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Diagnostic image quality of a comprehensive high-pitch dual-spiral cardiothoracic CT protocol in patients with undifferentiated acute chest pain

Fabian Bamberg*,[1], Roy Marcus[1], Wieland Sommer, Florian Schwarz, Konstantin Nikolaou, Christoph R. Becker, Maximilian F. Reiser, Thorsten R.C. Johnson

Department of Clinical Radiology, Ludwig-Maximilians University, Klinikum Grosshadern, Munich, Germany

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ABSTRACT

Objective: To evaluate diagnostic image quality of high-pitch dual source comprehensive cardiothoracic CT protocol in patients presenting with acute undifferentiated chest pain.
Materials and methods: Consecutive symptomatic subjects ($n = 51$) with undifferentiated acute chest pain underwent ECG-synchronized high-pitch dual-spiral chest CT angiography (Definition Flash, Siemens Medical Solutions, 2 × 100 kVp or 2 × 120 kV if BMI > 30, collimation: 128 × 0.6 mm, pitch: 3.2). Independent investigators determined the image quality of each cardiac and pulmonary vessel segment, measured contrast-to-noise-ratio (CNR), and determined radiation exposure. In addition, the prevalence of CT findings (pulmonary embolism (PE), aortic dissection (AD) and significant coronary stenosis (≥50%)) was determined. Univariate and multivariate analysis were performed to determine the subpopulation with highest diagnostic quality.
Results: Among 51 subjects (66% male, average age: 63 ± 15.8), the prevalence of positive CT findings was moderate (overall: 11.7%). Overall, image quality of the pulmonary, aortic and coronary vasculature was good (1.26 ± 0.43 and CNR: 2.52) with an average radiation dose of 3.82 mSv and 3.2% of segments rated non-evaluable. The image quality was lowest in the coronary arteries ($p = 0.02$), depending on the heart rate ($r = 0.52$, $p < 0.001$). In subjects with a heart rate of ≤65 bpm ($n = 30$) subjective image quality and CNR of the coronary arteries were higher (1.6 ± 0.5 vs. 2.1 ± 0.5, $p = 0.03$ and 1.21 ± 0.3 vs. 1.02 ± 0.3, $p = 0.05$) with only 1.5% segments classified as non-evaluable.
Conclusion: High-pitch dual-spiral comprehensive cardiothoracic CT provides low radiation exposure with excellent image quality at heart rates ≤65 bpm. In subjects with higher heart rates, image quality of the aortic and pulmonary vasculature remains excellent, while the assessment of the coronary arteries degrades substantially.

1. Introduction

Undifferentiated chest pain is one of the most common complaints in the acute care setting, accounting for over five million emergency department (ED) visits in the U.S. each year [1]. While contrast-enhanced spiral computed tomography angiography (CTA) has become a standard procedure in the evaluation of the presence of PE [2] and AD [3], noninvasive detection of coronary artery stenosis with multidetector CT was recently recognized as a potentially valuable method in the ED setting [4]. Coronary CTA has been shown to be an effective tool to rule out CAD with reported sensitivity of 93–99% and specificity of 95–97% as compared to invasive coronary angiography [5–7]. In addition, recent data indicate that coronary CTA accurately rules out ACS in subjects with acute chest pain and therefore may enhance the diagnostic work up of chest pain patients in the ED [8].

Several observational case series [4,9] have suggested a comprehensive cardiothoracic contrast-enhanced CT protocol as a method to simultaneously evaluate the thoracic aorta, coronary-, and pulmonary arteries. However, these acquisitions have been controversial due to the relatively high radiation exposure (~18 mSv), which is usually higher than dedicated PE and AD exams, and therefore limits a broader applicability especially in younger subjects and females [10]. With the introduction of second generation dual-source CT, a new high-pitch dual spiral technique has been proposed to acquire an ECG-gated dataset of the entire chest within <1 s at markedly reduced radiation exposure [11].

The purpose of this study is to evaluate diagnostic image quality of high comprehensive high-pitch dual spiral cardiothoracic CT

* Corresponding author at: Department of Clinical Radiology, University of Munich – Grosshadern Campus, Marchioninistrasse 15, 81377 Munich, Germany. Tel.: +49 89 70953620; fax: +49 89 70958832.
E-mail address: fbamberg@med.lmu.de (F. Bamberg).
[1] These authors contributed equally to the study.

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Table 1
Patient demographics and risk factors in the consecutive set of subjects undergoing the comprehensive cardiothoracic high-pitch CT protocol.

	Mean ± SD or *N* (%)
Age	63 ± 15.8
Male gender	35 (69%)
History of CAD	7 (14%)
History of stenting	6 (12%)
History of CABG	1 (2%)
History of MI	2 (4%)
History of PE	0 (0%)
History of AD	0 (0%)
Hyperlipidemia	14 (27%)
Hypertension	25 (50%)
Smoking	10 (20%)
Diabetes mellitus	9 (18%)
BMI	27.2 ± 5.2

Table 2
Scan parameters.

	Mean ± SD
kV average	105.6 ± 9
100 kV acquisition	36 (71%)
mAs	366.1 ± 46
Scan time (s)	0.8 ± 0.1
mSv	3.82 ± 0.9
Dose length product	224.7 ± 54
Contrast volume (ml)	91.8 ± 13.1
Injection volume (ml/s)	6.1 ± 0.52
Average heart rate (bpm)	73.4 ± 22
Min heart rate (bpm)	59.8 ± 15
Max heart rate (bpm)	97.3 ± 52
HR variability	40.8 ± 0.3

protocol in patients presenting with acute undifferentiated chest pain.

2. Methods

2.1. Subjects

Subjects with undifferentiated acute chest pain (suspected PE, AD, and/or ACS) who underwent a comprehensive cardiothoracic examination were retrospectively included in the analysis. Inclusion criteria were: subjects of ≥45 years of age, hemodynamically stable with an initial work-up inconclusive or suspicious for one of the above disease entities. Exclusion criteria were severe arrhythmia, allergy to iodinated contrast media or renal insufficiency (defined by a serum creatinine ≥1.5 mg/dl). No beta-blockers were administered in preparation for the scan.

The study was performed in compliance with the ethics committee guidelines. There was a clinical indication for coronary CTA in all cases and informed consent was obtained before the examination.

Table 3
Observed image quality and contrast-to-noise ratio (CNR) by vascular territory. PA: pulmonary artery; RA: right main pulmonary artery; LA: left main pulmonary artery; RULA: right upper lobe pulmonary artery; RLLA; right lower pulmonary artery; LULA: left upper lobe pulmonary artery; LLLA: left lower lobe pulmonary artery; LAD: left anterior descending coronary artery; LCX: left circumflex coronary artery; RCA: right coronary artery.

	Image quality	CNR
Pulmonary arteries		
Overall	1 ± 0	3.6 ± 0.4
Main PA	1 ± 0	3.2 ± 1
RA	1 ± 0	3.3 ± 1
LA	1 ± 0	3.2 ± 1
RULA	1 ± 0	4.4 ± 0.9
RLLA	1 ± 0	3.4 ± 0.9
LULA	1 ± 0	3.5 ± 1.6
LLLA	1 ± 0	3.5 ± 0.9
Aorta		
Overall	1.03 ± 0.2	1.75 ± 0.66
Ascending	1.00 ± 0	2.41 ± 0.86
Descending	1.08 ± 0.3	1.1 ± 0.57
Coronary arteries		
Overall	1.9 ± 0.6	1.12 ± 0.06
LAD	1.6 ± 0.5	1.19 ± 0.5
LCX	2.3 ± 0.9	1.04 ± 0.4
RCA	2.0 ± 0.9	1.13 ± 0.3

Table 4
Predictors of image quality and proportion of non-evaluable coronary segments in the study cohort. BMI: body mass index; CI: confidence interval.

	β (95% CI)	
	Image quality	Non-evaluable segments
Male gender	0.005 (−0.34 to 0.35)	0.3 (−6.0 to 7.0)
Age (per 10 years)	0.005 (−0.002 to 0.1)	0.1 (−0.06 to 0.3)
BMI	0.01 (−0.2 to 0.0)	0.4 (−10 to 0.4)
Heart rate (per 10 bpm)	1.0 (0.7–2.0)	9 (5–17)

2.2. CT imaging

The comprehensive cardiothoracic high-pitch protocol was performed using a second generation dual-source CT System (Siemens Somatom Definition Flash, Siemens Medical Solution, Forchheim, Germany) with tube voltages of 2 × 100 kV or 2 × 120 kV for severely obese patients (BMI > 30) and 370 mAs (100 kV) or 320 mAs (120 kV) tube current. The collimation was 128 × 0.6 mm and the pitch 3.2, avoiding data oversampling. Image acquisition was performed in cranio-caudal direction, from the lung apices to the diaphragm, during a single breath hold.

A Stellant D dual head power injector (Medrad, Volkach, Germany) was used for contrast media injection. Ultravist 370 (Bayer Schering Pharma, Berlin, Germany; 768 mg iopromide/ml) was administered dependent on body habitus (usually 90 ml at 6 ml/s). To ensure adequate opacification of the aorta, pulmonary and coronary arteries, the acquisition was initiated 5 s after initial opacification (≥100 HU) of the ascending aorta with automated bolus tracking.

For the evaluation of the coronary arteries, overlapping axial images were reconstructed using an iterative medium-smooth convolution kernel (I26f) with an image matrix of 512 × 512 pixels, slice thickness and increment of 0.75/0.5 with a small field of view restricted to the heart. The pulmonary as well as the aortic vasculature were evaluated using the same kernel with a slice thickness and increment of 1.0/0.6 mm and field of view that encompassed the entire chest.

Dose estimations were derived from the patient protocols. The dose length product (DLP) as provided by the manufacturer was multiplied by a corresponding weighting factor of 0.0186 mSv/mGy to obtain the equivalent dose [11–13].

2.3. Image evaluation

Two experienced observers evaluated all CT data sets on a dedicated workstation (Multi Modality Workplace, Siemens). Any discrepancy was solved by consensus. The images were displayed with a window width of 800 HU and level of 250 HU for the aortic vasculature, and a window width of 700 HU and level of 100 HU for the pulmonary vasculature, while the window setting for the evaluation of the coronary arteries was individually adjusted by the observer.