

# Optimization of the scan protocol in the measurements of coronary artery calcium

## Otimização do protocolo de exame nas medidas do cálcio arterial coronário

Larissa C. G. Oliveira<sup>1</sup>, Ilan Gottlieb<sup>2</sup>, Fabrício M. de Carvalho<sup>2</sup>, Larissa C. Pinheiro<sup>3</sup>, Simone Kodlulovich<sup>3</sup>, Fernando A. Mecca<sup>4</sup> and Ricardo T. Lopes<sup>1</sup>

<sup>1</sup>Laboratório de Instrumentação Nuclear (LIN/COPPE/UFRJ) - Centro de Tecnologia, Rio de Janeiro (RJ), Brazil.

<sup>2</sup>Clínica de Diagnóstico por Imagem, Rio de Janeiro (RJ), Brazil.

<sup>3</sup>Instituto de Radioproteção e Dosimetria (IRD/CNEN), Rio de Janeiro (RJ), Brazil.

<sup>4</sup>Instituto Nacional do Câncer, Rio de Janeiro (RJ), Brazil.

### Abstract

The aim of this study was to evaluate the influence of the tube current applied for studies of calcium score. The research was carried out in a private clinic of Rio de Janeiro, using a 64-slice MDCT scanner and an anthropomorphic cardiac computed tomography phantom. In all images, the Agatston score, the volume and mass of the calcifications, and the noise for each current tube were determined. The average computed tomography attenuation number obtained for all tube currents was  $261.6 \pm 3.2$  HU for the CaHA density insert and  $-0.2 \text{ HU} \pm 2.0$  for the water insert. The images obtained at lower tube currents were noisier and grainier than those obtained at higher tube currents. However, no significant differences were found in the calcium measurements, which suggest a high potential of patient dose reduction, around 50%, without compromising diagnostic information.

**Keywords:** cardiovascular disease, multi-detector computed tomography and quantification of coronary artery calcium.

### Resumo

O objetivo deste estudo foi avaliar a influência da corrente de tubo aplicada aos estudos do escore do cálcio. A pesquisa foi realizada em uma clínica particular no Rio de Janeiro, utilizando um tomógrafo computadorizado de 64 cortes e fantoma antropomórfico cardíaco de tomografia computadorizada. Em todas as imagens, o escore de Agatston, o volume e a massa das calcificações e o ruído para cada corrente de tubo foram determinados. O número de tomografia computadorizada médio, em unidades de Hounsfield (HU), obtido para todas as correntes de tubo foi de  $261,6 \pm 3,2$  HU, para a inserção da densidade CaHA, e  $-0,2 \text{ HU} \pm 2,0$ , para a água. As imagens obtidas em correntes de tubo baixas foram mais ruidosas e granuladas do que aquelas obtidas em correntes de tubo elevadas. No entanto, não foram encontradas diferenças significativas nas medidas do cálcio, o que sugere um grande potencial de redução da dose ao paciente, em torno de 50%, sem comprometer as informações para o diagnóstico.

**Palavras-chave:** doença cardiovascular, tomografia computadorizada multidetectores e quantificação de cálcio arterial coronário.

### Introduction

The amount of calcium deposits in the coronary arteries is an indirect marker of total atherosclerotic burden, and it has been strongly associated with future cardiac events in asymptomatic patients<sup>1,2</sup>. As calcium has high X-ray attenuation, its detection can be easily performed with a gated noncontrasted computed tomography (CT) of the heart<sup>3</sup>.

The Agatston score method was first used in 1990 and is based on the area and density of the calcified plaques<sup>4</sup>. High reproducibility of this scoring method is desirable, since it is widely used both in clinical and in research settings<sup>5</sup>.

The introduction of the multidetector CT (MDCT) improved the detection of lesions or obstructions (stenosis) of coronary arteries, especially in contrasted cardiac studies<sup>6,7</sup>. The combination of higher rotation speeds and larger coverage per rotation has allowed a more accurate depiction of the coronary artery tree. As a result, the usage of this procedure significantly increased in recent years, providing great clinical benefit in terms of incipient and obstructive atherosclerosis detection. However, the progressive increase of the collective dose became an important concern<sup>8</sup>. The aim of this study was to evaluate the influence of the tube current in measured calcium score.

## Materials and methods

The quantification of coronary calcium was performed in a private clinic of Rio de Janeiro, using a 64-slice MDCT scanner (Brilliance 64, Philips Medical Systems, the Netherlands) and an anthropomorphic cardiac CT phantom (QRM, Moehrendorf, Germany). The cardiac phantom was positioned on the patient's couch, and its rear edge was aligned with the laser beam of the gantry (Figure 1).

The cardiac CT contains nine calcified cylinders and two large calibrations inserts. The nine calcified cylinders are divided into three sets, each with calcium hydroxyapatite (CaHA) densities of 200, 400, and 800 mg/cm<sup>3</sup> and diameters of 5, 3, and 1 mm, respectively. The two large calibration inserts are made of water and spongy bone (200 mg/cm<sup>3</sup> CaHA density), which are equivalent materials.

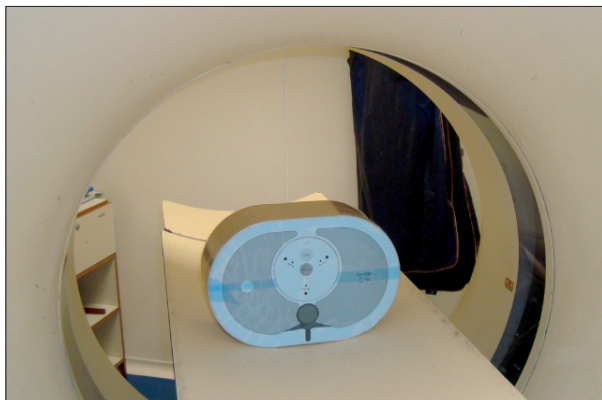
The scan protocol used was the standard spiral CT protocol for chest examination: 120 kVp, 64 x 0.625 mm collimation and 0.5 seconds, per rotation. The effective tube current levels increased from 80 to 180 mAs with an interval of 20 mAs.

After data acquisition, all images were transferred to a dedicated Philips workstation, where the Agatston, volume and mass scores were determined according to guidelines, but, in short, the Agatston score was determined by setting a threshold of 130 HU and ignoring structures smaller than 1 mm<sup>2</sup> to exclude noise from the calculation<sup>6</sup>. Depending on the peak attenuation of the calcified cylinder, the calcified area was multiplied by one of the following factors (F): 130-199-HU: F=1; 200-299 HU: F=2; 300-399 HU: F=3 and for higher than 400 HU: F=4.

The calcified cylinders volume was determined as the number of voxels  $N_{\text{voxel}}$  in the volume data set, which belong to the calcification multiplied by the number of one voxel  $V_{\text{voxel}}$ , according to the following equation:

$$V = N_{\text{voxel}} \cdot V_{\text{voxel}} \quad (1)$$

To obtain the CaHA mass, a calibration measurement of a calcified cylinder with known CaHA density ( $\rho_{\text{CaHA}}$ ) was



**Figure 1.** Anthropomorphic cardiac CT phantom in the gantry.

performed, and a calibration factor  $c$  was determined for each current level, according to the Eq. 2:

$$c = \rho_{\text{CaHA}} / (CT_{\text{cylinder}} - CT_{\text{water}}) \quad (2)$$

The calibration factor  $c$  is, therefore, given by the CaHA density ( $\rho_{\text{CaHA}}$ ) of the known calcified cylinder divided by the mean difference in CT numbers of the calcified cylinder and one of the two large inserts made of water-equivalent material ( $CT_{\text{cylinder}} - CT_{\text{water}}$ ), in the calibration measurement. The measured CaHA mass multiplied by the respective calibration factor corresponds to the value of the CaHA mass.

Image noise measurements were assessed in all images, which were obtained for different values of tube current. For each tube current, three region-of-interests (ROIs) were evaluated. A circular ROI (200 mm<sup>2</sup> approximately) was placed in each image. The CT number and the standard deviation (SD) were determined in the homogeneous large insert (CaHA density of 200 mg/cm<sup>3</sup>). The CT number and SD in the water insert were similarly measured to calculate the calibration factor.

## Results and Discussion

The averaged CT number attenuation obtained for all tube currents was 261.6 HU±3.2 for the CaHA density insert and -0.2 HU±2.0, for the water insert.

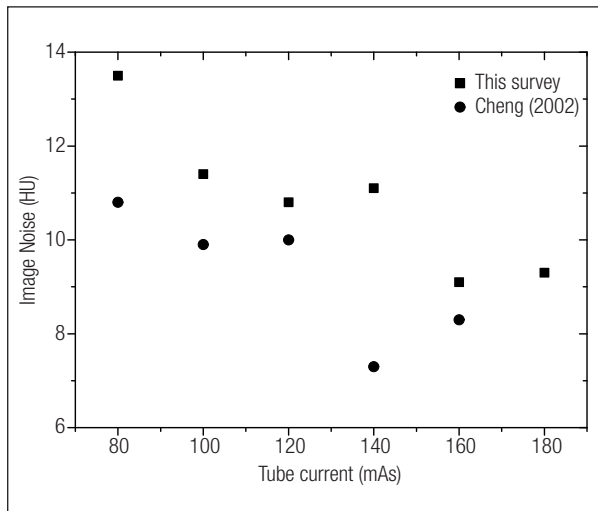
The values for Agatston score, the volume and mass measurements of the individual calcified cylinders, and their corresponding tube current are presented in Table 1. Of the nine calcified cylinder presented in the phantom, only six cylinders were visible on the image and measurable at the 130 HU threshold in each tube current. The three cylinders with 1 mm diameter were excluded in this survey due to their size limitation. The Agatston, volume and mass values, when compared, the values measured by the manufacture, our values were lower.

Image noise expressed as the SD of the CT number of the CaHA insert ranged from 13.5 HU, at 80 mAs, to 9.1 HU at 160 mAs. Figure 2 presents the values found in this survey and by Cheng et al.<sup>1</sup>. As expected, images obtained at lower tube currents were noisier and grainier than those

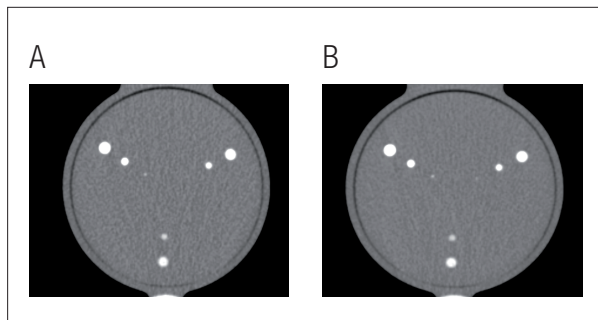
**Table 1.** Measurements for calcified cylinders in calibration insert at different tube current.

HA density (mg/cm <sup>3</sup> )	Size (mm)	Mean CT number (HU)	Agatston score	Volume (mm <sup>3</sup> )	Mean mass (mg)
200	5	197.0	39.2	58.7	9.7
	3	146.5	7.9	2.6	2.4
	1	-*	-	1.4	-
400	5	747.7	78.4	58.7	37.3
	3	473.6	31.6	22.6	8.9
	1	-	-	6.8	0.3
800	5	398.3	58.8	58.7	19.8
	3	239.8	15.8	22.6	4.6
	1	-	-	6.8	0.4

\*Nonmeasurable.



**Figure 2.** Relationship between tube current and image noise.



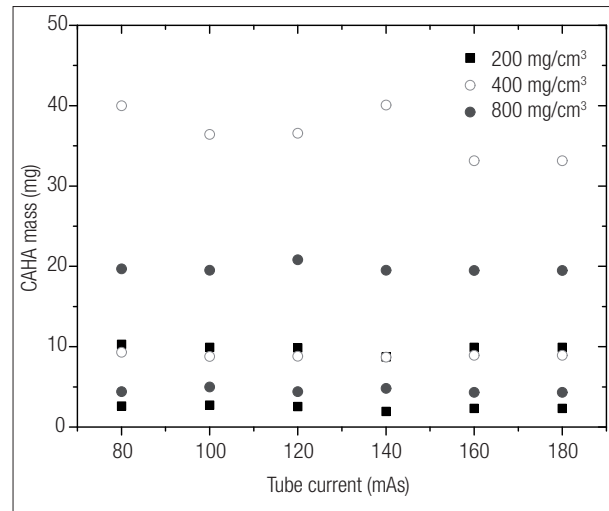
**Figure 3.** Images obtained at 80 (A) and 160 mAs (B) demonstrating image noise.

obtained at higher tube currents. However, in the Figure 3, it is possible to observe that it is feasible to obtain an image with an optimized current value adequate to the diagnostic and, consequently, to reduce the patient's dose.

Although a reduction in the tube current from 160 to 80 mAs resulted in a noisier image, no significant differences were found in the calcium measurements obtained with the CaHa mass (Figure 4). The same behavior was observed for the calcium volume.

## Conclusions

The results obtained in this research of calcium quantification deposits on coronary artery the quantitative scoring methods, such as Agatston, calcium volume, and mass scoring suggests a high potential of patient's dose reduction, around 50%, without compromising diagnostic information.



**Figure 4.** Relationship between tube current and CaHa mass.

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