

Objectives/Purpose: Aim of this study was to retrospectively compare the image quality and the radiation dose of an ultra high pitch CT scan for the evaluation of pulmonary embolism and visualization of cardiac structures in comparison to our institution's standard pulmonary embolism protocol.

Method and materials: The study cohort consisted of 115 consecutive patients, 57 underwent CT pulmonary angiography on a dual source 128 slice scanner (Siemens Somatom Definition FLASH) via an ultra high pitch mode (Pitch 2.8) while 58 were scanned on a dual source 64 slice scanner (Siemens Somatom Definition Dual Source) with standard pitch (Pitch 0.9). Qualitative image assessment was determined by two blinded radiologists with 3 and 15 years' experience in chest and cardiac CT. Quantitative image assessment was determined by the signal to noise ratio (SNR) and contrast to noise ratio (CNR). Effective radiation dose was calculated via the product of the dose length product.

Results: For the ultra high pitch protocol, 14% (8/57) were positive for pulmonary embolus compared to 13.7% (8/58) for the standard pitch group. 98.2% of the ultra high pitch scans were diagnostic for pulmonary embolus vs. 94.8% of the standard protocol. Visualization of cardiac structures was significantly improved with the ultra high pitch protocol ($p < 0.0001$). Significantly more lung parenchymal motion was observed on the standard protocol ($p < 0.0001$). The mean pulmonary vessel attenuation, SNR, and CNR were not significantly different. The mean effective dose was lower for the ultra high pitch studies (4.09 mSv ± 0.78 vs. 7.72 mSv ± 2.60, $p < 0.0001$).

Conclusion: Ultra high pitch CT imaging for pulmonary embolus is a technique which has potential to assess motion free evaluation of most cardiac structures and proximal coronary arteries at lower radiation doses.

1. Introduction

Computed tomography pulmonary angiography is now the accepted gold standard for the diagnosis of pulmonary embolism (PE) [1]. In addition to detecting emboli in the pulmonary vasculature, CT has the ability to detect other pulmonary abnormalities that may support an alternative diagnosis [2]. Given its wide availability and rapid acquisition times, CT is much more practical to obtain than to perform a pulmonary angiogram or a perfusion/ventilation szintigram, which carries numerous procedural risks as well as increased radiation exposure compared to CT [3–5] Given these factors, there have been an increasing number of patients examined with CT for suspected PE [6]. Weir et al. showed a 13 fold increase in the number of patients being examined for PE in their emergency department from 2000–2005 [7]. Despite the rising number of CT studies conducted, the number of positive PE studies only ranges between 9–35% [8,9]. Given the concern of radiation doses, there is a need to significantly reduce CT radiation doses while maintaining diagnostic image quality [2,6,8,10].

Pitch is defined as table movement per rotation divided by single slice collimation. High pitch increases the speed of imaging, improving temporal resolution thus "freezing" motion in the thoracic cavity [12–14], which is ideal for CT pulmonary angiography. Improved temporal resolution afforded by high pitch CT allow for imaging of patients unable to breath hold, limits aortic pulsation artifacts, and reduces cardiac related pulmonary parenchyma motion artifacts [11–13]. Another advantage of high

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Table 1
CT pulmonary angiography scanning protocol for Standard (STD) and Ultra high pitch (UHP) using a second-generation dual-source CT.

Parameter	STD Protocol	UHP Protocol
mAs (Tube A) kV 120	220	220
Kernel B	B36 (Mediastinum) Axial 2 mm × 1 mm	B36 (Mediastinum) Axial 2 mm × 1 mm
Kernel B	B70 (Lung) Axial 2 mm × 1 mm	B70 (Lung) Axial 2 mm × 1 mm
Kernel B	B36 (Mediastinum) Axial 2 mm × 1 mm	B36 (Mediastinum) Axial 2 mm × 1 mm
Collimation	128 mm × 0.6 mm	128 mm × 0.6 mm
Pitch	0.9	2.8
Rot Time	0.33	0.28
CTDI vol	12	12

pitch dual-source CT is the visualization of coronary arteries due to the reduction of cardiac motion artifact, although this has not been evaluated for CT scans for PE [13]. De Zordo et al. compared image quality for the diagnosis of PE using a high pitch versus standard pitch protocol [15]. A pilot study investigated the ability of a non-gated high pitch CT angiogram to visualize the coronary arteries and found diagnostic image quality in the proximal coronary segments in 67% of patients and 23% for the proximal and mid-coronary segments [16]. However, no studies to date have assessed the image quality of both coronary arteries and cardiac structures with a non-gated high pitch thoracic CT PE protocol.

The purpose of this study was twofold. The first was to compare the image quality of a non-gated ultra high pitch (UHP) thoracic CT scan using a 128-slice dual-source CT scanner to our institution's standard (STD) non-gated regular pitch thoracic CT scan (64-slice dual source CT) for the evaluation of PE. The second goal was to compare the radiation dose of a non-gated UHP thoracic CT scan to a non-gated STD pitch thoracic CT scan.

2. Materials and methods

This is an ethics approved retrospective study that consisted of 115 patients who were scanned at our institution's emergency room for suspected PE. Patient group A consisted of 57 consecutive emergency room patients scanned over a 4 week period from March 29, 2010 to April 29, 2010 whom were imaged via the UHP Protocol. Exclusion criteria included patients with an estimated glomerular filtration rate (GFR) < 45 ml/min, pregnant women, and patients with a documented history of allergy to iodine contrast. Patients with a BMI > 30 were not scanned with the UHP protocol. Patient group B consisted of 58 consecutive emergency room patients whom were scanned via our institution's STD Protocol over a 4 week period from March 29, 2009 to April 29, 2009. With the same exclusion criteria applied.

2.1. Scanning protocols

UHP patients were scanned using a second-generation 128-slice dual-source CT (Somatom Definition FLASH, Siemens Healthcare, Forchheim, Germany). The STD protocol used a first generation 64-slice dual source CT (Somatom Definition Dual Source, Siemens, Healthcare, Forchheim, Germany). Patients were placed supine with both arms extended above their heads. The scan was performed utilizing a single breath hold and patients were scanned in a caudocranial fashion. The two protocols utilized are summarized in Table 1. The quality mAs reference values were kept constant for both protocols at 220 mAs and both used a tube current of 120 kV. The pitch of the UHP protocol was 2.8, whereas a pitch of 0.9 was used for the STD protocol. Rotation time of the UHP protocol was reduced to 0.28 s versus 0.33 s in the STD protocol. Both protocols utilized 120 kV in order to investigate the effect of pitch on image quality and radiation dose.

Contrast opacification of the vessels was obtained utilizing a contrast bolus injection of 80 cc of Optiray 350 at 5 cc/s, followed by 40 cc of saline chaser. The scan utilized bolus tracking and was triggered when opacification reached 100 HU over the main pulmonary artery. The STD Protocol used a 5 s delay after the HU threshold was reached whereas the UHP Protocol used a 10 s delay after the HU threshold was reached to ensure additional opacification of the pulmonary vasculature.

2.2. Image assessment

Both quantitative and qualitative measurements were used for image assessment. Qualitative assessment was performed by two blinded emergency trauma radiologists, whom evaluated the trans-axial sections for three factors: clarity of cardiac structures, presence of PE, and lung parenchyma definition.

Evaluation of the cardiac structures was based on a grading scale from 0–3. Images given a score of 0 were completely non-diagnostic for evaluating the cardiovascular structures. A score of 1 denoted significant motion, a score of 2 denoted minor motion, and a score of 3 denoted clear visualization. Cardiac structures evaluated included aortic valve leaflets, mitral valve leaflets, myocardial right ventricular septae, papillary muscles, pericardium anterior to heart, pericardium at heart apex, right coronary artery (proximal, middle, distal), left mainstem coronary artery, left anterior descending coronary artery (proximal, middle, distal, first diagonal, second diagonal), and left circumflex coronary artery (proximal, distal, and obtuse marginals).

The images were also evaluated for their diagnostic capabilities for evaluating segmental PE. Images were noted to be either diagnostic for segmental PE or non-diagnostic for PE.

Finally, subjective evaluation was made regarding the lung parenchyma based on a grading scale of 0–2. Images were given a score 0 constituted significant motion in which there was no clear visualization of the fissures or cardiovascular contours. A score of 1 constituted mild motion within the fissures and cardiovascular contours. A score of 2 constituted no motion to the fissures or cardiovascular contours.

For objective image quality analysis density measurements were performed as follows. The Hounsfield units of the pulmonary arteries were determined by drawing 3 regions of interest (ROI's) within the main pulmonary artery, the right pulmonary artery, and the left pulmonary artery. Each ROI was chosen to be as large as each corresponding vessel. These values were averaged to determine the mean pulmonary artery signal intensity (SI_{PA}). Background noise was determined by 3 ROIs within the central, right, and left surrounding air in front of patient. ROIs were chosen to be 1 cm^2. These values were averaged to determine the mean background noise (BN). Muscle signal intensity was calculated via 2 ROIs within the pectoral muscle and paraspinal muscle. To account for spatial restrictions these ROIs were chosen to be 0.5 cm^2. These values were averaged to determine the mean muscle signal intensity ($MUSCLE_{SI}$). Quantitative assessment was performed by determining the signal to noise ratio (SNR) and the contrast to noise ratio (CNR). These were obtained by the equations: $SNR = SI_{PA}/BN$ and $CNR = (SI_{PA} - MUSCLE_{SI})/BN$.

2.3. Radiation dose evaluation

Dose length products (DLP) and Volume CT Dose Index were provided by the scanner system and were documented. The DLP was multiplied by the conversion factor of 0.014 to calculate an estimate of the effective radiation dose in mSv. Extrathoracic fat and soft tissues was assessed by averaging the perpendicular distance