ORIGINAL ARTICLE

High pitch CT in triple rule-out studies: Radiation dose and image quality compared to multidetector CT

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KEYWORDS
Chest pain; Radiation dose; Computed tomography

Abstract
Objective: To compare the image quality and radiation dose from high pitch dual source CT (128-DSCT) vs. those from retrospective acquisition with 64-row multidetector CT (64-MDCT) in triple rule-out studies.

Material and methods: We retrospectively studied 60 patients with acute chest pain: 30 with a retrospective EKG acquisition with 64-MDCT and 30 with high pitch 128-DSCT. We quantitatively analyzed the image quality by calculating the vascular density, muscular density, and contrast/noise ratio (CNR). We qualitatively evaluated the artifacts in the vena cava, aorta, and coronary arteries. We estimated the effective dose (ED) of radiation by means of the dose-length product.

Results: There were no significant differences between 128-DSCT and 64-MDCT in the vascular density. The VDNR and CNR were higher on 128-DSCT than on 64-MDCT in the aorta (VDNR: 28.9 ± 11.7 vs. 20 ± 5.5; CNR: 24.4 ± 10.9 vs. 16.8 ± 5.4; P < .01), in the pulmonary arteries (VDNR: 25.5 ± 10 vs. 20.6 ± 6.5; CNR: 24.5 ± 5.4 vs. 17.4 ± 6.4; P < .01), and in the coronary arteries (VDNR: 25.9 ± 8.2 vs. 18.9 ± 4.9; CNR: 24.9 ± 8.2 vs. 15.6 ± 4.6; P < .01). There were fewer artifacts in the coronary arteries on 128-DSCT than on 64-MDCT (3 vs. 34 nondiagnostic segments; P < .001), and the ED in 128-DSCT was lower than in 64-MDCT (13.77 ± 4 vs. 27.77 ± 0.6 mSv; P < .01).

Conclusion: In triple rule-out studies, high pitch 128-DSCT delivers a lower dose of radiation and provides better image quality than retrospective acquisition with 64-MDCT.

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PALABRAS CLAVE
Dolor torácico; Dosis de radiación; Tomografía computarizada

Tomografía computarizada de pitch alto en estudios de triple descarte: dosis de radiación y calidad de la imagen comparada con la de la tomografía computarizada multidetector

Resumen
Objetivo: Comparar la calidad de imagen y dosis de radiación de la TC de doble fuente (128-TCDF) con pitch alto y la adquisición retrospectiva con TC de 64 filas de detectores (64-TCMD) en estudios de triple descarte.

Material y métodos: Estudiamos retrospectivamente 60 pacientes con dolor torácico agudo: 30 con una adquisición ECG-retrospectiva con 64-TCMD y 30 con 128-TCDF y pitch alto. Analizamos cuantitativamente la calidad de la imagen calculando la densidad vascular (DV), densidad muscular (DM), ruido y cocientes densidad vascular/ruido (CDVR) y contraste/ruido (CCR). Valoramos cualitativamente los artefactos en la vena cava, aorta y coronarias. Calculamos la dosis de radiación efectiva estimada (DRE) con el producto dosis-longitud.

Resultados: No hubo diferencias significativas en la DV. Con 128-TCDF los CDVR y CCR fueron mayores en la aorta (CDVR: 28.9 ± 11.7 y 20.5 ± 5.5; CCR: 24.4 ± 10.9 y 16.8 ± 5.4; p<0.01), arterias pulmonares (CDVR: 25.5 ± 10 y 20.6 ± 6.5; CCR: 24.5 ± 5.4 y 17.4 ± 6.4; p<0.01) y coronarias (CDVR: 25.9 ± 8.2 y 18.9 ± 4.9; CCR: 24.9 ± 8.2 y 15.6 ± 4.6; p<0.01). Los artefactos coronarios (3 y 34 segmentos no diagnósticos p<0.001) y la DRE (13.77 ± 4 y 2.77 ± 0.6 mSv; p<0.001) fueron menores con 128-TCDF.

Conclusión: El pitch alto en el triple descarte disminuye la dosis de radiación y mejora la calidad de la imagen con respecto a la adquisición retrospectiva con 64-TCMD.

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Introduction

Acute chest pain (ACP) is one of the most common reasons patients go to the Spanish emergency services, accounting for 5–20% of all visits. There are multiple causes, but it is necessary to make sure when examining and ruling out those that can compromise the patient’s own life, such as aortic dissections (AD), pulmonary thromboembolisms (PTE) or acute coronary syndromes (ACS). Initial evaluation in the emergency services is performed with the medical history, the cardiac enzymes, the ECG and chest X-rays. However they may not be enough to determine the origin of pain and most patients with ACP are kept under observation even though they do not suffer from a life-threatening disease. This increases assistance pressure and the need for healthcare resources.

Multidetector computed tomography (MDCT) is the modality of choice to diagnose PTE and AD. It has been confirmed recently that it can assess coronary arteries in patients with low and medium risk of coronary disease, that is why it is being included in the ACP diagnostic algorithm in the emergency services. In addition to its capabilities of diagnosing the three (3) of them separately, a specific protocol has been developed allowing doctors to study at once the pulmonary arteries, the aorta and the coronary arteries—called triple rule-out CT. Several studies have demonstrated its capabilities in a single test. However the main disadvantage is its high radiation dose ranging between 10 and 17 mS of average.1–10

The development of 128-detector double source CT (128-DSCT) has made it possible to obtain high pitch data from the entire chest in less than a second while dramatically reducing the dose of radiation. Through high pitch cardiac DSCT it is possible to reduce the dose of radiation in up to 90% compared to retrospective studies and in 61% compared to prospective studies.11 However so far there are no clinical studies comparing the image quality of high pitch DSCT with that of conventional MDCT in triple rule-out studies.

The goal of this paper is to compare image quality and radiation dose of high pitch 128-DSCT and 64-MDCT with retrospective acquisition in triple rule-out studies in patients with ACP.

Material and methods

Patients

We studied retrospectively 60 patients who came to the ER with a clinical presentation of ACP without any related causes with low or intermediate chance of coronary disease. All patients had normal ECG and enzymes. We categorized the patients into 2 groups depending on the piece of equipment used to perform the triple rule-out CT. Thirty (30) patients had been examined using a 64-MDCT (Somatom Sensation 64; Siemens, Erlangen, Germany) and the remaining 30 through a 128-DSCT (Somatom Definition Flash; Siemens, Erlangen, Germany). All patients previously signed a written informed consent to take the diagnostic test but because it was a retrospective trial the consent to participate in the study was not obtained—requirement accepted after the hospital ethics committee approval.

We determined the age, sex, body mass index and heart rate during the acquisition in all the patients. Patients with
irregular heart rates or rates >65 beats per minute, or those allergic to iodized contrast, with kidney failure or younger than 18 years were not included.

Study modality

The studies were performed with a heart rate below 65 beats per minute. In case the rate before the test was higher, and as long as there were no contraindications, IV beta-blockers were administered (metoprolol in 5 mg boluses every 2 min, until the appropriate heart rate was reached, with a maximum of 15 mg). All patients were administered 5 mg of sublingual isosorbide.

In the 64-MDCT group a synchronized retrospective acquisition was performed with the ECG, in a caudocranial direction from the diaphragm to the apex pulmonis, 0.6 mm, 120 kV, 800 mAs collimation, 330 ms rotation time, and pitch 0.2. To optimize the dose of radiation, the modulation of dose was applied using the whole current of the tube between 60 and 75% of the cardiac cycle and reducing it to 40% outside that time window. In the 128-DSCT group, a high pitch prospective helical acquisition was performed in a caudocranial direction from the diaphragm to the apex pulmonis, 0.6 mm (2 mm × 128 mm × 0.6 mm), 120 kV, 370 mAs collimation, 280 ms rotation time, pitch 3.4. The acquisition was performed beginning at 60% of the R–R interval. In both groups the acquisition was performed in inspiration.

To properly enhance the coronary arteries, the aorta and the pulmonary arteries simultaneously we used a triple-phase injection of IV contrast. To that end, an antecubital vein was canalized and 60 ml of iopromide (Ultravist 370; Bayer Schering Pharma, Berlin, Germany) were injected at 5 ml/s, followed by 60 ml of a 30/70 mixture of contrast and serum at 5 ml/s and finally 30 ml of saline at 5 ml/s through an automatic injector (Stellant Dual; Medrad, Pennsylvania, USA). In all patients the bolus tracking technique was used placing a region of interest (ROI) of 1 cm in diameter in the ascending aorta, with a shot threshold of 160 Hounsfield units (HU) and a prefixed delay of 5 secs for the 64-MDCT and 100 HU and 11 s for the 128-DSCT.

To evaluate the coronary arteries, the images were reconstructed through a 0.6 mm cut thickness—a 0.4 mm increase, a B26f reconstruction filter and a field of vision (FOV) restricted to the heart. When the acquisition was retrospective, the reconstruction was made in the cardiac cycle phase where the coronary arteries could be better seen. The reconstructions of the entire chest were made through a 1 mm thickness—a 0.7 mm increase, a B26f reconstruction filter and a FOV of the entire chest.

Image analysis

A radiologist with 10 years of experience and a third-year resident independently analyzed the images both qualitatively and quantitatively at a working station (Leonardo; Siemens; Erlangen, Germany). Afterwards, the images were analyzed in consensus to settle any discrepancies. For the quantitative assessment, vascular density (VD) was measured in HU in the descending aorta, the pulmonary artery trunk, the main pulmonary arteries and the coronary arteries, placing a ROI of a similar diameter to the size of the vascular lumen and excluding the mural thrombi or the calcified plaques of the wall.

Muscular density (MD) was estimated by measuring the density with a 1 cm² ROI in the left paravertebral musculature. The background noise (N) was calculated through the standard deviation of a 1 cm² ROI placed in the air of 3 regions in front of the patient’s mid-chest region: right, central and left (Fig. 1). Through these measurements, the vascular density/noise ratio (VDNR) and the contrast/noise ratio (CNR) were calculated using the following equations: VDNR = VD/N and CNR = (VD − MD)/N.

The artifacts were qualitatively studied in the superior vena cava in a two-point scale (1: an important artifact that alters the image of the adjacent coronary segment; 2: without an artifact or a minor artifact that allows us to evaluate the adjacent coronary segment). The movement artifact in the aortic root was also assessed in a two-point scale (1: an artifact that does not allow us to assess the aortic valve; 2: without artifacts) and the artifacts in each of the segments of the coronary arteries divided based on the

Figure 1  Example of regions of interest (ROI) to assess vascular density in the trunk of the pulmonary artery and the descending aorta (A), right and left main pulmonary arteries (B) and coronary arteries (C). ROIs for the assessment of the left paravertebral muscle density (B). ROIs for the assessment of the noise in the air of the mid-chest region (C).
American Heart Association (AHA) classification in a five-point scale (1: without artifacts; 2: minimal artifact only diffusing the arterial wall; 3: moderate artifact; 4: significant artifact making the diagnosis difficult; and 5: significant artifact not allowing the assessment of the segment) (Fig. 2).

Estimating the dose of radiation

The effective radiation dose (ERD) was estimated through the dose-length product (DLP) with a conversion factor for the anatomical region studied that in the case of the chest, is 0.014 mSv/mGy × cm.\(^{15,15}\) The DLP was obtained based on the figure supplied by the piece of equipment in the examination protocol.

Statistical analysis

The results of the measurements of VD, MD, VDNR, CNR, subjective image quality, DLP and ERD were expressed as mean ± standard deviation. The demographic characteristics (age, sex, body mass index) VD, MD, VDR, CNR, DLP, ERD and the subjective image quality of both groups were compared using the Student \(-t\) test for unpaired samples and the Chi square. Statistical significance was established for a \(P < 0.01\).

All calculations were made through a standard PC (SPSS for Windows, version 15.0.1 SPSS, Chicago, IL).

Results

The results are summarized in Table 1. There were no significant differences in VD, but with the 128-DSCT the noise was significantly lower and the VDNR and CNR were significantly greater than those of the 64-MDCT. The artifacts in the superior vena cava and the aortic root were not significantly different. When it comes to the coronary arteries, 319 of the 425 segments evaluated through the 64-MDCT scored 1 and 36 segments scored 4 and 5 (non-diagnostic). Through the 128-DSCT 400 of the 424 segments scored 1 and only 3 were not diagnostic.

Through the 64-MDCT, 5 patients had significant coronary lesions and one patient one penetrating aortic ulcer. The remaining 25 patients did not show acute cardiovascular lesions. Through the 128-DSCT, 9 patients had significant coronary lesions and 21 did not though one patient showed signs of pericarditis and another patient one pneumothorax. PTE was not diagnosed in any of the two groups. Through the 128-DSCT and since the FOV was limited to 33 cm, 7 patients could not be studied completely from the ninth rib on. Also in three of them 1 cm of the posterior segment of the pulmonary parenchyma was cut but it had no repercussion in the diagnosis of PTE, pulmonary disease or thoracic wall disease.

There were significant differences in the DLP (810.3 ± 237.2 and 198.5 ± 45.4 mGy × cm; \(P < 0.001\)) and the ERD (13.77 ± 4 vs. 2.77 ± 0.6 mSv; \(P < 0.001\)), which were significantly lower with the 128-DSCT.

Discussion

This work confirms that high pitch triple dose CT in a DSCT decreases considerably the dose of radiation providing high diagnostic quality images.

The importance of MDCT in the study of ACP in ER has been evident in many studies,\(^{2,5,6,10,12}\) and several multicentric studies confirm the benefits of incorporating MDCT to the ACP diagnostic algorithm.\(^{16-19}\) The highly positive predictive value of the test allows ruling out coronary disease with
Table 1  Results.

<table>
<thead>
<tr>
<th></th>
<th>64-MDCT</th>
<th>128-DSCT</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>57.7 ± 11.9</td>
<td>61.2 ± 14.6</td>
<td>0.315</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>18</td>
<td>24</td>
<td>0.158</td>
</tr>
<tr>
<td>Women</td>
<td>12</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>28.1 ± 4.2</td>
<td>28.6 ± 6.7</td>
<td>0.62</td>
</tr>
<tr>
<td>Cardiac frequency (bpm)</td>
<td>63.5 ± 15.8</td>
<td>56.9 ± 6.5</td>
<td>0.039</td>
</tr>
<tr>
<td>VD (HU)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aorta</td>
<td>319 ± 72</td>
<td>324 ± 92</td>
<td>0.81</td>
</tr>
<tr>
<td>Pulmonary arteries</td>
<td>327 ± 86</td>
<td>285 ± 62</td>
<td>0.03</td>
</tr>
<tr>
<td>Coronary arteries</td>
<td>300 ± 55</td>
<td>295 ± 68</td>
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<tr>
<td>Noise</td>
<td>16.5 ± 3.6</td>
<td>11.8 ± 2.2</td>
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<td>VDNR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aorta</td>
<td>20 ± 5.5</td>
<td>28.9 ± 11.7</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Pulmonary arteries</td>
<td>20.6 ± 6.5</td>
<td>25.5 ± 10</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Coronary arteries</td>
<td>18.9 ± 4.9</td>
<td>25.9 ± 8.2</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>CNR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aorta</td>
<td>16.8 ± 5.4</td>
<td>24.4 ± 10.9</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Pulmonary arteries</td>
<td>17.4 ± 6.4</td>
<td>24.5 ± 5.4</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Coronary arteries</td>
<td>15.6 ± 4.6</td>
<td>24.9 ± 8.2</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Aorta artifacts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1: Yes</td>
<td>7</td>
<td>5</td>
<td>0.14</td>
</tr>
<tr>
<td>2: No</td>
<td>23</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Artifacts in the SCV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1: Yes</td>
<td>12</td>
<td>8</td>
<td>0.21</td>
</tr>
<tr>
<td>2: No</td>
<td>18</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Artifacts in the coronary arteries</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1 (without artifact)</td>
<td>319</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>2 (minimal artifact)</td>
<td>38</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>3 (moderate artifact)</td>
<td>34</td>
<td>5</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>4 (significant artifact)</td>
<td>18</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>5 (severe artifact)</td>
<td>16</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>DLP (mGy × cm)</td>
<td>810.3 ± 237.2</td>
<td>198.5 ± 45.4</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>ERD (mSv)</td>
<td>13.77 ± 4</td>
<td>2.77 ± 0.6</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

CNR: contrast/noise ratio; VDNR: vascular density/noise ratio; cm: centimeter; DLP: dose length product; ERD: effective radiation dose; VD: vascular density; BMI: body mass index; bpm: beats per minute; mGy: miligrays; mSv: millisievert; DSCT: dual source computed tomography; MDCT: multidetector computer tomography; HU: Hounsfield units; SCV: superior cava vein.

much certainty that in turn improves the clinical decision-making process by allowing doctors to discharge patients who have a normal test without an increase in the coronary episodes or deaths. Another advantage is the lower costs, since the length of hospital stay per patient and the number of readmissions are reduced.16-19 However, CT coronaryography is more useful in patients with low and intermediate risk of coronary disease. In high-risk patients calcified plaques of the arterial wall make it difficult to assess the vascular lumen, can lead to false positives and increase the number of catheterisms.20,21

A main setback of CT coronaryography is the dose of radiation—close to 17 mSv. Technological advances have made it possible to develop strategies to reduce it: low kilovoltage,22 modification of the tube current,23,24 prospective acquisition,25 acquisition in a single heartbeat—both with 320 detector pieces of equipment26 and with the high pitch protocol in the DSCT13 and, more recently, iterative reconstruction27 or the kilovoltage automatic selection systems.28 The goal is trying to reduce the dose of radiation to the minimum without affecting image quality significantly.

Several studies have proved in patients and mannequins that the assessment of coronary arteries with DSCT and high pitch diminishes the doses of radiation and increases image quality compared to conventional MDCT.29-32 However, we have no knowledge of other published studies evaluating image quality and doses of radiation comparing both pieces of equipment in triple rule-out studies, including the joint evaluation of coronary arteries, pulmonary arteries and the aorta. Our major finding is the reduction of the dose of radiation with DSCT up to five times lower than that of the MDCT. This may be due to the fact that the high pitch protocol allows us to study the entire chest in a single heartbeat,
synchronizing the best timing of cardiac acquisition at 60% of the cardiac cycle, which dramatically reduces the examination time and the dose of radiation. In addition, noise was significantly lower with the DSCT which can be due to a larger number but above all due to the technological advancements made in new detectors in last-generation pieces of equipment capable of generating lower levels of noise which in turn increases the correlation between vessel density and noise as represented by the VDNR and CNR ratios. The VD values in the aorta, pulmonary arteries and coronary arteries are high and fit to assess alterations in all territories. This is achieved through a three-phase protocol that while mixing contrast and serum maintains an adequate enhancement of the pulmonary and coronary arteries, and the aorta by minimizing the artifacts due to excessive contrast in the superior cava vein.33

The qualitative assessment of coronary segments was better in the DSCT as well. The temporal resolution of these pieces of equipment is greater, and with the high pitch protocol, the acquisition of the heart and the telediastole are made to coincide—the optimal phase to assess it. Therefore, the movement artifacts due to heart beats of remaining steps for reconstruction with data from different cardiac cycles and the artifacts due to respiratory movement are less common. All this explains why there is a smaller number of non-diagnostic coronary segments with the DSCT.

This study has some limitations. It was conducted in just one center with a small number of patients. Broader, prospective, randomized and multicenter studies are necessary to ensure the advantages of this protocol in the study of ACP. Also we compared 2 different acquisitions with 2 different pieces of equipment, with different numbers of detectors. Ideally, the retrospective acquisition and the high pitch acquisition should be compared with the same DSCT piece of equipment. Another limitation is the influence of heart rate on image quality though the high temporal resolution of the retrospective ECG studies with DSCT allows us to get diagnostic images in patients with a broad range of heart rates.34,35 When the high pitch protocol is used it is still essential to keep a low, stable rate, with broad, regular diastoles that allow predicting the optimal timing for the acquisition in order to get all data when cardiac movement is the lowest.36 So in an effort to minimize this limitation, beta-blockers were administered to patients whose heart rate was over 65 bpm. Finally, another limitation is the calculation of the dose of radiation not done directly with mannequins yet it is true that the formula that allowed us to obtain the dose with the protocol supplied by the piece of equipment has proven to be highly concordant with real doses in adult patients.37

Yet despite these limitations, we can conclude that the high pitch-protocol DSCT in triple rule-out studies uses less dose of radiation and has a better image quality than the retrospective acquisition of the 64-MDCT.

Data confidentiality. The authors declare that the protocols of their institution on the publishing of data from patients have been followed.

Protection of people and animals. The authors declare that the proceedings followed abide by the rules settled by the corresponding ethical committee on human experimentation, the World Health Organization and the Helsinki Declaration.

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3. Study design: CDS, GTF.
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5. Data analysis and interpretation: AFV, CDS.
6. Statistical analysis: CDS, GTF.
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8. Writing: AFV, CDS.
9. Critical review of the manuscript with intellectually relevant remarks: CTL, ROP, ABF, AGA, GTF, CDS, AFV.
10. Approval of final version: AFV, CDS, ROP, AGA, ABF, CTL, GTF.

Conflict of interests

The authors declare no conflict of interests.

References


Ethical responsibilities

Right to privacy and informed consent. The authors have obtained prior informed written consent from patients and/or subjects referred to in this article. This document is in the possession of the corresponding author.


