



# Dual-Energy Evaluation of High Calcium Score (>400) Coronary Artery

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## Abstract

Coronary computed tomography angiography (CCTA) is widely used as a noninvasive cardiovascular imaging modality that allows visualization of both calcified and noncalcified atherosclerotic plaques and exclusion of coronary luminal stenoses with high diagnostic performance. However, high (>400) coronary artery calcium score (CACS) may increase the false-positive rate and decrease diagnostic accuracy due to beam-hardening artifacts resulting from heavily calcified plaques. For patients with high CACS cannot be reliably evaluated with CCTA and invasive coronary angiography (ICA) is frequently recommended in routine clinical practice. Recently, dual-energy CT (DECT) has been introduced to reduce beam-hardening artifacts and improve the diagnostic performance of CCTA in patients with severe coronary calcification. In this chapter, we will investigate the implication of CACS and further discuss the application of DECT in patients with CACS.

## 4.1 Case of High Calcium Score (>400) Coronary Artery

### 4.1.1 History

A 52-year-old male patient felt sudden chest pain in the night, which travels to the left arm, shortness of breath, sweating, nausea, and vomiting 2 months ago. After taking medicine, his symptoms relieved. For further diagnosis, this patient came to our hospital and made a reservation for a cardiac CT examination due to suspected myocardial infarction.

#### 4.1.1.1 Physical Examination

- Blood pressure: 103/73 mmHg
- Breathing rate: 15/min
- Heart rate: 67 bpm

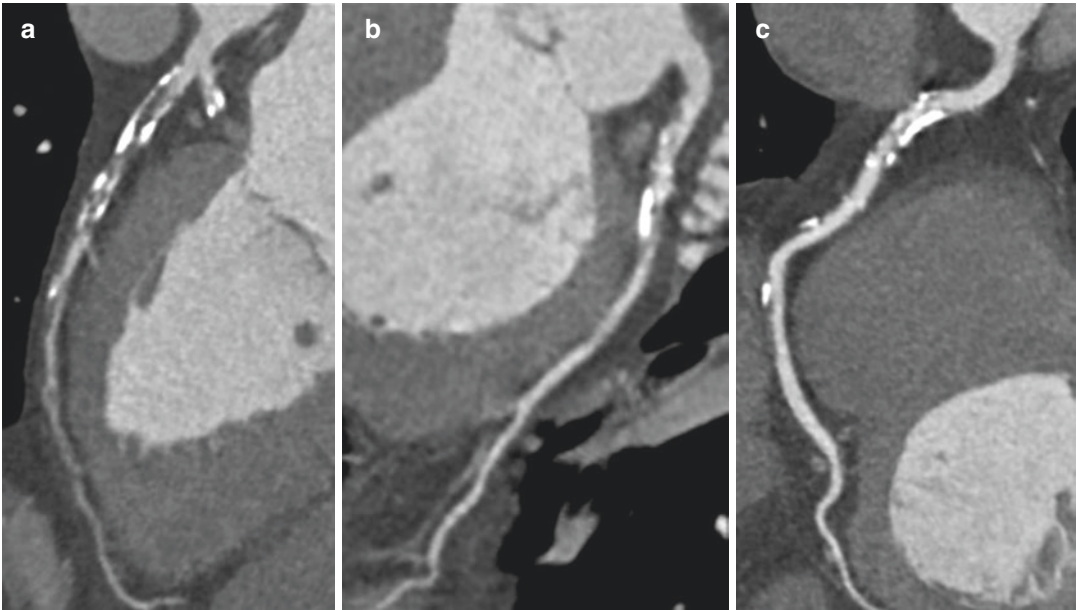
#### 4.1.1.2 Electrocardiograph

Reversed T wave, ST segment elevation.

#### 4.1.1.3 Laboratory

Serum myocardial enzyme spectrum showed negative results.

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**Fig. 4.1** Curved multi-planar (CPR) reconstructed images (**a**, left anterior descending [LAD]; **b**, left circumflex artery [LCX]; **c**, right coronary artery [RCA]) of the

CCTA. There are multiple calcified plaque and mixed plaque in the three coronary arteries

## 4.1.2 Imaging Examination

### 4.1.2.1 CT Images

CCTA image was obtained from DECT to evaluate plaque and coronary lumen (Figs. 4.1 and 4.2)

### 4.1.2.2 Conventional Coronary Angiography (Fig. 4.3)

## 4.1.3 Imaging Findings and Diagnosis

The CCTA image results showed multiple mixed plaque in LAD, in which severe stenosis in the proximal and middle segment and moderate stenosis in the distal segment. There were multiple mixed plaques in the proximal–middle segments of LCX leading to severe stenosis. Mild-moderate stenosis exists in the middle segment resulting

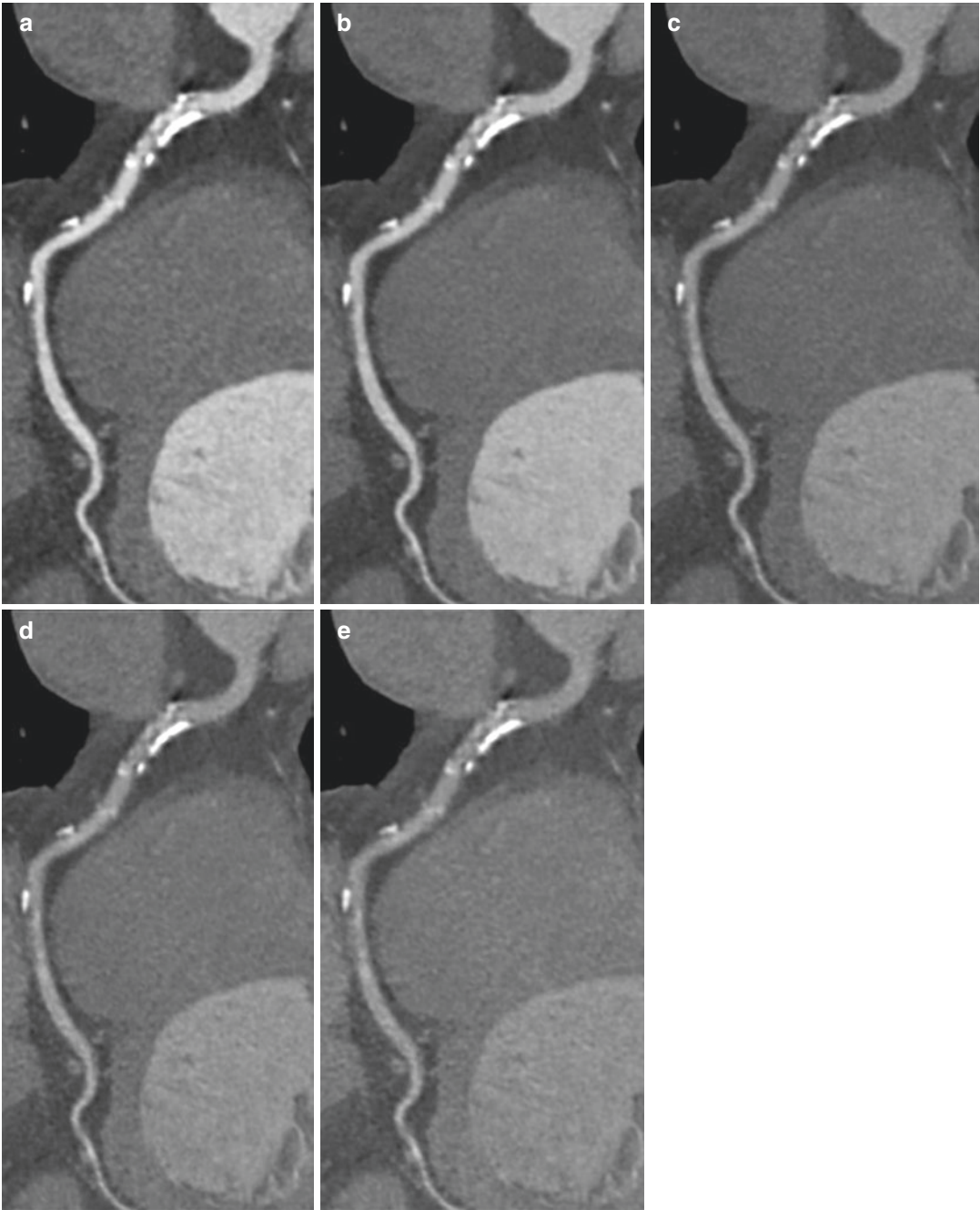
from multiple mixed plaques of RCA. High monoenergetic imaging from DECT can decrease effectively calcified blooming artifact. The invasive coronary angiography images confirmed multiple stenosis in three coronary arteries.

## 4.1.4 Management

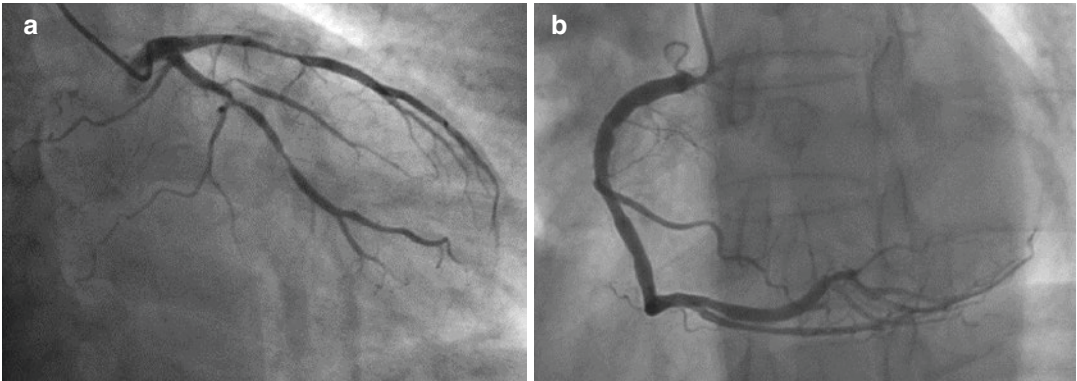
- Coronary artery bypass grafting operation
- Conventional medical therapy for coronary artery disease (CAD)

## 4.2 Discussion

Coronary artery calcium (CAC) is a highly specific feature of coronary atherosclerosis in CAD. The prevalence of CAC continues to increase with growing age, and men have higher



**Fig. 4.2** Different monoenergetic image [(a) conventional CT image; (b) 80 keV monoenergetic image; (c) 100 keV monoenergetic image; (d) 120 keV monoenergetic image; (e) 150 keV monoenergetic image] were obtained from DECT. High monoenergetic image can reduce calcium blooming artifact



**Fig. 4.3** Percutaneous coronary intervention (PCI) results. Invasive coronary angiography image for LAD (a), LCX (a) and RCA (b), confirmed multiple stenosis in three coronary arteries

calcium levels than women [1]. In addition, patients with high risk factors, such as diabetes mellitus, dyslipidemia, and hypertension, are more susceptible to CAC. The calcium score proposed by Agatston et al. remains the most widely accepted technique for predicting major adverse cardiovascular events and it is determined by the product of the total size and density of the calcified plaque deposited in the coronary artery tree [2]. Standardized categories for CACS include scores of 0 with the absence of calcified plaque, 1 to 10 with minimal plaque, 11 to 100 with mild plaque, 101 to 400 with moderate plaque, and >400 with severe plaque. And CACS >400 indicates significant prognostic implications in specific patient groups [3]. Other techniques for the measurement of coronary artery calcium are volume score and mass score [4].

Intravascular ultrasound (IVUS) has high diagnostic performance in identifying and characterizing plaque composition [5]. According to the range of calcified lesion detected by IVUS, CAC is divided into four classes: Class I with  $0^{\circ}$ – $90^{\circ}$  calcification, Class II with  $91^{\circ}$ – $180^{\circ}$  calcification, Class III with  $181^{\circ}$ – $270^{\circ}$  calcification, and Class IV  $>270^{\circ}$  calcification [3].

Optical coherence tomography (OCT) is also an intravascular imaging modality that enables providing cross-sectional images of tissue and has high sensitivity and specificity to identify atherosclerotic plaques [6]. Moreover, optical

coherence tomography can be used to assess the thickness and volume of calcified plaque.

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### 4.3 Current Technical Status and Applications of CT

DECT is a novel technology that allows the acquisition of two different datasets from two different X-ray spectra energies. Current techniques for DECT are divided into source-based and detector-based technique [7]. Source-based DECT includes dual-source scanner (two X-ray source–detector systems), rapid kVp switching scanner (a single X-ray source–detector system), dual-spin scanner (a single X-ray source and a single detector layer), and twin-beam scanner (X-ray beam is split into two energy spectra by pre-filtration). Detector-based DECT includes dual-layer detector and photon counting scanner. These techniques not only provide new clinical application for cardiac CT, but also overcome some disadvantages which exist in conventional CT.

Virtual monoenergetic imaging (VMI) generated from DECT reconstruction is analogous to imaging with a monoenergetic beam at single kiloelectron voltage (keV). Although calcium blooming artifact from coronary calcified plaque can lead to overestimate lumen stenosis at conventional CT, it is reduced at DECT by using high monoenergetic imaging. There are some



evidences that calcium blooming effectively decreases at higher monoenergetic levels [8, 9]. Moreover, the use of monochromatic reconstructions improved the overall accuracy of coronary stenosis assessment using ICA as a standard of reference [10].

Calcium subtraction imaging can be obtained at conventional CT, but this technique will increase image misregistration risk and radiation dose [11]. In contrast, DECT has the ability to differentiate intravascular calcium from iodine contrast medium based on its material decomposition during image acquisition. Consequently, virtual calcium subtracted images derived from DECT were generated using dedicated subtraction algorithms. The study of De Santis D et al. demonstrated a prototype calcium subtraction algorithm from DECT that can improve coronary lumen assessment and increase diagnostic confidence in patients with heavy calcified coronary artery [12].

Virtual non-contrast (VNC) imaging is characterized by iodine elimination from CT angiographic imaging. Compared with true non-contrast imaging, VNC imaging can be obtained at one acquisition and thereby reduce radiation dose. Moreover, this technique can be used to differentiate contrast medium and other non-iodine material, such as calcified plaque and metal implanted material. VNC imaging can be used for CACS analysis. CACS from VNC imaging has excellent correlations compared with those from true non-contrast imaging [13, 14].

DECT provides multiple possibilities for calcified plaque analysis by different reconstruction algorithms, which are beneficial to disease diagnosis and clinical management.

#### 4.4 Key Points

- CACS is a reliable technique for cardiac events risk evaluation.
- High keV monoenergetic imaging can decrease calcium blooming artifact.
- Calcium subtraction imaging and VNC imaging can reduce radiation dose.

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