HeartFlow®

Acquisition and Reconstruction Techniques for Coronary CT Angiography

United Imaging ATLAS

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DOC-000283 V2

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1. Overview

Coronary computed tomography angiography (CCTA) is a non-invasive diagnostic for detecting coronary artery disease (CAD). CCTA is increasingly utilized in clinical practice for evaluating coronary anatomy for obstructive disease and plaque.

It is, however, imperative that artifact free CCTA image data is obtained in order for it to be successfully analyzed for anatomic assessment and/or to act as adequate input for adjunct analyses such as physiologic simulations. Data acquisition strategies and scanning protocols may vary depending on scanner manufacturer, system, and institutional preferences. This document provides references for reliable image acquisition for CCTA.

2. Introduction

Image acquisition in computed tomography is governed ultimately by the principle of As Low As Reasonably Achievable (ALARA). In the first 10 years of CCTA, the focus was almost exclusively on the detection of anatomical stenosis in low to intermediate risk patients. With the evolution of technology, the clinical utility of CCTA has extended beyond stenosis assessment to atherosclerosis characterization, the evaluation of structural heart disease, and the functional and physiological assessment of coronary stenoses. Recently the SCCT acquisition guidelines were updated and provide an excellent reference for Cardiac CT imaging specialists to help optimize their scan protocols. That being said, given the growing information that is provided from cardiac CT, the imaging requirements have evolved and require tailoring to meet the clinical indication. The purpose of this white paper is to highlight the parameters and image acquisition protocols that are important to help optimize image quality, provide accurate representation of anatomy and thus enable quantitative CT.

Importance of Heart Rate Control

With the advancements in scanner technology, the necessary requirement for heart rate reduction has decreased over time. The demands for a low and steady heart rate to ensure diagnostic image quality may not be what they once were but best practice remains to optimize image quality through heart rate control. SCCT guidelines recommend performing CCTA with heart rates below 60 bpm.

In addition, CCTA no longer simply provides stenosis evaluation but needs to enable the interpreting physician to identify and characterize plaque and, following the identification of a stenosis, to perform functional or physiologic evaluation. As a result, while latest generation CT scanners may enable diagnostic image quality at higher heart rates, there remains meaningful image quality benefits from heart rate reduction. In addition, lower heart rates allow the use of lower dose scan acquisitions that are not possible at higher heart rates. Heart rate control strategies are well established and the appropriate strategy is dependent on a number of variables including available medications, setting of practice and site preference. For recommendations please refer to the recently updated SCCT acquisition guidelines.

Importance of Nitrates

Nitrates as smooth muscle dilators have direct effect on coronary vasodilation and result in tangible enlargement of coronary size. As such, similar to invasive coronary catheterization, nitroglycerine (glyceryl trinitrate) should be administered prior to CCTA to optimize image quality and enable the most accurate stenosis evaluation. A commonly used regimen is 400-800 µg of sublingual nitroglycerin administered as either sublingual tablets or a metered lingual spray (commonly 1-2 tablets or 1-2 sprays) prior to the CCTA. While the evidence is modest and there is no randomized data, both a higher dose and administration via spray are becoming increasingly preferred in clinical practice and have been shown to help optimize coronary evaluation.

Selection of Tube Current and Potential

The scan parameters used for any cardiac CT should be tailored to the individual patient but also the intended application. The image quality issues with the greatest impact on the interpretability of CT are misalignment and image noise. As such, care must be given to ensure that image noise properties are appropriate and adequate for accurate lumen segmentation. To do so, tube current and potential should be selected carefully, guided by chest wall circumference, the iodine concentration of the intravenous contrast medium, and whether iterative reconstruction is available or not.

Iterative reconstruction (IR) has the ability to reduce image noise in CT without compromising the diagnostic quality of the CT image dataset, which permits a significant reduction in effective radiation dose. In current clinical practice, IR has enabled a significant reduction in radiation dose by allowing for a reduction in tube current and is now increasingly available across all cardiac capable CT scanners. IR commonly takes the form of a blended reconstruction of IR and filtered back projection (FBP). While a very helpful tool, care should be given when using a very high percentage of IR for quantitative CT analysis due to the potential impact on vessel segmentation.

3. Reference Protocol: ATLAS

1. Scout

General	Data Acquisition	Comments
Volume scout covering the heart and coronaries 82 cm bore and 700 lb table load capacity	• AP Scout: 120 kVp/40 mA • LAT Scout: 120 kVp/60 mA • ECG Trace: On • Scout Plane: Volume • Auto Voice (Breath hold command):	Take note on the scouts to ensure that the patient is positioned within 2 cm of isocenter to allow for best image quality. Adjust table height and lateral table location to adjust isocenter location if more than 2 cm off. Place the patient's arms above their head with the ECG leads outside the scan range. Have the patient practice breath holding before starting the examination. This should be a single "breathe in and hold" command. .

2. Non-enhanced Scan (optional)- Calcium Score

General	Ca Score Acquisition Mode
Can be used for quantification of annular calcification Can be used for planning of subsequent contrast-enhanced data acquisition Volume data can be acquired as a single-beat/one rotation scan Helical Acquisition	• Field of View limited to the heart: 200-250 mm • Scan Length:160 mm • Tube Voltage: 120 kVp • mAs: 80 • R-R Scanning Window: 75% • Rotation time: 0.25 sec • Slice Thickness: 0.5 mm • Filter: C_Soft_B • Adaptive Filter: ON • KARL 3D: ON, Level 5

3. Axial Coronary CTA

General	CCTA Acquisition
ECG-gated axial data acquisition of the heart Scan range beginning 2 cm below the carina to the base of the heart for routine CCTA without previous CABG procedure	General Data: • Field of View limited to the heart: 200-250 mm • Scan Length:160 mm • Increment: 160.0 mm • Rotation time: 0.25 sec • Slice Thickness: 0.5 mm Primary Scan Data: • Acquisition Mode: Manual • Type: % • CCTA with Function: ON, 20% • CardioAdapt: ON • R-R Scanning Window: 70-85% Dose: • Tube Voltage: 120 kVp • mAs: 200 Injection: • Post Threshold Delay: 5.0sec • Trigger: Bolus Tracking

4. United Imaging Recons

1. ePhase: Full Cycle

- Thickness: 0.5 mm
- Adaptive Filter: ON
- KARL 3D: ON, 8
- Filter: C_SOFT_BA

2. Multiphase

- Thickness: 0.5 mm
- Increment: 0.25 mm
- Adaptive Filter: ON
- KARL 3D: ON, 8
- ePhase: OFF
- Multiphase: ON, Interval 5, 40-80%
- Filter: C_SOFT_BA

Multiphase Sharp

- Thickness: 0.5 mm
- Increment: 0.25 mm
- Adaptive Filter: ON
- KARL 3D: OFF
- ePhase: OFF
- Multiphase: ON, Interval 5, 40-80%
- Filter: B_SHARP_A
- Enhancement: 2

Patient HR>65 bpm or irregular HR>3 bpm variability, Retrospective

- Recon 1: Full Cycle (CardioXphase), C_Soft_BA, 40-80%, 5 increments, Adaptive ON, KARL ON
- Recon 2: Multiphase, C_Soft_BA, 40-80%, 5 increments, Adaptive ON, KARL ON
- Recon 3: Multiphase, B_Sharp_A, 40-80%, 5 increments, Edge enhancement 2, Adaptive ON, KARL OFF

Patient HR<60 bpm and less than 3 beats variability

- Recon 1: Full Cycle (CardioXphase), C_Soft_BA, 70-85%, 5 increments, Adaptive ON, KARL ON
- Recon 2: Multiphase, C_Soft_BA, 70-85%, 5 increments, Adaptive ON, KARL ON
- Recon 3: Multiphase, B_Sharp_A, 70-85%, 5 increments, Edge enhancement 2, Adaptive ON, KARL OFF

CTA- C_SOFT_B

STENT- C_SOFT_DA

SHARP- B_SHARP_A

MAC- Metal Artifact Corrector

5. Contrast Protocol

General	Contrast Formula
The injection rate should be increased for shorter scan times and larger patients! CTA requires contrast medium with an iodine concentration of at least 350 mg/mL. Place a 20- or 18-gauge IV cannula in the RIGHT arm. Set the trigger at 180 HU Single Phase Contrast with Saline Flush. This protocol ensures complete washout of the right side of the heart. Streak artifacts from undiluted contrast medium are eliminated, providing excellent visualization of the RCA. The saline solution replaces about 20 mL (5 seconds of injection) of the contrast medium	For normal weighted patients and an iodinated contrast agent with 350-370 mg/mL, apply 70 mL contrast at 5 mL/sec, followed by 30 mL saline at 5 mL/sec; 350-370 mg/mL 5 mL/sec of 70 mL contrast 5 mL/sec of 50 mL saline For large patients and an iodinated contrast agent with 350-370 mg/mL, apply 70 mL contrast at 6 mL/sec, followed by 50 mL saline at 6 mL/sec; 350-370 mg/mL 6 mL/ sec of 70 mL contrast 6 mL/sec of 50 mL saline

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