

Acquisition and reconstruction techniques for Coronary CT Angiography

Siemens Healthineers Scanner Platforms



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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. 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

This patient preparation protocol aligns with the 2016 SCCT Guidelines for the performance and acquisition of coronary computed tomographic angiography.¹

Patient Preparation

The referring physician or provider should review the patient's history and screen them prior to the CCTA for any contraindications such as contrast allergies, pregnancy, renal impairment, and clinical instabilities (acute myocardial infarction, heart failure, and severe hypotension).¹

Note: Cleerly is unable to analyze coronary artery bypass grafts. If a CABG study is submitted, Cleerly will reject the scan. However, pacemakers and stents are acceptable for analysis.

If a patient cannot cooperate with scan preparation, acquisition, and/or breath-hold instructions then it is best advised to forgo the CCTA scan. It is pertinent that the patient collaborates with CT technologists to achieve a high quality scan.

Patients should be informed of the preparation at the time of scheduling their CCTA. It is recommended that patients discontinue solid foods at least 3–4 hours before their scan to reduce nausea and a potential spike in heart rate, however water and clear fluids are acceptable and encouraged to consume. The patient should discontinue caffeine or stimulants 12 hours before the scan as this can decrease the ability to lower and stabilize the heart rate. The patient may continue to take routine medications under the direction of their physician. Since Nitroglycerin may be administered, it is important to discontinue the use of erectile dysfunction medication 72 hours before the scan (24 hours for sildenafil) and 24 hours post scan.¹

The 2016 SCCT guidelines for the performance and acquisition of CCTAs recommends the use of Nitroglycerin and beta-blockers to enhance image quality. Cleerly recommends a Nitroglycerin dose of 0.8 mg, as it falls within guideline parameters and represents an optimal range to achieve consistent coronary vasodilation for improved visualization. A best practice is to wait 5 minutes post Nitroglycerin administration to ensure proper vasodilation. Beta-blockers can be prescribed by the patient's referring physician or upon arrival at the discretion of a qualified medical professional.

The guidelines recommend to pre-medicate patients with 50 mg metoprolol by mouth 12 hours before the scan and another 50–100 mg metoprolol by mouth 1 hour before the scan. Slow-release forms of beta-blockers should not be used. Supplement IV beta-blockers can be administered to help reduce the patient's heart rate immediately prior to the exam. If Supplemental IV beta-blockers are called for, then it is common practice to administer 5 mg of IV metoprolol followed by 5 minutes of monitoring. If the target heart rate is not reached and the patient's vitals allow for it, this process can be repeated for a total dose of up to 20–25 mg.¹

Even if the patient's heart rate is within the target threshold, it is common practice to administer a small dose of beta-blockers to stabilize and to avoid an elevated heart rate due to contrast administration.¹

It is essential to educate and instruct the patient of what to expect during the scan such as breathing instructions, IV contrast administration, and scan duration. Convey clear expectations for the patient. For example, explain what the patient can expect before, during, and after the scan and the purpose of beta-blockers and Nitroglycerin. Brief the patient on potential side effects of the contrast and medication. By informing the patient this can drastically reduce anxiety thus help produce excellent image quality.

Guidelines Suggested ECG-Gated Acquisition

- ▲ Prospective gating should be utilized if the heart rate is at, or below, the target heart rate and if there is minimal variance (< 4 bpm).
- ▲ Retrospective gating should be utilized if the heart rate is greater than the target heart rate and/or if there is significant variance (≥ 4 bpm). ■

3. NAEOTOM Alpha/Alpha.Peak

NAEOTOM Alpha/Alpha.Peak is a Dual Source photon-counting CT system allowing for a heart rate independent temporal resolution of 66 ms.

1. Topogram

General	Data Acquisition (Default)	Patient Preparation
AP topogram covering the chest. Additional LAT topogram performed in opposite direction (enables fully automated iso-centering of the heart).	▲ Sn100 kV; 55 mA ▲ Scan mode: ScanplanningTopoAdultQuantumSn ▲ Length: 512 mm	▲ Patient positioning: The following technique provides patient comfort and optimal image quality for the study: – Head or feet first; supine with head, knees, and lower legs supported by appropriate accessories. – Arms raised above the head; resting comfortably on the head-arm support. – The torso of the patient must be straight, not rotated. – Torso slightly below the middle of the scan field (~3cm), centered with the help of the laser light markers aimed at the iso-center of the heart. ▲ Place ECG-electrodes, as anatomically depicted on the labeled electrodes and IV access in accordance with institutional policies. Recommendation: 18-gauge or larger intravenous needle in the right antecubital vein. Automated contrast injection using a dual-cylinder injector. ▲ Provide enough time for the patient to practice breath holds prior to acquisition. To avoid breathing motion artifacts, the patient is instructed not to breathe and swallow during the acquisition. It is necessary to observe the ECG behavior during the breath hold procedure. The heart rate may decrease during the initial seconds of breath-holding or increase if the patient is straining to hold his breath at the end of the scan.

2. CaSc (optional) – Non-contrast Examination

General	Data Acquisition	Data Reconstruction
Scan range of 12–15 cm from the carina to the apex of the heart. Can be used for subsequent contrast-enhanced data acquisition. Can be used to rule out the presence of excessive calcification, which may reduce the diagnostic accuracy of the CTA study.	▲ Flash or Prospective ECG-triggering ▲ CARE Dose4D™ & CARE keV: Full ▲ CARE keV IQ level: 19 ▲ Scan mode: CardiacDualsourceFlashAdultQuantumplus or CardiacDualsourceSequenceAdultQuantumplus ▲ Rotation time: 0.25 s ▲ Temporal resolution: 66 ms ▲ Acquisition: 144 x 0.4 mm ▲ Scan direction: craniocaudal	▲ Axial reconstruction within the ECG trigger window, commonly BestDiast ▲ Field of view limited to the heart ▲ Slice thickness: 3 mm ▲ Increment: 1.5 mm ▲ Convolution kernel: Qr36 ▲ Monoenergetic Plus level: 70 keV ▲ Quantum iterative reconstruction strength: 2

3. Test Bolus

General	Data Acquisition
A series of sequential scans to monitor the arrival of the bolus to generate a time density curve. The peak of the curve is then used to determine the scanning delay for the CTA acquisition. Scans are set up at the level of ascending aorta at the level of the carina. The region of interest (ROI) is placed within the ascending aorta. A small bolus of contrast plus saline chaser is injected at the same flow rate that will be used for CTA acquisition.	▲ Delay: 10 s ▲ CARE Dose4D™ & CARE keV: Manual kV ▲ 90 kV ▲ CARE keV IQ level: 25 ▲ Slice/Collimation: 1 x 5 mm ▲ No. of scans: 15 ▲ Cycle time: 0.9 s But can be suspended when the bolus has passed through the region

3.1 Alternatively, CARE Bolus

General	Data Acquisition
CARE Bolus (automatic bolus tracking) monitors the attenuation within the vessel of interest (ascending aorta). Scans are set up at the level of ascending aorta at the level of the carina. The full dose of contrast media is injected at the decided flow rate. The CTA acquisition is automatically triggered when the vessel enhancement reaches the pre-defined HU level (100–150HU) above the baseline. See “Contrast Protocols” for customers’ best practice.	▲ Delay: 10 s ▲ CARE Dose4D™ & CARE keV: Manual kV ▲ CARE keV IQ level: 25 ▲ Slice/Collimation: 1 x 5 mm

4. Prospective or Retrospective Triggered Coronary CT Angiography (Recommended Heart Rates: up to 70 bpm)^a

General	Data Acquisition	Data Reconstruction
General ECG triggered Dual Source data acquisition of the heart. Scan range 12–15 cm from the carina to the apex of the heart. Use unenhanced CaSc CT data for planning if available. kV will be automatically selected by CARE kV. Use ZeeFree reconstructions.	If Test Bolus was used: ▲ Delay: time-to-peak value in s ▲ CARE Dose4D™ & CARE keV: Full ▲ CARE keV IQ level: 83 ▲ Slice/Collimation: 144 x 0.4 mm ▲ Scan mode*: CardiacDualsourceSequanceAdultAngioFlexQuantum or CardiacDualsourceSpiralAdultAngioQuantum ▲ ECG Pulsing*: standard ▲ Scan direction: craniocaudal ▲ Rotation time: 0.25 s ▲ Temporal resolution: 66 ms ▲ Scan window*: Stable HR HR < 70 bpm: 60%–80%^a HR > 70 bpm: 30%–80% Arrhythmic HR (e.g. atrial fibrillation) 300ms–400ms	▲ Axial reconstruction within the ECG trigger window at 67 keV (or equivalent to 120 kVp)^a, multiphase (5%), BestDiast. Choose BestSyst and Millisecond unit (smallest interval)^{a,b} for arrhythmic heart rates. ▲ Field of view limited to the heart. ▲ Slice thickness: 0.4 mm^a – 0.6 mm can be used if disease is low or if images are too noisy ▲ Increment: 0.2 mm^a – 0.3 mm can be used if disease is low or if images are too noisy ▲ ZeeFree enables misalignment correction algorithm. (Enable at least one reconstruction with TrueStack to enable manual crosscheck for the presence of misalignment in the data set.) ▲ Multiphase kernel set to Bv48 and BestDiast/Syst kernel set to Bv48 and Bv56. All reconstructions to have iterative reconstruction (e.g. QIR, strength ≤ 2). ▲ If the patient has high calcium, consider a sharper convolution kernel: Bv60.

* With myExam Companion, the system automatically chooses the correct scan mode and pulsing window, depending on the HR and HR variability.

a – Based on Cleerly's data requirements

b –Smallest ms interval changes depending on the systems' SW version and operating systems:
SOMARIS 10: VB20 and above, 20ms. VB10 and below, 50ms

4.1 Alternatively, Retrospective Gated Quantum HD Cardiac (stable HR, good patient breath-hold, high calcium burden)

General	Data Acquisition	Data Reconstruction
General ECG triggered Dual Source data acquisition of the heart. Scan range 12–15 cm from the carina to the apex of the heart. Use unenhanced CaSc CT data for planning if available. kV will be automatically selected by CARE kV. Use ZeeFree reconstructions.	If Test Bolus was used: ▲ Delay: time-to-peak value in s ▲ CARE Dose4D™ & CARE keV: Full ▲ CARE keV IQ level: 65 ▲ Slice/Collimation: 120 x 0.2 mm ▲ Scan mode*: CardiacDualsourceSpiralAdultAngio HighresultraQuantum ▲ ECG Pulsing*: standard ▲ Scan direction: craniocaudal ▲ Rotation time: 0.25 s ▲ Temporal resolution: 66 ms ▲ Scan window*: Stable HR HR < 70 bpm: 60%–80%^a HR > 70 bpm: 30%–80% Arrhythmic HR (e.g. atrial fibrillation) 300ms–400ms	▲ Axial reconstruction within the ECG trigger window at 67 keV (or equivalent to 120 kVp)^a, multiphase (5%), BestDiast. Choose BestSyst and Millisecond unit (smallest interval)^{a,b} for arrhythmic heart rates. ▲ Field of view limited to the heart. ▲ Matrix size: auto (or 768 x 768 if supported) ▲ Slice thickness: 0.2 mm ▲ Increment: 0.2 mm ▲ ZeeFree enables misalignment correction algorithm. (Enable at least one reconstruction with TrueStack to enable manual crosscheck for the presence of misalignment in the data set.) ▲ Multiphase kernel set to Bv56 and Best Diast/Syst kernel set to Bv56. All reconstructions to have iterative reconstruction (e.g. QIR, strength ≤ 2). ▲ Additional sharp convolution kernel applied to Best Diast/Syst: Bv60.

5. Contrast Protocol

General	Data Acquisition	Comments
The injection rate and volume should be increased for larger patients. Place a 20- or 18-gauge IV cannula in the RIGHT arm.	Test Bolus ▲ CM Bolus: 10–15mL ▲ Saline chaser: 40–50mL ▲ Flow rate: 5–7.5mL/s^a (same as during CTA Acquisition) CCTA - Generally: ▲ Iodine Concentration: 320–370mg Iodine/mL ▲ Contrast Volume: 65–97mL^a ▲ Saline Volume: 50mL ▲ Flow rate: 5–7.5mL/s^a	

^a – Based on Cleerly's data requirements

^b –Smallest ms interval changes depending on the systems' SW version and operating systems:
SOMARIS 10: VB20 and above, 20ms. VB10 and below, 50ms

4. NAEOTOM Alpha.Pro

NAEOTOM Alpha.Pro is a Dual Source photon-counting CT system allowing for a heart rate independent temporal resolution of 66 ms.

1. Topogram

General	Data Acquisition (Default)	Patient Preparation
AP topogram covering the chest. Additional LAT topogram performed in opposite direction (enables fully automated iso-centering of the heart).	▲ Sn100 kV; 55 mA ▲ Scan mode: ScanplanningTopoAdultQuantumSn ▲ Length: 512 mm	▲ Patient positioning: The following technique provides patient comfort and optimal image quality for the study: – Head or feet first; supine with head, knees, and lower legs supported by appropriate accessories. – Arms raised above the head; resting comfortably on the head-arm support. – The torso of the patient must be straight, not rotated. – Torso slightly below the middle of the scan field (~3cm), centered with the help of the laser light markers aimed at the iso-center of the heart. ▲ Place ECG-electrodes, as anatomically depicted on the labeled electrodes and IV access in accordance with institutional policies. Recommendation: 18-gauge or larger intravenous needle in the right antecubital vein. Automated contrast injection using a dual-cylinder injector. ▲ Provide enough time for the patient to practice breath holds prior to acquisition. To avoid breathing motion artifacts, the patient is instructed not to breathe and swallow during the acquisition. It is necessary to observe the ECG behavior during the breath hold procedure. The heart rate may decrease during the initial seconds of breath-holding or increase if the patient is straining to hold his breath at the end of the scan.

2. CaSc (optional) – Non-contrast Examination

General	Data Acquisition	Data Reconstruction
Scan range of 12–15 cm from the carina to the apex of the heart. Can be used for subsequent contrast-enhanced data acquisition. Can be used to rule out the presence of excessive calcification, which may reduce the diagnostic accuracy of the CTA study.	▲ Flash or Prospective ECG-triggering ▲ CARE Dose4D™ & CARE keV: Full ▲ CARE keV IQ level: 19 ▲ Scan mode: CardiacDualsourceFlashAdultQuantumplus or CardiacDualsourceSequenceAdultQuantumplus ▲ Rotation time: 0.25 s ▲ Temporal resolution: 66 ms ▲ Acquisition: 96 x 0.4 mm ▲ Scan direction: craniocaudal	▲ Axial reconstruction within the ECG trigger window, commonly BestDiast ▲ Field of view limited to the heart ▲ Slice thickness: 3 mm ▲ Increment: 1.5 mm ▲ Convolution kernel: Qr36 ▲ Monoenergetic Plus level: 70 keV ▲ Quantum iterative reconstruction strength: 2

3. Test Bolus

General	Data Acquisition
A series of sequential scans to monitor the arrival of the bolus to generate a time density curve. The peak of the curve is then used to determine the scanning delay for the CTA acquisition. Scans are set up at the level of ascending aorta at the level of the carina. The region of interest (ROI) is placed within the ascending aorta. A small bolus of contrast plus saline chaser is injected at the same flow rate that will be used for CTA acquisition.	▲ Delay: 10 s ▲ CARE Dose4D™ & CARE keV: Manual kV ▲ 90 kV ▲ CARE keV IQ level: 25 ▲ Slice/Collimation: 1 x 5 mm ▲ No. of scans: 15 ▲ Cycle time: 0.9 s But can be suspended when the bolus has passed through the region

3.1 Alternatively, CARE Bolus

General	Data Acquisition
CARE Bolus (automatic bolus tracking) monitors the attenuation within the vessel of interest (ascending aorta). Scans are set up at the level of ascending aorta at the level of the carina. The full dose of contrast media is injected at the decided flow rate. The CTA acquisition is automatically triggered when the vessel enhancement reaches the pre-defined HU level (100–150HU) above the baseline. See “Contrast Protocols” for customers’ best practice.	▲ Delay: 10 s ▲ CARE Dose4D™ & CARE keV: Manual kV ▲ CARE keV IQ level: 25 ▲ Slice/Collimation: 1 x 5 mm

4. Prospective or Retrospective Triggered Coronary CT Angiography (Recommended Heart Rates: up to 70 bpm)^a

General	Data Acquisition	Data Reconstruction
General ECG triggered Dual Source data acquisition of the heart. Scan range 12–15 cm from the carina to the apex of the heart. Use unenhanced CaSc CT data for planning if available. kV will be automatically selected by CARE kV. Use ZeeFree reconstructions.	If Test Bolus was used: ▲ Delay: time-to-peak value in s ▲ CARE Dose4D™ & CARE keV: Full ▲ CARE keV IQ level: 83 ▲ Slice/Collimation: 96 x 0.4 mm ▲ Scan mode*: CardiacDualsourceSequanceAdult AngioFlexQuantum or CardiacDualsourceSpiralAdultAngio Quantum ▲ ECG Pulsing*: standard ▲ Scan direction: craniocaudal ▲ Rotation time: 0.25 s ▲ Temporal resolution: 66 ms ▲ Scan window*: Stable HR HR < 70 bpm: 60%–80%^a HR > 70 bpm: 30%–80% Arrhythmic HR (e.g. atrial fibrillation) 300ms–400ms	▲ Axial reconstruction within the ECG trigger window at 67 keV (or equivalent to 120 kVp)^a, multiphase (5%), BestDiast. Choose BestSyst and Millisecond unit (smallest interval)^{a,b} for arrhythmic heart rates. ▲ Field of view limited to the heart. ▲ Slice thickness: 0.4 mm^a — 0.6 mm can be used if disease is low or if images are too noisy ▲ Increment: 0.2 mm^a — 0.3 mm can be used if disease is low or if images are too noisy ▲ ZeeFree enables misalignment correction algorithm. (Enable at least one reconstruction with TrueStack to enable manual crosscheck for the presence of misalignment in the data set.) ▲ Multiphase kernel set to Bv48 and Best Diast/Syst kernel set to Bv48 and Bv56. All recons to have iterative reconstruction (e.g. QIR, strength ≤ 2). ▲ If the patient has high calcium, consider a sharper convolution kernel: Bv60.

* With myExam Companion, the system automatically chooses the correct scan mode and pulsing window, depending on the HR and HR variability.

a – Based on Cleerly's data requirements

b –Smallest ms interval changes depending on the systems' SW version and operating systems:
SOMARIS 10: VB20 and above, 20ms. VB10 and below, 50ms

4.1 Alternatively, Retrospective Gated Quantum HD Cardiac (stable HR, good patient breath-hold, high calcium burden)

General	Data Acquisition	Data Reconstruction
General ECG triggered Dual Source data acquisition of the heart. Scan range 12–15 cm from the carina to the apex of the heart. Use unenhanced CaSc CT data for planning if available. kV will be automatically selected by CARE kV. Use ZeeFree reconstructions.	If Test Bolus was used: ▲ Delay: time-to-peak value in s ▲ CARE Dose4D™ & CARE keV: Full ▲ CARE keV IQ level: 65 ▲ Slice/Collimation: 120 x 0.2 mm ▲ Scan mode: CardiacDualsourceSpiralAdultAngio HighresultraQuantum ▲ ECG Pulsing: standard ▲ Scan direction: craniocaudal ▲ Rotation time: 0.25 s ▲ Temporal resolution: 66 ms ▲ Scan window: Stable HR HR < 70 bpm: 60%–80%^a HR > 70 bpm: 30%–80% Arrhythmic HR (e.g. atrial fibrillation) 300ms–400ms	▲ Axial reconstruction within the ECG trigger window at 67 keV (or equivalent to 120 kVp)^a, multiphase (5%), BestDiast. Choose BestSyst and Millisecond unit (smallest interval)^{a,b} for arrhythmic heart rates. ▲ Field of view limited to the heart. ▲ Matrix size: auto (or 768 x 768 if supported) ▲ Slice thickness: 0.2 mm ▲ Increment: 0.2 mm ▲ ZeeFree enables misalignment correction algorithm. (Enable at least one reconstruction with TrueStack to enable manual crosscheck for the presence of misalignment in the data set.) ▲ Multiphase kernel set to Bv56 and Best Diast/Syst kernel set to Bv56. All recons to have iterative reconstruction (e.g. QIR, strength ≤ 2). ▲ Additional sharp convolution kernel applied to Best Diast/Syst: Bv60.

5. Contrast Protocol

General	Data Acquisition	Comments
The injection rate and volume should be increased for larger patients. Place a 20- or 18-gauge IV cannula in the RIGHT arm.	Test Bolus ▲ CM Bolus: 10–15mL ▲ Saline chaser: 40–50mL ▲ Flow rate: 5–7.5mL/s^a (same as during CTA Acquisition) CCTA - Generally: ▲ Iodine Concentration: 320–370mg Iodine/mL ▲ Contrast Volume: 65–97mL^a ▲ Saline Volume: 50mL ▲ Flow rate: 5–7.5mL/s^a	

^a – Based on Cleerly's data requirements

^b –Smallest ms interval changes depending on the systems' SW version and operating systems:
SOMARIS 10: VB20 and above, 20ms. VB10 and below, 50ms

5. NAEOTOM Alpha.Prime

NAEOTOM Alpha.Prime is a Single Source photon-counting CT system allowing for a heart rate independent temporal resolution of 125 ms.

1. Topogram

General	Data Acquisition (Default)	Patient Preparation
AP topogram covering the chest. Additional LAT topogram performed in opposite direction (enables fully automated iso-centering of the heart).	▲ Sn100 kV; 55 mA ▲ Scan mode: ScanplanningTopoAdultQuantumSn ▲ Length: 512 mm	▲ Patient positioning: The following technique provides patient comfort and optimal image quality for the study: – Head or feet first; supine with head, knees, and lower legs supported by appropriate accessories. – Arms raised above the head; resting comfortably on the head-arm support. – The torso of the patient must be straight, not rotated. – Torso slightly below the middle of the scan field (~3cm), centered with the help of the laser light markers aimed at the iso-center of the heart. ▲ Place ECG-electrodes, as anatomically depicted on the labeled electrodes and IV access in accordance with institutional policies. Recommendation: 18-gauge or larger intravenous needle in the right antecubital vein. Automated contrast injection using a dual-cylinder injector. ▲ Provide enough time for the patient to practice breath holds prior to acquisition. To avoid breathing motion artifacts, the patient is instructed not to breathe and swallow during the acquisition. It is necessary to observe the ECG behavior during the breath hold procedure. The heart rate may decrease during the initial seconds of breath-holding or increase if the patient is straining to hold his breath at the end of the scan.

2. CaSc (optional) – Non-contrast Examination

General	Data Acquisition	Data Reconstruction
Scan range of 12–15 cm from the carina to the apex of the heart. Can be used for subsequent contrast-enhanced data acquisition. Can be used to rule out the presence of excessive calcification, which may reduce the diagnostic accuracy of the CTA study.	▲ Prospective ECG-triggering ▲ CARE Dose4D™ & CARE keV: Full ▲ CARE keV IQ level: 19 ▲ Scan mode: CardiacSequenceAdultQuantumplus ▲ Rotation time: 0.25 s ▲ Temporal resolution: 125 ms ▲ Acquisition: 144 x 0.4 mm ▲ Scan direction: craniocaudal	▲ Axial reconstruction within the ECG trigger window, commonly BestDiast ▲ Field of view limited to the heart ▲ Slice thickness: 3 mm ▲ Increment: 1.5 mm ▲ Convolution kernel: Qr36 ▲ Monoenergetic Plus level: 70 keV ▲ Quantum iterative reconstruction strength: 2

3. Test Bolus

General	Data Acquisition
A series of sequential scans to monitor the arrival of the bolus to generate a time density curve. The peak of the curve is then used to determine the scanning delay for the CTA acquisition. Scans are set up at the level of ascending aorta at the level of the carina. The region of interest (ROI) is placed within the ascending aorta. A small bolus of contrast plus saline chaser is injected at the same flow rate that will be used for CTA acquisition.	▲ Delay: 10 s ▲ CARE Dose4D™ & CARE keV: Manual kV ▲ 90 kV ▲ CARE keV IQ level: 25 ▲ Slice/Collimation: 1 x 5 mm ▲ No. of scans: 15 ▲ Cycle time: 0.9 s But can be suspended when the bolus has passed through the region

3.1 Alternatively, CARE Bolus

General	Data Acquisition
CARE Bolus (automatic bolus tracking) monitors the attenuation within the vessel of interest (ascending aorta). Scans are set up at the level of ascending aorta at the level of the carina. The full dose of contrast media is injected at the decided flow rate. The CTA acquisition is automatically triggered when the vessel enhancement reaches the pre-defined HU level (100–150HU) above the baseline. See “Contrast Protocols” for customers’ best practice.	▲ Delay: 10 s ▲ CARE Dose4D™ & CARE keV: Manual kV ▲ CARE keV IQ level: 25 ▲ Slice/Collimation: 1 x 5 mm

4. Prospective or Retrospective Triggered Coronary CT Angiography (Recommended Heart Rates: up to 65 bpm)^a

General	Data Acquisition	Data Reconstruction
General ECG triggered Dual Source data acquisition of the heart. Scan range 12–15 cm from the carina to the apex of the heart. Use unenhanced CaSc CT data for planning if available. kV will be automatically selected by CARE kV. Use ZeeFree reconstructions.	If Test Bolus was used: ▲ Delay: time-to-peak value in s ▲ CARE Dose4D™ & CARE keV: Full ▲ CARE keV IQ level: 83 ▲ Slice/Collimation: 144 x 0.4 mm ▲ Scan mode*: CardiacSequenceAdultAngioFlexQuantum or CardiacSpiralAdultAngioQuantum ▲ ECG Pulsing*: standard ▲ Scan direction: craniocaudal ▲ Rotation time: 0.25 s ▲ Temporal resolution: 125 ms ▲ Scan window*: Stable HR HR < 65 bpm: 60%–80%^a HR > 65 bpm: 30%–80%^a Arrhythmic HR (e.g. atrial fibrillation) 300ms–400ms	▲ Axial reconstruction within the ECG trigger window, at 67 keV (or equivalent to 120 kVp)^a, multiphase (5%), BestDiast. Choose BestSyst and Millisecond unit (smallest interval)^{a,b} for arrhythmic heart rates. ▲ Field of view limited to the heart. ▲ Slice thickness: 0.4 mm^a – 0.6 mm can be used if disease is low or if images are too noisy ▲ Increment: 0.2 mm^a – 0.3 mm can be used if disease is low or if images are too noisy ▲ ZeeFree enables misalignment correction algorithm. (Enable at least one reconstruction with TrueStack to enable manual crosscheck for the presence of misalignment in the data set.) ▲ Multiphase kernel set to Bv48 and Best Diast/Syst kernel set to Bv48 and Bv56. All recons to have iterative reconstruction (e.g. QIR, strength ≤ 2). ▲ If the patient has high calcium, consider a sharper convolution kernel: Bv60.

* With myExam Companion, the system automatically chooses the correct scan mode and pulsing window, depending on the HR and HR variability.

5. Contrast Protocol

General	Data Acquisition	Comments
The injection rate should be increased for shorter scan times and larger patients. CTA requires contrast medium with an iodine concentration of at least 320 mgI/mL.^a Place a 20- or 18-gauge IV cannula in the RIGHT arm.	Test Bolus ▲ CM Bolus: 10–15mL ▲ Saline chaser: 40–50mL ▲ Flow rate: 5–7.5mL/s^a (same as during CTA Acquisition) CCTA - Generally: ▲ Iodine Concentration: 320–370mg Iodine/mL ▲ Contrast Volume: 65–97mL^a ▲ Saline Volume: 50mL ▲ Flow rate: 5–7.5mL/s^a	

^a – Based on Cleerly's data requirements

^b –Smallest ms interval changes depending on the systems' SW version and operating systems:
SOMARIS 10: VB20 and above, 20ms. VB10 and below, 50ms

6. SOMATOM Pro.Pulse

SOMATOM Pro.Pulse is a Dual Source CT system allowing for a heart rate independent temporal resolution of 86 ms.

1. Topogram

General	Data Acquisition (Default)	Patient Preparation
AP topogram covering the chest. Additional LAT topogram performed in opposite direction (enables fully automated iso-centering of the heart).	▲ Sn100 kV; 55 mASn100 kV; 40 mA ▲ Scan mode: ScanplanningTopoAdultSn ▲ Length: 512 mm	▲ Patient positioning: The following technique provides patient comfort and optimal image quality for the study: – Head or feet first; supine with head, knees, and lower legs supported by appropriate accessories. – Arms raised above the head; resting comfortably on the head-arm support. – The torso of the patient must be straight, not rotated. – Torso slightly below the middle of the scan field (~3cm), centered with the help of the laser light markers aimed at the iso-center of the heart. ▲ Place ECG-electrodes, as anatomically depicted on the labeled electrodes and IV access in accordance with institutional policies. Recommendation: 18-gauge or larger intravenous needle in the right antecubital vein. Automated contrast injection using a dual-cylinder injector. ▲ Provide enough time for the patient to practice breath holds prior to acquisition. To avoid breathing motion artifacts, the patient is instructed not to breathe and swallow during the acquisition. It is necessary to observe the ECG behavior during the breath hold procedure. The heart rate may decrease during the initial seconds of breath-holding or increase if the patient is straining to hold his breath at the end of the scan.

2. CaSc (optional) – Non-contrast Examination

General	Data Acquisition	Data Reconstruction
Scan range of 12–15 cm from the carina to the apex of the heart. Can be used for subsequent contrast-enhanced data acquisition. Can be used to rule out the presence of excessive calcification, which may reduce the diagnostic accuracy of the CTA study.	▲ Retrospective ECG-gating ▲ CARE Dose4D™ & CARE kV: Full ▲ CARE keV IQ level: 21 ▲ Scan mode: CardiacFlashSpiralAdult ▲ Rotation time: 0.33 s ▲ Temporal resolution: 86 ms ▲ Acquisition: 64 x 0.6 mm ▲ Scan direction: craniocaudal	▲ Axial reconstruction within the ECG trigger window, commonly BestDiast ▲ Field of view limited to the heart ▲ Slice thickness: 3 mm ▲ Increment: 1.5 mm ▲ WFBP Reconstruction (filtered back projection) Convolution kernel: Sa36

3. Test Bolus

General	Data Acquisition
A series of sequential scans to monitor the arrival of the bolus to generate a time density curve. The peak of the curve is then used to determine the scanning delay for the CTA acquisition. Scans are set up at the level of ascending aorta at the level of the carina. The region of interest (ROI) is placed within the ascending aorta. A small bolus of contrast plus saline chaser is injected at the same flow rate that will be used for CTA acquisition.	▲ Delay: 10 s ▲ CARE Dose4D™ & CARE kV: Manual kV ▲ 100 kV ▲ CARE keV IQ level: 25 ▲ Slice/Collimation: 1 x10 mm ▲ No. of scans: 15 ▲ Cycle time: 0.9 s But can be suspended when the bolus has passed through the region

3.1 Alternatively, CARE Bolus

General	Data Acquisition
CARE Bolus (automatic bolus tracking) monitors the attenuation within the vessel of interest (ascending aorta). Scans are set up at the level of ascending aorta at the level of the carina. The full dose of contrast media is injected at the decided flow rate. The CTA acquisition is automatically triggered when the vessel enhancement reaches the pre-defined HU level (100–150HU) above the baseline. See “Contrast Protocols” for customers’ best practice.	▲ Delay: 10 s ▲ CARE Dose4D™ & CARE kV: Manual kV ▲ CARE keV IQ level: 25 ▲ Slice/Collimation: 1 x 10 mm

4. Prospective or Retrospective Triggered Coronary CT Angiography (Recommended Heart Rates: up to 70 bpm)^a

General	Data Acquisition	Data Reconstruction
General ECG triggered Dual Source data acquisition of the heart. Scan range 12–15 cm from the carina to the apex of the heart. Use unenhanced CaSc CT data for planning if available. kV will be automatically selected by CARE kV. Use ZeeFree reconstructions.	If Test Bolus was used: ▲ Delay: time-to-peak value in s ▲ CARE Dose4D™ & CARE kV: Full △ Limit CARE kV minimum kV to 100 and CARE kV maximum kV to 120 kV^a ▲ CARE keV IQ level: 83 ▲ Slice/Collimation: 64 x 0.6 mm ▲ Scan mode*: CardiacDualsourceSequenceAdultAngioFlex or CardiacDualsourceSpiralAdultAngio ▲ ECG Pulsing*: standard ▲ Scan direction: craniocaudal ▲ Rotation time: 0.33 s ▲ Temporal resolution: 86 ms ▲ Scan window*: Stable HR HR < 70 bpm: 60%–80%^a HR > 70 bpm: 30%–80%^a Arrhythmic HR (e.g. atrial fibrillation) 300ms–400ms <i>*If the patient has high calcium or stents consider the Care kV setting to 'Semi' or adjust the kV to 120^a</i>	▲ Axial reconstruction within the ECG trigger window, multiphase (5%), BestDiast. Choose BestSyst and Millisecond unit (smallest interval)^{a,b} for arrhythmic heart rates. ▲ Field of view limited to the heart. ▲ Slice thickness: 0.8 mm^a ▲ Increment: 0.4 mm^a ▲ ZeeFree enables misalignment correction algorithm. (Enable at least one reconstruction with TrueStack to enable manual crosscheck for the presence of misalignment in the data set.) ▲ Medium smooth convolution kernel with either filtered back projection: Bv40 or Bv44 Or iterative reconstruction (e.g. QIR, strength ≤ 2). ▲ If the patient has high calcium, consider a sharper convolution kernel: Bv48.

* With myExam Companion, the system automatically chooses the correct scan mode and pulsing window, depending on the HR and HR variability.

5. Contrast Protocol

General	Data Acquisition	Comments
The injection rate and volume should be increased for larger patients. Place a 20- or 18-gauge IV cannula in the RIGHT arm.	Generally: ▲ Iodine Concentration: 320–370mg Iodine/mL ▲ Contrast Volume: 55–97mL^a ▲ Saline Volume: 50mL ▲ Flow rate: 4.0–7.5mL/s^a	

^a – Based on Cleerly's data requirements

^b –Smallest ms interval changes depending on the systems' SW version and operating systems:
SOMARIS 10: VB20 and above, 20ms. VB10 and below, 50ms

7. SOMATOM Definition Flash, SOMATOM Drive and SOMATOM Force

SOMATOM Definition Flash, SOMATOM Drive and Siemens SOMATOM Force are Dual Source systems allowing for a heart rate independent temporal resolution of 75 ms for both the SOMATOM Definition Flash and SOMATOM Drive and 66 ms for the SOMATOM Force.

1. Topogram

General	Data Acquisition (Default)	Patient Preparation
AP topogram covering the chest.	▲ Ref. kVp: 120 kVp ▲ Qual. ref. mAs: 35 mAs ▲ Slice/Collimation: 6 x 0.6 mm ▲ Length: 512 mm	▲ Patient positioning: The following technique provides patient comfort and optimal image quality for the study: – Head or feet first; supine with head, knees, and lower legs supported by appropriate accessories. – Arms raised above the head; resting comfortably on the head-arm support. – The torso of the patient must be straight, not rotated. – Torso slightly below the middle of the scan field (~3cm), centered with the help of the laser light markers aimed at the iso-center of the heart. ▲ Place ECG-electrodes, as anatomically depicted on the labeled electrodes and IV access in accordance with institutional policies. Recommendation: 18-gauge or larger intravenous needle in the right antecubital vein. Automated contrast injection using a dual-cylinder injector. ▲ Provide enough time for the patient to practice breath holds prior to acquisition. To avoid breathing motion artifacts, the patient is instructed not to breathe and swallow during the acquisition. It is necessary to observe the ECG behavior during the breath hold procedure. The heart rate may decrease during the initial seconds of breath-holding or increase if the patient is straining to hold his breath at the end of the scan.

2. CaSc (optional) – Non-contrast Examination

General	Data Acquisition	Data Reconstruction
Scan range of 12–15 cm from the carina to the apex of the heart. Can be used for subsequent contrast-enhanced data acquisition. Can be used to rule out the presence of excessive calcification, which may reduce the diagnostic accuracy of the CTA study.	▲ Prospective ECG-triggering ▲ Ref. kVp: 120 kVp ▲ Qual. ref. mAs: 80 mAs ▲ CARE kV: Off (CARE kV: On in combination with kV independent CaSc with a Sa36 reconstruction. CARE kV setting: Bone) ▲ CARE Dose4D™: on ▲ Rotation time: 0.28 s (SOMATOM Definition Flash, SOMATOM Drive), 0.25 s (SOMATOM Force) ▲ Temporal resolution: 75 ms (SOMATOM Definition Flash, SOMATOM Drive), 66 ms (SOMATOM Force) ▲ Slice/Collimation: 2 x 128 x 0.6 mm (SOMATOM Definition Flash, SOMATOM Drive), 2 x 192 x 0.6 mm (SOMATOM Force) ▲ Scan direction cranio-caudal	▲ Axial reconstruction within the ECG trigger window, commonly BestDiast ▲ Field of view limited to the heart ▲ Kernel: Qr36 (Kernel: Sa36, if available, allows CaSc with CARE kV On.) ▲ WFBP Reconstruction ▲ Slice thickness: 3 mm ▲ Increment: 1.5 mm

3. Test Bolus

General	Data Acquisition
A series of sequential scans to monitor the arrival of the bolus to generate a time density curve. The peak of the curve is then used to determine the scanning delay for the CTA acquisition. Scans are set up at the level of ascending aorta at the level of the carina. The region of interest (ROI) is placed within the ascending aorta. A small bolus of contrast plus saline chaser is injected at the same flow rate that will be used for CTA acquisition.	▲ Delay: 10 s ▲ Ref. kVp: 100 kVp ▲ Qual. ref. mAs: 24 mAs ▲ Slice/Collimation: 1 x10 mm ▲ No. of scans: 15 But can be suspended when the bolus has passed through the region

3.1 Alternatively, CARE Bolus

General	Data Acquisition
CARE Bolus (automatic bolus tracking) monitors the attenuation within the vessel of interest (ascending aorta). Scans are set up at the level of ascending aorta at the level of the carina. The full dose of contrast media is injected at the decided flow rate. The CTA acquisition is automatically triggered when the vessel enhancement reaches the pre-defined HU level (100–150HU) above the baseline. See “Contrast Protocols” for customers’ best practice.	▲ Delay: 10 s ▲ Ref. kVp: 100 kVp ▲ Qual. ref. mAs: 24 mAs ▲ Slice/Collimation: 1 x10 mm

4. Prospective Adaptive Triggered Sequential Coronary CT Angiography (Recommended Heart Rates: up to 70 bpm)^a

General	Data Acquisition	Data Reconstruction
General ECG triggered Dual Source data acquisition of the heart. Scan range 12–15 cm from the carina to the apex of the heart. Use unenhanced CaSc CT data for planning if available. kV will be automatically selected by CARE kV. Use TrueStack reconstructions.	If Test Bolus was used: ▲ Delay: time-to-peak value in s ▲ Ref kVp: 100 kVp * ▲ Qual ref mAs: 380 mAs (Flash), 300 mAs (Drive), 300 mAs (Force) ▲ Slice/Collimation: 2 x 128 x 0.6 mm (Flash, Drive), 2 x 192 x 0.6 mm (Force) ▲ CARE kV: on △ Limit CARE kV minimum kV to 100 and CARE kV maximum kV to 120 kV^a ▲ CARE Dose4D™: on ▲ ECG Pulsing: auto ▲ Scan direction: craniocaudal ▲ Rotation time: 0.28 s (Flash, Drive), 0.25 s (Force) ▲ Temporal resolution: 75 ms (Flash, Drive), 66 ms (Force) ▲ Scan window: Stable HR HR < 70 bpm: 60%–80%^a HR > 70 bpm: 30%–80% Arrhythmic HR * switch to retrospective gated CCTA (e.g. atrial fibrillation) 200ms–400ms <i>*If the patient has high calcium or stents consider the Care kV setting to 'Semi' or adjust the kV to 120^a</i>	▲ Axial reconstruction within the ECG trigger window, multiphase (5%), BestDiast. Choose BestSyst and Millisecond unit (10ms) for arrhythmic heart rates. ▲ Field of view limited to the heart. ▲ Slice thickness: 0.8 mm^a ▲ Increment: 0.4 mm^a ▲ TrueStack: on ▲ Medium smooth convolution kernel with either filtered back projection: Bv38 or Bv40 Or additional iterative reconstruction (e.g. SAFIRE/ADMIRE, strength ≤ 2). ▲ If the patient has high calcium, consider a sharper convolution kernel: Bv48 (Flash, Drive), or Bv49 (Force).

* With myExam Companion, the system automatically chooses the correct scan mode and pulsing window, depending on the HR and HR variability.

5. Contrast Protocol

General	Data Acquisition	Comments
The injection rate and volume should be increased for larger patients. CTA requires contrast medium with an iodine concentration of at least 320 mgI/mL.^a Place a 20- or 18-gauge IV cannula in the RIGHT arm.	Test Bolus ▲ CM Bolus: 10–15mL ▲ Saline chaser: 40–50mL ▲ Flow rate: 4.0–7.5mL/s^a (same as during CTA Acquisition) CCTA - Generally: ▲ Iodine Concentration: 320–370mg Iodine/mL ▲ Contrast Volume: 50–80mL^a ▲ Saline Volume: 50mL ▲ Flow rate: 4.0–7.5mL/s^a	

^a – Based on Cleerly's data requirements

8. SOMATOM X.ceed & X.cite

Siemens SOMATOM X.ceed and X.cite are single-source systems allowing for a temporal resolution of 125 ms for the X.ceed (with rotation times of 250 ms) and 150 ms for the X.cite (with a rotation time of 300 ms).

1. Topogram

General	Data Acquisition (Default)	Patient Preparation
AP topogram covering the chest. Additional LAT topogram performed in opposite direction (enables fully automated iso-centering of the heart).	▲ Sn100 kV; 55 mA ▲ Scan mode: ScanplanningTopoAdultSn ▲ Length: 512 mm	▲ Patient positioning: The following technique provides patient comfort and optimal image quality for the study: – Head or feet first; supine with head, knees, and lower legs supported by appropriate accessories. – Arms raised above the head; resting comfortably on the head-arm support. – The torso of the patient must be straight, not rotated. – Torso slightly below the middle of the scan field (~3cm), centered with the help of the laser light markers aimed at the iso-center of the heart. ▲ Place ECG-electrodes, as anatomically depicted on the labeled electrodes and IV access in accordance with institutional policies. Recommendation: 18-gauge or larger intravenous needle in the right antecubital vein. Automated contrast injection using a dual-cylinder injector. ▲ Provide enough time for the patient to practice breath holds prior to acquisition. To avoid breathing motion artifacts, the patient is instructed not to breathe and swallow during the acquisition. It is necessary to observe the ECG behavior during the breath hold procedure. The heart rate may decrease during the initial seconds of breath-holding or increase if the patient is straining to hold his breath at the end of the scan.

2. CaSc (optional) – Non-contrast Examination

General	Data Acquisition	Data Reconstruction
Scan range of 12–15 cm from the carina to the apex of the heart. Can be used for subsequent contrast-enhanced data acquisition. Can be used to rule out the presence of excessive calcification, which may reduce the diagnostic accuracy of the CTA study.	▲ Prospective ECG-triggering ▲ CARE Dose4D™ & CARE kV: Full ▲ CARE keV IQ level: 19 ▲ Scan mode: CardiacSequenceAdult ▲ Rotation time: 0.30 s (SOMATOM X.cite) 0.25 s (SOMATOM X.ceed) ▲ Temporal resolution: 150 ms (SOMATOM X.cite) 125 ms (SOMATOM X.ceed) ▲ Acquisition: 128 x 0.60 mm (z-sharp) ▲ Scan direction: craniocaudal	▲ Axial reconstruction within the ECG trigger window, commonly BestDiast ▲ Field of view limited to the heart ▲ Slice thickness: 3 mm ▲ Increment: 1.5 mm ▲ WFBP Reconstruction (filtered back projection) Convolution kernel: Sa36

3. Test Bolus

General	Data Acquisition
A series of sequential scans to monitor the arrival of the bolus to generate a time density curve. The peak of the curve is then used to determine the scanning delay for the CTA acquisition. Scans are set up at the level of ascending aorta at the level of the carina. The region of interest (ROI) is placed within the ascending aorta. A small bolus of contrast plus saline chaser is injected at the same flow rate that will be used for CTA acquisition.	▲ Delay: 10 s ▲ CARE Dose4D™ & CARE kV: Manual kV ▲ 100 kV ▲ CARE keV IQ level: 25 ▲ Slice/Collimation: 1 x 10 mm ▲ No. of scans: 15 ▲ Cycle time: 0.9 s - But can be suspended when the bolus has passed through the region

3.1 Alternatively, CARE Bolus

General	Data Acquisition
CARE Bolus (automatic bolus tracking) monitors the attenuation within the vessel of interest (ascending aorta). Scans are set up at the level of ascending aorta at the level of the carina. The full dose of contrast media is injected at the decided flow rate. The CTA acquisition is automatically triggered when the vessel enhancement reaches the pre-defined HU level (100–150HU) above the baseline. See “Contrast Protocols” for customers’ best practice.	▲ Delay: 10 s ▲ CARE Dose4D™ & CARE keV: Manual kV ▲ CARE keV IQ level: 25 ▲ Slice/Collimation: 1 x 10 mm

4. Prospective or Retrospective Triggered Coronary CT Angiography (Recommended Heart Rates: up to 65 bpm)^a

General	Data Acquisition	Data Reconstruction
General ECG triggered Dual Source data acquisition of the heart. Scan range 12–15 cm from the carina to the apex of the heart. Use unenhanced CaSc CT data for planning if available. kV will be automatically selected by CARE kV. Use ZeeFree reconstructions.	If Test Bolus was used: ▲ Delay: time-to-peak value in s ▲ CARE Dose4D™ & CARE kV: Full △ Limit CARE kV minimum kV to 100 and CARE kV maximum kV to 120 kV^a ▲ CARE keV IQ level: 83 ▲ Slice/Collimation: 128 x 0.60 mm (z-sharp) ▲ Scan mode*: CardiacSequenceAdultAngioFlex or CardiacSpiralAdultAngio ▲ ECG Pulsing*: standard ▲ Scan direction: craniocaudal ▲ Rotation time: 0.30 s (SOMATOM X.cite) 0.25 s (SOMATOM X.ceed) ▲ Temporal resolution: 150 ms (SOMATOM X.cite) 125 ms (SOMATOM X.ceed) ▲ Scan window*: Stable HR HR < 65 bpm: 60%–80%^a HR > 65 bpm: 30%–80%^a Arrhythmic HR (e.g. atrial fibrillation) 300ms–400ms <i>*If the patient has high calcium or stents consider the Care kV setting to 'Semi' or adjust the kV to 120^a</i>	▲ Axial reconstruction within the ECG trigger window, multiphase (5%), BestDiast. Choose BestSyst and Millisecond unit (smallest interval)^{a,b} for arrhythmic heart rates. ▲ Field of view limited to the heart. ▲ Slice thickness: 0.8 mm ▲ Increment: 0.4 mm^a ▲ ZeeFree enables misalignment correction algorithm. (Enable at least one reconstruction with TrueStack to enable manual crosscheck for the presence of misalignment in the data set.) ▲ Medium smooth convolution kernel with either filtered back projection: Bv40 or Bv44 Or iterative reconstruction (e.g. ADMIRE, strength ≤ 2). ▲ If the patient has high calcium, consider a sharper convolution kernel: Bv49.

* With myExam Companion, the system automatically chooses the correct scan mode and pulsing window, depending on the HR and HR variability.

5. Contrast Protocol

General	Data Acquisition	Comments
The injection rate and volume should be increased for larger patients. Place a 20- or 18-gauge IV cannula in the RIGHT arm.	Test Bolus ▲ CM Bolus: 10–15mL ▲ Saline chaser: 40–50mL ▲ Flow rate: 4–7.5mL/s^a (same as during CTA Acquisition) CCTA - Generally: ▲ Iodine Concentration: 320–370mg Iodine/mL ▲ Contrast Volume: 55–97mL^a ▲ Saline Volume: 50mL ▲ Flow rate: 4–7.5mL/s^a	

^a – Based on Cleerly's data requirements

^b –Smallest ms interval changes depending on the systems' SW version and operating systems:
 SOMARIS 10: VB20 and above, 20ms. VB10 and below, 50ms

9. SOMATOM Definition AS+ & Edge

Siemens SOMATOM Definition AS+ and Edge are single source systems allowing for a temporal resolution of 166 ms and optionally 150 ms and 142 ms, respectively, when rotation times of 300 ms and 285 ms are employed.

1. Topogram

General	Data Acquisition (Default)	Patient Preparation
AP topogram covering the chest.	▲ Ref. kVp: 120 kVp ▲ Qual. ref. mAs: 35 mAs ▲ Slice/Collimation: 6 x 0.6 mm ▲ Length: 512 mm	▲ Patient positioning: The following technique provides patient comfort and optimal image quality for the study: – Head or feet first; supine with head, knees, and lower legs supported by appropriate accessories. – Arms raised above the head; resting comfortably on the head-arm support. – The torso of the patient must be straight, not rotated. – Torso slightly below the middle of the scan field (~3cm), centered with the help of the laser light markers aimed at the iso-center of the heart. ▲ Place ECG-electrodes, as anatomically depicted on the labeled electrodes and IV access in accordance with institutional policies. Recommendation: 18-gauge or larger intravenous needle in the right antecubital vein. Automated contrast injection using a dual-cylinder injector. ▲ Provide enough time for the patient to practice breath holds prior to acquisition. To avoid breathing motion artifacts, the patient is instructed not to breathe and swallow during the acquisition. It is necessary to observe the ECG behavior during the breath hold procedure. The heart rate may decrease during the initial seconds of breath-holding or increase if the patient is straining to hold his breath at the end of the scan.

2. CaSc (optional) – Non-contrast Examination

General	Data Acquisition	Data Reconstruction
Scan range of 12–15 cm from the carina to the apex of the heart. Can be used for subsequent contrast-enhanced data acquisition. Can be used to rule out the presence of excessive calcification, which may reduce the diagnostic accuracy of the CTA study.	▲ Prospective ECG-triggering ▲ Ref. kVp: 120 kVp ▲ Qual. ref. mAs: 40 mAs ▲ CARE kV: Off (CARE kV: On in combination with kV independent CaSc with a Sa36 reconstruction. CARE kV setting: Bone) ▲ CARE Dose4D™: on ▲ Rotation time: 0.30 s (SOMATOM Definition AS+) 0.28 s (SOMATOM Definition Edge) ▲ Temporal resolution: 150 ms (SOMATOM Definition AS+) 142 ms (SOMATOM Definition Edge) ▲ Slice/Collimation: 128 x 0.60 mm ▲ Scan direction cranio-caudal	▲ Axial reconstruction within the ECG trigger window, commonly BestDiast ▲ Field of view limited to the heart ▲ Kernel: Qr36 (Kernel: Sa36, if available, allows CaSc with CARE kV On.) ▲ WFBP Reconstruction ▲ Slice thickness: 3 mm ▲ Increment: 1.5 mm

3. Test Bolus

General	Data Acquisition
A series of sequential scans to monitor the arrival of the bolus to generate a time density curve. The peak of the curve is then used to determine the scanning delay for the CTA acquisition. Scans are set up at the level of ascending aorta at the level of the carina. The region of interest (ROI) is placed within the ascending aorta. A small bolus of contrast plus saline chaser is injected at the same flow rate that will be used for CTA acquisition.	▲ Delay: 10 s ▲ Ref. kVp: 100 kVp ▲ Qual. ref. mAs: 30 mAs ▲ Slice/Collimation: 1 x 10 mm ▲ No. of scans: 15 But can be suspended when the bolus has passed through the region

3.1 Alternatively, CARE Bolus

General	Data Acquisition
CARE Bolus (automatic bolus tracking) monitors the attenuation within the vessel of interest (ascending aorta). Scans are set up at the level of ascending aorta at the level of the carina. The full dose of contrast media is injected at the decided flow rate. The CTA acquisition is automatically triggered when the vessel enhancement reaches the pre-defined HU level (100–150HU) above the baseline. See “Contrast Protocols” for customers’ best practice.	▲ Delay: 10 s ▲ Ref. kVp: 100 kVp ▲ Qual. ref. mAs: 30 mAs ▲ Slice/Collimation: 1 x 10 mm

4. Prospective Adaptive Triggered Sequential Coronary CT Angiography (Recommended Heart Rates: up to 65 bpm)^a

General	Data Acquisition	Data Reconstruction
General ECG triggered Dual Source data acquisition of the heart. Scan range 12–15 cm from the carina to the apex of the heart. Use unenhanced CaSc CT data for planning if available. kV will be automatically selected by CARE kV. Use TrueStack reconstructions.	If Test Bolus was used: ▲ Delay: time-to-peak value in s ▲ Ref. kVp: 100 kVp * ▲ Qual. ref. mAs: 190 mAs (AS+), 150 mAs (Edge) ▲ Slice/Collimation: 128 x 0.60 mm ▲ CARE kV: on * △ Limit CARE kV minimum kV to 100 and CARE kV maximum kV to 120 kV^a ▲ CARE Dose4D™: on ▲ ECG Pulsing: auto ▲ Scan direction craniocaudal ▲ Rotation time: 0.30 s (AS+), 0.28 s (Edge) ▲ Temporal resolution: 150 ms (AS+), 142 ms (Edge) ▲ Scan window*: Stable HR HR ≤ 65 bpm: 60%–80% HR > 65 bpm: 30%–80% Arrhythmic HR (e.g. atrial fibrillation) HR ≤ 65 bpm: switch to retrospective gated CCTA. 200–400 ms For HRs > 65 bpm: switch to retrospective gated CCTA with 30–80%. <i>*If the patient has high calcium or stents consider the Care kV setting to 'Semi' or adjust the kV to 120^a</i>	▲ Axial reconstruction within the ECG trigger window, multiphase (5%), BestDiast. - Choose BestSyst and Millisecond unit (smallest interval) for arrhythmic heart rates. ▲ Field of view limited to the heart. ▲ Slice thickness: 0.8 mm^a ▲ Increment: 0.4 mm ▲ TrueStack: on ▲ Medium smooth convolution kernel with either filtered back projection: Bv38 or Bv40 Or additional iterative reconstruction (e.g. SAFIRE/ADMIRE, strength ≤ 2). ▲ If the patient has high calcium, consider a sharper convolution kernel: Bv44 or Bv48.

* With myExam Companion, the system automatically chooses the correct scan mode and pulsing window, depending on the HR and HR variability.

5. Contrast Protocol

General	Data Acquisition	Comments
The injection rate and volume should be increased for larger patients. Place a 20- or 18-gauge IV cannula in the RIGHT arm.	Test Bolus ▲ CM Bolus: 10–15mL ▲ Saline chaser: 40–50mL ▲ Flow rate: 4–7.5mL/s^a (same as during CTA Acquisition) CCTA - Generally: ▲ Iodine Concentration: 320–370mg Iodine/mL ▲ Contrast Volume: 55–97mL^a ▲ Saline Volume: 50mL ▲ Flow rate: 4–7.5mL/s^a	

10. SOMATOM go.Top

Siemens SOMATOM go.Top is a single source system allowing for a temporal resolution of 165 ms, when rotation times of 330 ms are employed.

1. Topogram

General	Data Acquisition (Default)	Patient Preparation
AP topogram covering the chest. Additional LAT topogram performed in opposite direction (enables fully automated iso-centering of the heart).	▲ Sn100 kV; 60 mA ▲ Scan mode: ScanplanningTopoAdultSn ▲ Length: 512 mm	▲ Patient positioning: The following technique provides patient comfort and optimal image quality for the study: – Head or feet first; supine with head, knees, and lower legs supported by appropriate accessories. – Arms raised above the head; resting comfortably on the head-arm support. – The torso of the patient must be straight, not rotated. – Torso slightly below the middle of the scan field (~3cm), centered with the help of the laser light markers aimed at the iso-center of the heart. ▲ Place ECG-electrodes, as anatomically depicted on the labeled electrodes and IV access in accordance with institutional policies. Recommendation: 18-gauge or larger intravenous needle in the right antecubital vein. Automated contrast injection using a dual-cylinder injector. ▲ Provide enough time for the patient to practice breath holds prior to acquisition. To avoid breathing motion artifacts, the patient is instructed not to breathe and swallow during the acquisition. It is necessary to observe the ECG behavior during the breath hold procedure. The heart rate may decrease during the initial seconds of breath-holding or increase if the patient is straining to hold his breath at the end of the scan.

2. CaSc (optional) – Non-contrast Examination

General	Data Acquisition	Data Reconstruction
Scan range of 12–15 cm from the carina to the apex of the heart.	▲ Prospective ECG-triggering	▲ Axial reconstruction within the ECG trigger window, commonly BestDiast
Can be used for subsequent contrast-enhanced data acquisition.	▲ CARE Dose4D™ & CARE kV: Full	▲ Field of view limited to the heart
Can be used to rule out the presence of excessive calcification, which may reduce the diagnostic accuracy of the CTA study.	▲ CARE keV IQ level: 19	▲ Slice thickness: 3 mm
	▲ Scan mode: CardiacSequenceAdult	▲ Increment: 1.5 mm
	▲ Acquisition: 64 x 0.60 mm	▲ WFBP Reconstruction (filtered back projection) Convolution kernel: Sa36
	▲ Scan direction: craniocaudal	

3. Test Bolus

General	Data Acquisition
A series of sequential scans to monitor the arrival of the bolus to generate a time density curve. The peak of the curve is then used to determine the scanning delay for the CTA acquisition.	▲ Delay: 10 s
Scans are set up at the level of ascending aorta at the level of the carina. The region of interest (ROI) is placed within the ascending aorta.	▲ CARE Dose4D™ & CARE kV: Manual kV
A small bolus of contrast plus saline chaser is injected at the same flow rate that will be used for CTA acquisition.	▲ 100 kV
	▲ CARE keV IQ level: 25
	▲ Slice/Collimation: 1 x10 mm
	▲ No. of scans: 15
	▲ Cycle time: 0.9 s But can be suspended when the bolus has passed through the region

3.1 Alternatively, CARE Bolus

General	Data Acquisition
CARE Bolus (automatic bolus tracking) monitors the attenuation within the vessel of interest (ascending aorta).	▲ Delay: 10 s
Scans are set up at the level of ascending aorta at the level of the carina.	▲ CARE Dose4D™ & CARE kV: Manual kV
The full dose of contrast media is injected at the decided flow rate. The CTA acquisition is automatically triggered when the vessel enhancement reaches the pre-defined HU level (100–150HU) above the baseline. See “Contrast Protocols” for customers’ best practice.	▲ CARE keV IQ level: 25
	▲ Slice/Collimation: 1 x 10 mm

4. Coronary CT Angiography (Recommended Heart Rates: up to 60 bpm)^a

General	Data Acquisition	Data Reconstruction
General ECG triggered Dual Source data acquisition of the heart. Scan range 12–15 cm from the carina to the apex of the heart. Use unenhanced CaSc CT data for planning if available. kV will be automatically selected by CARE kV. Use ZeeFree reconstructions.	If Test Bolus was used: ▲ Delay: time-to-peak value in s + 3s ▲ CARE Dose4D™ & CARE kV: Full △ Limit CARE kV minimum kV to 100 and CARE kV maximum kV to 120 kV^a ▲ CARE keV IQ level: 83 ▲ Scan mode: CardiacSpiralAdultAngio ▲ Acquisition: 64 x 0.6 mm ▲ ECG Pulsing: standard ▲ Scan direction: craniocaudal ▲ Scan window: Stable HR HR < 60 bpm: 60%–80%^a HR > 60 bpm: 30%–80%^a Arrhythmic HR (e.g. atrial fibrillation) 300ms–400ms <i>*If the patient has high calcium or stents consider the Care kV setting to 'Semi' or adjust the kV to 120^a</i>	▲ Axial reconstruction within the ECG trigger window, multiphase (5%), BestDiast. Choose BestSyst and Millisecond unit (smallest interval)^{a,b} for arrhythmic heart rates. ▲ Field of view limited to the heart. ▲ Slice thickness: 0.8 mm ▲ Increment: 0.4 mm^a ▲ ZeeFree enables misalignment correction algorithm. (Enable at least one reconstruction with TrueStack to enable manual crosscheck for the presence of misalignment in the data set.) ▲ Medium smooth convolution kernel with either filtered back projection: Bv40 or Bv44 Or iterative reconstruction (e.g. SAFIRE/ADMIRE, strength ≤ 2). ▲ If the patient has high calcium, consider a sharper convolution kernel: Bv49.

* With myExam Companion, the system automatically chooses the correct scan mode and pulsing window, depending on the HR and HR variability.

5. Contrast Protocol

General	Data Acquisition	Comments
The injection rate and volume should be increased for larger patients. Place a 20- or 18-gauge IV cannula in the RIGHT arm.	Test Bolus ▲ CM Bolus: 10–15mL ▲ Saline chaser: 40–50mL ▲ Flow rate: 4–7.5mL/s^a (same as during CTA Acquisition) CCTA - Generally: ▲ Iodine Concentration: 320–370mg Iodine/mL ▲ Contrast Volume: 55–97mL^a ▲ Saline Volume: 50mL ▲ Flow rate: 4–7.5mL/s^a	

^a – Based on Cleerly's data requirements

^b –Smallest ms interval changes depending on the systems' SW version and operating systems:
SOMARIS 10: VB20 and above, 20ms. VB10 and below, 50ms

11. SOMATOM go.All

Siemens SOMATOM go.All is a single source system allowing for a temporal resolution of 165 ms, when rotation times of 330 ms are employed. Adaptive retrospective ECG triggered scanning only.

1. Topogram

General	Data Acquisition (Default)	Patient Preparation
AP topogram covering the chest. Additional LAT topogram performed in opposite direction (enables fully automated iso-centering of the heart).	▲ Sn100 kV; 60 mA ▲ Scan mode: ScanplanningTopoAdultSn ▲ Length: 512 mm	▲ Patient positioning: The following technique provides patient comfort and optimal image quality for the study: – Head or feet first; supine with head, knees, and lower legs supported by appropriate accessories. – Arms raised above the head; resting comfortably on the head-arm support. – The torso of the patient must be straight, not rotated. – Torso slightly below the middle of the scan field (~3cm), centered with the help of the laser light markers aimed at the iso-center of the heart. ▲ Place ECG-electrodes, as anatomically depicted on the labeled electrodes and IV access in accordance with institutional policies. Recommendation: 18-gauge or larger intravenous needle in the right antecubital vein. Automated contrast injection using a dual-cylinder injector. ▲ Provide enough time for the patient to practice breath holds prior to acquisition. To avoid breathing motion artifacts, the patient is instructed not to breathe and swallow during the acquisition. It is necessary to observe the ECG behavior during the breath hold procedure. The heart rate may decrease during the initial seconds of breath-holding or increase if the patient is straining to hold his breath at the end of the scan.

2. CaSc (optional) – Non-contrast Examination

General	Data Acquisition	Data Reconstruction
Scan range of 12–15 cm from the carina to the apex of the heart.	▲ Prospective ECG-triggering	▲ Axial reconstruction within the ECG trigger window, commonly BestDiast
Can be used for subsequent contrast-enhanced data acquisition.	▲ CARE Dose4D™ & CARE kV: Full	▲ Field of view limited to the heart
Can be used to rule out the presence of excessive calcification, which may reduce the diagnostic accuracy of the CTA study.	▲ CARE keV IQ level: 19	▲ Slice thickness: 3 mm
	▲ Scan mode: CardiacSequenceAdult	▲ Increment: 1.5 mm
	▲ Acquisition: 32 x 0.7 mm	▲ WFBP Reconstruction (filtered back projection) Convolution kernel: Sa36
	▲ Scan direction: craniocaudal	

3. Test Bolus

General	Data Acquisition
A series of sequential scans to monitor the arrival of the bolus to generate a time density curve. The peak of the curve is then used to determine the scanning delay for the CTA acquisition.	▲ Delay: 10 s
Scans are set up at the level of ascending aorta at the level of the carina. The region of interest (ROI) is placed within the ascending aorta.	▲ CARE Dose4D™ & CARE kV: Manual kV
A small bolus of contrast plus saline chaser is injected at the same flow rate that will be used for CTA acquisition.	▲ CARE keV IQ level: 25
	▲ Slice/Collimation: 1 x10 mm
	▲ No. of scans: 15
	▲ Cycle time: 0.9 s But can be suspended when the bolus has passed through the region

3.1 Alternatively, CARE Bolus

General	Data Acquisition
CARE Bolus (automatic bolus tracking) monitors the attenuation within the vessel of interest (ascending aorta).	▲ Delay: 10 s
Scans are set up at the level of ascending aorta at the level of the carina.	▲ CARE Dose4D™ & CARE kV: Manual kV
The full dose of contrast media is injected at the decided flow rate. The CTA acquisition is automatically triggered when the vessel enhancement reaches the pre-defined HU level (100–150HU) above the baseline. See “Contrast Protocols” for customers’ best practice.	▲ CARE keV IQ level: 25
	▲ Slice/Collimation: 1 x 10 mm

4. Coronary CT Angiography (Recommended Heart Rates: up to 60 bpm)^a

General	Data Acquisition	Data Reconstruction
General ECG triggered data acquisition of the heart. Scan range 12–15 cm from the carina to the apex of the heart. Use unenhanced CaSc CT data for planning if available. kV will be automatically selected by CARE kV. Use ZeeFree reconstructions.	If Test Bolus was used: ▲ Delay: time-to-peak value in s + 3s ▲ CARE Dose4D™ & CARE kV: Full △ Limit CARE kV minimum kV to 100 and CARE kV maximum kV to 120 kV^a ▲ Scan mode: CardiacSpiralAdultAngio ▲ Acquisition: 32 x 0.7 mm ▲ ECG Pulsing: standard ▲ Scan direction: craniocaudal ▲ Scan window: Stable HR HR < 60 bpm: 60%–80%^a HR > 60 bpm: 30%–80%^a Arrhythmic HR (e.g. atrial fibrillation) 300ms–400ms <i>*If the patient has high calcium or stents consider the Care kV setting to 'Semi' or adjust the kV to 120^a</i>	▲ Axial reconstruction within the ECG trigger window, multiphase (5%), BestDiast. Choose BestSyst and Millisecond unit (smallest interval)^{a,b} for arrhythmic heart rates. ▲ Field of view limited to the heart. ▲ Slice thickness: 0.8 mm ▲ Increment: 0.4 mm^a ▲ ZeeFree enables misalignment correction algorithm. (Enable at least one reconstruction with TrueStack to enable manual crosscheck for the presence of misalignment in the data set.) ▲ Medium smooth convolution kernel with either filtered back projection: Bv40 or Bv44 Or iterative reconstruction (e.g. SAFIRE/ADMIRE, strength ≤ 2). ▲ If the patient has high calcium, consider a sharper convolution kernel: Bv49.

* With myExam Companion, the system automatically chooses the correct scan mode and pulsing window, depending on the HR and HR variability.

5. Contrast Protocol

General	Data Acquisition	Comments
The injection rate and volume should be increased for larger patients. Place a 20- or 18-gauge IV cannula in the RIGHT arm.	Test Bolus ▲ CM Bolus: 10–15mL ▲ Saline chaser: 40–50mL ▲ Flow rate: 4–7.5mL/s^a (same as during CTA Acquisition) CCTA - Generally: ▲ Iodine Concentration: 320–370mg Iodine/mL ▲ Contrast Volume: 55–97mL^a ▲ Saline Volume: 50mL ▲ Flow rate: 4–7.5mL/s^a	

^a – Based on Cleerly's data requirements

^b –Smallest ms interval changes depending on the systems' SW version and operating systems:
SOMARIS 10: VB20 and above, 20ms. VB10 and below, 50ms

12. Bibliography

1. Abbara S, Blanke P, Maroules CD, et al. SCCT guidelines for the performance and acquisition of coronary computed tomographic angiography: A report of the society of Cardiovascular Computed Tomography Guidelines Committee: Endorsed by the North American Society for Cardiovascular Imaging (NASCI). *J Cardiovasc Comput Tomogr*. 2016 Nov-Dec;10(6):435-449.

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