



Comprehensive guide to coronary CT angiography protocols & technique

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Abstract

Coronary CT angiography (CCTA) is a non-invasive imaging technique used for evaluating coronary artery disease (CAD). To achieve diagnosis accuracy, careful planning and a well-organized technique are essential. The Coronary artery image quality while minimizing radiation exposure and to patient discomfort CT angiography is preferably used. The key elements of a thorough CCTA protocol, including as patient preparation, scanning parameters, and post-processing techniques, are described in this article. The procedures include breath-hold training to minimize motion artifacts, beta-blocker-assisted heart rate management, and fasting for the best possible contrast enhancement [1].

Electrocardiogram (ECG) gating is used during the scan to synchronize image acquisition with the cardiac cycle, improving quality and minimizing distortions caused by motion. Intravenous contrast administration is used for better visualization of coronary arteries. Optimization techniques are employed for radiation dose reduction in order to ensure patient safety. Images are reconstructed with thin slices after scanning, and 3D volume rendering and multiplanar reconstruction (MPR) are used for analysis. For accurate interpretation and the best possible image quality depend on proper technique and protocol [2].

Keywords: Coronary CT angiography electrocardiogram (ECG) gating, multiplanar reconstruction (MPR), interpretation, 3D volume, and optimization techniques

Introduction

Coronary Artery Computed Tomography Angiography (CCTA) has become a key component in the non-invasive assessment of coronary artery disease (CAD). Its capacity to produce high-resolution pictures of the coronary arteries allows for a detailed assessment of the coronary anatomy, plaque burden, and luminal stenosis. Recent developments in scanner technology, image reconstruction techniques, and protocol optimization have led to a major expansion in the use of CCTA. Current developments in CT hardware and scanning methods for coronary CTA include 64-slices to 384 slice, and dual-source CTs, which are clinically utilized for coronary CTA [3-4].

There are numerous scan modes available; such as the following; Adaptive prospective ECG-triggered axial sequence coronary angiography in dual-source CT without heart rate control, prospective ECG-triggered volume axial scan with wide detector arrays, and retrospective electrocardiography (ECG)-gated helical scan [5].

In addition, coronary artery calcium (CAC) scoring protocol is another tool used in CCTA to determine the extent of coronary disease like; stenosis, arteriosclerosis etc. CAC scoring section explores the technique, scan acquisition protocols, parameters used for coronary CT angiography. This article provides the basis for exploring the indications, protocols, technical aspects, scanning parameters, contrast administration, and post-processing techniques required to achieve optimal diagnostic outcomes [6].

Aims and Objectives

The purpose of coronary CT angiography is to instruct trainees and associates who are performing coronary procedure on CT scan that how to meet the numerous challenges related to its protocols and technique. These challenges may affect patient outcomes, diagnostic precision, and image quality. For example; Irregular heart

rates due to atrial fibrillation, ectopic beats that can result in motion artifacts, which lowers the quality of images. Motion artifacts can also be caused by inadequate breath-holding of the patient during image acquisition [7].

Additional, to provide detailed images of the coronary arterial wall and lumen to detect and assess coronary artery disease (CAD) like; stenosis, atherosclerotic plaques, and other abnormalities by integrating artificial intelligence (AI) [8] with sophisticated software and other methods to enhance patient outcomes [9].

Morphology

Morphology in Coronary CT Angiography (CCTA) is particularly valuable in evaluating the characteristics of its high resolution and ability to provide detailed imaging techniques. Morphology assessment is essential in CCTA for the diagnosis and evaluation of congenital abnormalities, coronary artery disease (CAD), and other structural abnormalities.

The overview of the Morphology of Coronary CT Angiography (CCTA)

1. Coronary Artery Anatomy Main Coronary Arteries:

- The Left Anterior Descending (LAD) and Circumflex (LCx) arteries are the two branches of the Left Main Coronary Artery (LMCA).
- Right Coronary Artery (RCA): Supplies blood to the right heart and posterior regions.

2. Coronary Artery Pathologies

Atherosclerotic Plaque Characterization

- High-density deposits inside the artery wall are known as calcified plaques.
- Soft, lipid-rich plaques with less attenuation are known as non-calcified plaque.

- A mix of calcified and non-calcified materials makes up mixed plaque ^[10].

Stenosis

- Evaluation of arterial segment narrowing severity
- Stenosis is classified as mild (<50%), moderate (50–70%), and severe (>70%) ^[11].

3. Coronary Arteries Anomalies

- **Anomalous Origin:** Coronary arteries that emerge from an odd place, such as the left coronary sinus (RCA).
- **Aberrant Course:** The inter-arterial course is the name given to the arteries that run between the large vessels.
- **Congenital Absence:** In rare instances, certain coronary branches are absent ^[12].

4. Remodeling of Coronary Arteries

- **Positive Remodeling:** expansion of the artery wall at the plaque site, which is frequently observed in atherosclerotic plaques that pose a high risk.
- **Negative Remodeling:** calcification or fibrosis-induced vessel narrowing ^[13].

5. Plaque Morphology

The Attenuation Values

- Soft plaques (less than 30 HU, or Hounsfield Units).
- Plaques with fibrous material (30–150 HU).
- Plaques of calcification (>150 HU).

Features at High Risk

- Plaques with low attenuation.
- Enhancing remodeling
- Localized calcification.
- The napkin-ring indication, which indicates plaques that are susceptible ^[14].

Methods and Material

Coronary CT angiography was performed on Dual Source 2x128 slice (SOMATOM definition Flash) Siemens Helical CT Scan system.



Fig 1: Siemens SOMATOM Definition Flash CT Scanner

General Specifications

- **CT Type:** Dual Source, Dual Energy
- **Slice Count:** 2x128 slices
- **Detector Rows:** Two separate arrays of detectors
- **Rotation Speed:** 0.28 seconds per full rotation
- **Spatial Resolution:** Up to 0.33 mm
- **Temporal Resolution:** 75 ms (ideal for cardiac imaging).
- **Maximum Scan Speed:** Up to 458 mm/sec with Flash Spiral.
- **Tube Voltage:** 70, 80, 100, 120, and 140 kVp
- **Tube Current:** Up to 1300 mA (per tube)
- **X-ray Tubes:** Two high-powered X-ray tubes.
- **Generator:** 200 kW (2 x 100 kW)
- **Detector Technology:** Stellar Detector with 128 detector rows per source.
- **Field of View (FOV):** Maximum scan FOV: 500 mm and Reconstruction FOV: Up to 700 mm.
- **Gantry opening:** 78 cm
- **Table Load Capacity:** 300 kg (600 lbs) ^[15]

Software Used for Coronary CTA

1. **Syngo.Via Imaging Platform:** Advanced tools for viewing, processing, and interpreting coronary CTA images are provided by the central imaging software.

Important Cardiac Modules

Syngo. CT Cardiac Function: Automates coronary artery stenosis measurement, labelling, and segmentation.

Syngo. CT Calcium Scoring: Computes Agatston scores for coronary artery calcifications.

Syngo. CT Dynamic Angio: enables real-time assessment of blood flow and cardiac perfusion.

2. **Dual Energy Imaging Software:** Enables dual-energy imaging to distinguish between compounds such as calcium and iodine by using both X-ray sources. Allows for iodine mapping and virtual non-contrast imaging, which eliminates the need for extra scans.

3. Iterative Reconstruction Techniques

Safire (Sinogram Affirmed Iterative Reconstruction): Improves image sharpness while using low radiation dose.

Admire (Advanced Model-Based Iterative Reconstruction): Produces incredibly high-quality images with very little radiation exposure.

4. **Heart Rate Adaptive Imaging:** Reduces motion artifacts by dynamically modifying scanning methods according to the patient's heart rate.

5. Automated Workflow Tools

Care KV: The optimal x-ray tube voltage is automatically determined based on the patient's size and the scan type.

Care Dose 4D: enables real-time tube current adjustment for dose optimization.

Fast Care: helps to improve workflow productivity by automating bolus tracking, scan range, and positioning.

6. **Syngo.via Cinematic Rendering:** For diagnostic and instructional purposes, it offers comprehensive, lifelike 3D representations of coronary arteries [16].

Coronary Ct Angiography (Ccta) Protocols & Technique

Protocols of CCTA: Coronary CT Angiography (CCTA) protocols are used to reduce motion artifacts and increases contrast enhancement while obtaining high-resolution images of the coronary arteries.

Scan Modes

Electrocardiogram (ECG) Gating: Electrocardiogram (ECG) gating, which synchronizes picture capture with specific cardiac cycle phases to minimize motion artifacts and enhance image clarity, is a crucial technique in Coronary CT Angiography (CCTA).

Types of Ecg Gating

1. **Sequential Scanning with Prospective ECG-Gated:** A certain cardiac cycle phase—typically diastole—is used to capture the images.

Benefits: Reduced radiation exposure in contrast to retrospective gating. And Ideal for people whose heart rates are steady and modest (50–65 bpm).

Limitations: Restricted phase acquisition makes it difficult to evaluate heart function [17].

2. **Retrospective ECG-Gated Spiral Scanning:** Constant scanning with synchronized ECG throughout the cardiac cycle.

Benefits: Provide pictures for functional evaluation (wall motion, ejection fraction). And ideal for people with elevated heart rates or arrhythmias.

Limitations: Higher dose of radiation than with prospective gating.

3. **High-Pitch Spiral Scanning (Flash Mode):** Dual-source CT systems record image in a single pulse at high pitch (e.g., >3).

Benefits: Low radiation with ultra-fast imaging and perfect for those whose heart rates are steady and extremely low.

Limitations: Not suitable for arrhythmic patients [18].

Phases of Cardiac Cycle

For Coronary CT Angiography (CCTA), the best times during the cardiac cycle to acquire images are essential for

reducing motion artifacts and improving image quality.

Types of Cardiac Phase Cycle

1. **Diastolic Phase (between 70 and 80 percent of the R-R period):** low heart motion, making it ideal for coronary artery imaging.

2. **Phase of Systole (30–40% of the R-R interval):** used in certain situations (like as tachycardia) where diastole is less steady [19].

Protocol for Coronary CT Angiography (CCTA)

- DS Cardiac CTA Safire.
- Topogram
- DSCaSC
- Contrast – Test Bolus
- Contrast - DS Cor CTA

Calcium Scanning

There is a correlation between the amount of calcium in the coronary arteries and the severity of coronary artery disease and, in turn, the risk of a cardiac event.

Software is then used to analyze the resulting images in order to detect calcium in the arteries as well as its volume. The degree of calcification is then graded using the "score" that is produced [20].

Method of Cardiac Scan

1. **Prospective Gating**
2. **Retrospective Gating**

1. Prospective ECG-Gated Axial Scan

- Compared to a retrospectively gated helical approach, Step & Shoot cardiac scans can save up to 80% on dose while preserving the best possible image quality.
- **Calcium Scoring Technique:** The examination begins by positioning the patient on the CT examination table in supine position.
- An electrocardiograph (ECG) device, which records the electrical activity of the heart, has electrodes connected to the chest. Because of this, CT scans can be taken even when the heart is not beating [21-22].
- To ascertain the proper starting position for the scans, the table is then swiftly moved through the scanner. The actual CT scanning is then carried out by slowly moving the table through the scanner.
- While pictures are being taken from the carina to the base of the heart, patients are urged to hold their breath for eight to ten seconds.
- The entire procedure including the actual CT scanning is usually completed within 10 minutes [23-24].

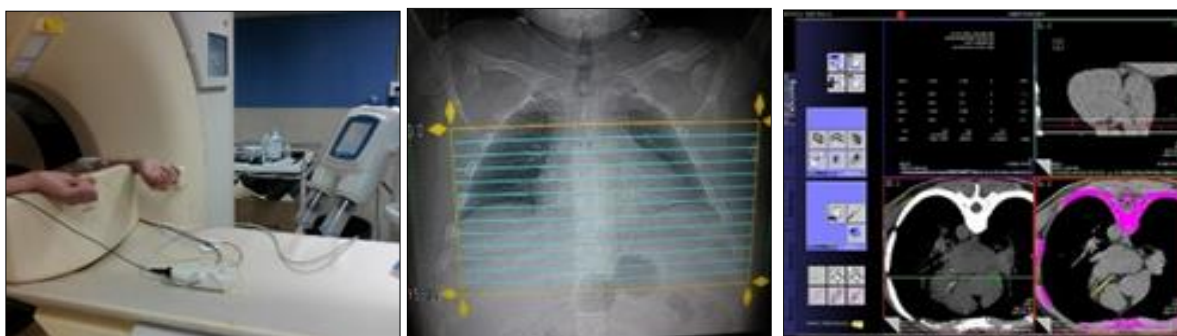


Fig (2,3, 4): A. (Positioning of patient) B. (Planning of patient) C. (calcium scoring)

Calcium scoring: Results: Based on the calcium score, the degree of CAD is rated.

Table 1

Calcium Score	Presence of CAD
0	No evidence of CAD
1-10	Minimal evidence of CAD
11-100	Mild evidence of CAD
101-400	Moderate evidence of CAD
Over 400	Extensive evidence of CAD

2. Standard for Retrospective Gating ECG-gated Helical Scan in Retrospection

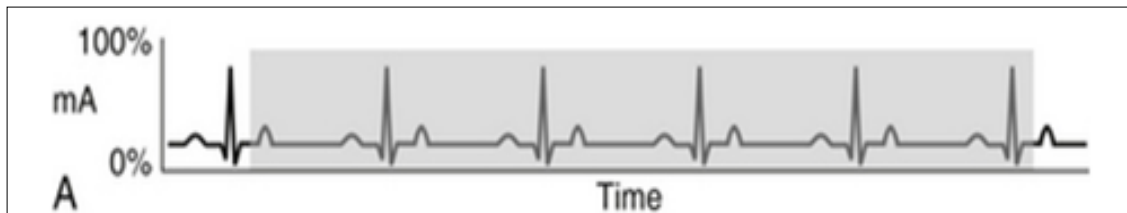


Fig 5

- Exposure is made continuously.
- Cardiovascular functional evaluation with superior image quality and good diagnosis accuracy.
- Greater flexibility for compensation for arrhythmia artifacts.
- Patient is moved slowly through the scanner with low pitch, so, high radiation exposure to patient around 15mSv.
- One method of lowering the dosage is ECG-controlled tube current modulation.
- Low voltage scan of the tube

ECG-gated Helical Scan in Retrospection with ECG-controlled Tube Current Modulation:

- Exposure is controlled with ECG.
- Tube current is reduced to 20% for other cardiac phases and maximized for the limited cardiac phase.
- This method reduces effective dose approximately 30%–50%.
- When electrocardiography is utilized to trigger high-pitch acquisition, individuals with sufficiently low and regular heart rates (>65 bpm) have the greatest effects of dosage reduction^[25].
- Data can be reconstructed at any interval of R-R interval.
- In coronary CT angiography, iterative reconstruction maintains diagnostic precision and image quality while using less radiation^[26].

Results

Examine and contrast the morphology, distribution, and orientation of atherosclerotic plaques at the coronary arteries in patients with low and intermediate pre-test probabilities of significant coronary artery disease (CAD) using non-invasive coronary angiography and 128-Multi Detector Computed Tomography (MDCT) with diagnostic accuracy and effective radiation dose (ERD) of high pitch dual source.^[27] With the use of electrocardiography-triggered high-pitch acquisition, a high-pitched 128 × 2-slice dual source CT scan decreased the dose by more than 50%^[28].

Coronary CT Angiography Technique: Nonionic intravenous contrast 80 cc at a flow rate of 5 ml/sec using a dual head pressure injector and is followed by a flush of 20 ml of normal saline.

- Starts from carina to base of heart.
- Timing (bolus triggered) - scan starts as contrast reaches the aortic root highest Peak value (180HU). Or in test bolus we can calculate the delay and volume of contrast.

Discussion

Currently, the most popular CT modality for coronary artery imaging is high-Pitch Spiral Scanning (Flash Mode) with 128 slice Dual-source CT systems. DSCT has been effectively utilized to evaluate congenital coronary abnormalities and identify stenoses in coronary arteries and coronary artery bypass grafts. Patients should undergo CT-CA with DSCT if they have an irregular cardiac rhythm or a heart rate more than 65 beats per minute.^[29] Theoretically, dual-source CT enhances the diagnostic picture quality of coronary artery exams by improving temporal resolution without the need for beta-blockade prior to the examination. Our study's goal was to demonstrate that, even if dual-source CT scans do not use pre-examination beta-blockade, they nonetheless produce better diagnostic images than single-source CT scans^[30].

Conclusion

This study compares high-pitch and step-and-shoot (SAS) modes for low-dose CT coronary angiography. High accuracy was achieved in both techniques when evaluating severe coronary stenoses. Without sacrificing diagnostic precision, the high-pitch mode dramatically decreased radiation exposure as compared to the SAS mode. While the high-pitch mode further greatly reduces the radiation dose, both the SAS and high-pitch modes for low-dose CT coronary angiography offer high accuracy for the assessment of severe coronary stenoses^[31].

The effectiveness of 128-slice DSCT in treating individuals with significant coronary calcification (score >400) was assessed in this study. The findings showed that 128-DSCT can accurately evaluate calcified coronary segments, with excellent sensitivity and specificity in identifying severe stenosis^[32].

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