

Rachael Grant chapter script:

Hello! Welcome to the HeartFlow nursing education program on Coronary CTA plus FFR-CT. My name is Rachael Grant, and I am a nurse by training and hold the roles of Program Manager and Nurse Navigator manager for Sanger Heart and Vascular in Charlotte, NC. I have worked with cardiac imaging patients for many years. This presentation will provide an overview of the technology of Coronary CTA and CT-based fractional flow reserve, or FFR-CT. We will review best practices for image acquisition and patient care during

a Coronary CTA.

Faculty



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Program Manager – Advanced Cardiac Imaging
Nurse Navigator & Cardiac Schedulers Manager
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Charlotte, NC



Jonathon Leipsic, MD, FRCPC, MSCCT
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Sara Wallace, RN, BSN
Program Coordinator – Cardiac Imaging
Nurse Navigator
Cone Health Heart & Vascular Center
Greensboro, NC

I will be providing some of the training during the course along with Dr. Jonathon Leipsic and Sara Wallace.

Learning Objectives

Following this course, participants will understand:

- Common diagnostic testing options for patients with suspected coronary artery disease
- Why a better diagnostic pathway for these patients is Coronary Computed Tomographic Angiography (CCTA) plus FFR_{CT}
- Appropriate patient selection and preparation for CCTA and FFR_{CT}
- Guidelines and best practices for CCTA heart rate control and medication administration to optimize image quality for FFR_{CT}
- How to manage patients before, during, and post CCTA scan
- The role of a nurse navigator in cardiac CT

These are the learning objectives associated with this training course

Agenda

Chapter	Topic
1	Overview of Coronary CTA and FFR_{CT}
2	Diagnosing Coronary Artery Disease with Coronary CTA + FFR_{CT}
3	Appropriate Patients for CCTA + FFR_{CT}
4	Patient Factors that can Affect Image Quality
5	Patient Disease States and How They Can Affect Scanning
6	Patient Education
7	Patient Management
8	Medications Used in CCTA
9	The Cardiac Nurse Navigator Role
Quiz	Patient Case Studies Quiz

The agenda for this training course is divided into 9 chapters plus a quiz to earn a certificate. The initial chapters focus on basic background information about coronary CTA and FFRCT.
Subsequent chapters focus on patient-specific factors to consider when preparing and imaging patients, plus patient education and management.
The final chapters describe medications used in Coronary CTA imaging, the role of the cardiac nurse navigator, and case study application to assess your understanding of the content.

Overview of Coronary CTA and FFR_{CT}

Chapter 1

Let’s move into Chapter 1, which is a brief overview of Coronary CTA and FFRCT so these concepts can be familiar as we progress throughout the training.

Coronary Computed Tomographic Angiography (CCTA)

- Noninvasive cardiac assessment
- Identifies coronary artery stenoses, lipid plaques, calcifications, aneurysms, and other conditions
- Uses IV contrast dye
- Anatomic test

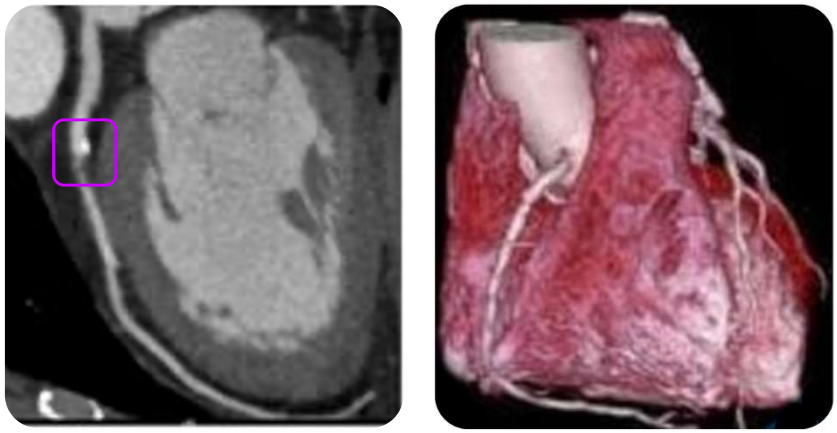


Coronary CTA is a specialized form of cardiac CT, which focuses on the coronary arteries. Like all forms of computed tomography, it uses X-rays along with computerized processing to create cross-sectional images of the heart, as seen here. Coronary CTA is a noninvasive diagnostic test for coronary artery disease, which means it is safer for the patient than an invasive procedure such as cardiac catheterization. It can identify coronary stenoses, atherosclerotic plaques, calcification, and other abnormalities such as aneurysms or structural anomalies. Although it is

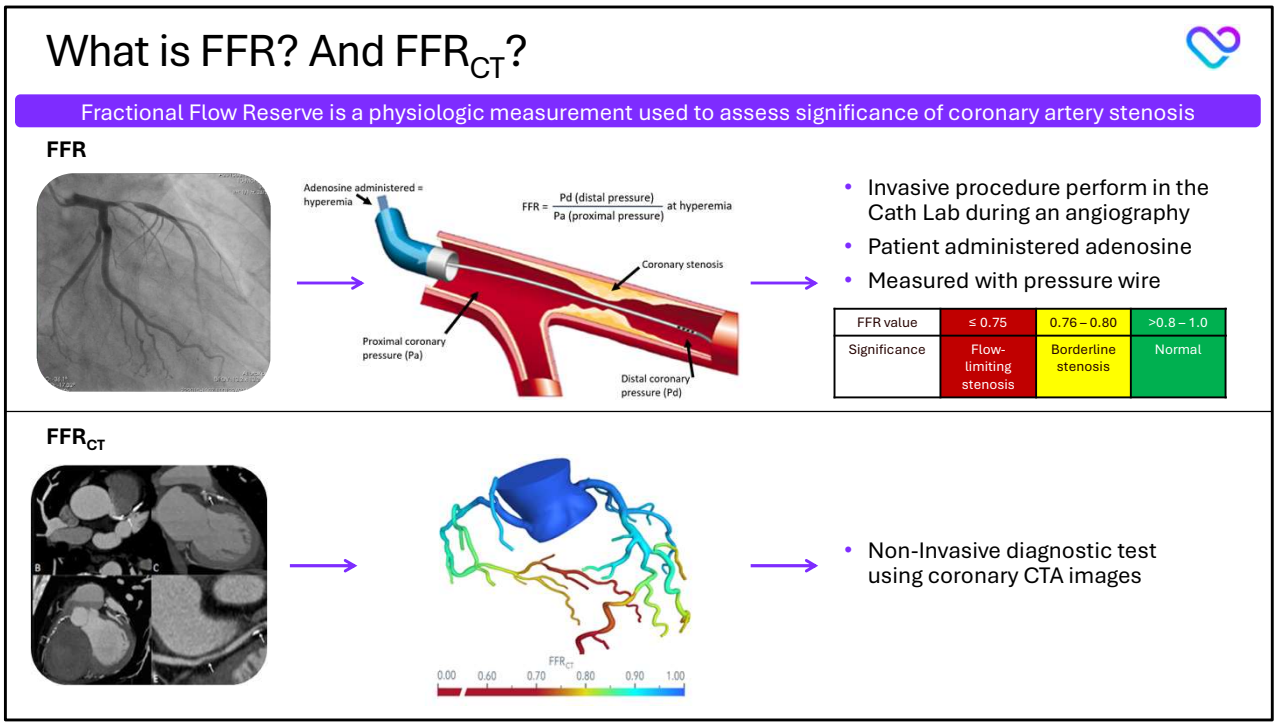
noninvasive, it does involve utilization of IV contrast dye to visualize the coronary arteries.

Coronary CTA is an anatomic test, meaning that it visualizes the anatomy of the coronary arteries. Some of the other diagnostic cardiac tests we will review are physiologic tests, meaning they evaluate the function of the heart. This is an important distinction that will become more meaningful as we move forward in this training.

Images from Coronary CTA



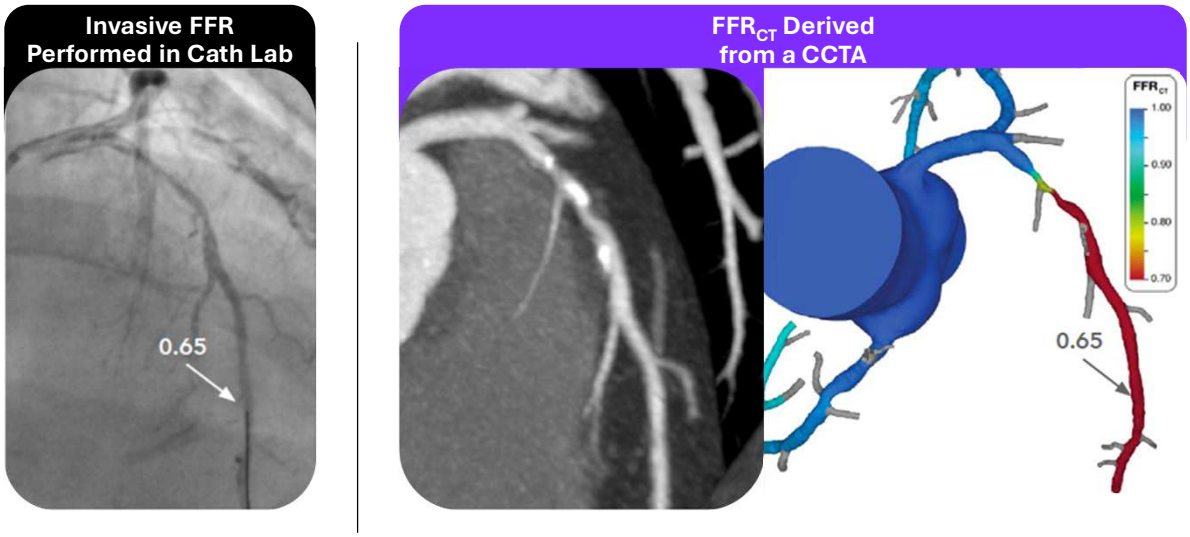
The left image shows a slice of a coronary CTA in black and white. Notice the bright white spot in the coronary artery with the narrowing immediately following. This image allows us to visually see the calcium and narrowing in a patient's artery. However, we don't know if these characteristics cause a loss of blood flow to the myocardium. This is the difference between an anatomic test versus a physiologic or functional test. On the right is a reconstructed, color image of a coronary CTA.



Understanding if a stenosis is causing a loss of blood flow to the heart muscle can be determined by something called Fractional Flow Reserve, or FFR (using a pressure wire invasively in the cath lab) or FFRCT (using coronary CTA). Let's dig into some basics. Fractional flow reserve, or FFR, is a physiologic measurement and is used to assess the significance of a coronary artery stenosis on blood flow. It is typically used to determine if the patient's vessel would benefit from revascularization. Fractional flow reserve is the ratio of two pressures across a coronary stenosis. FFR is defined as the pressure distal to the coronary stenosis divided by the pressure proximal to the coronary stenosis. If there is no stenosis in an artery, the pressure in the distal vessel should be the same as the pressure of the proximal vessel at the aorta, with an FFR measurement of 1.0. A completely normal FFR value is 1.0, indicating no obstruction to blood flow. A value of less than or equal to 0.75 is considered abnormal, indicating a flow-limiting stenosis. An FFR value of 0.76-0.79 would be considered as a borderline stenosis, or "in the grey zone".

Fractional flow reserve can be obtained invasively in the cath lab, where a wire is placed down the coronary artery, or it can be derived from Coronary CTA images, non-invasively. For this reason, FFR derived from a coronary CTA is known as FFR-CT.

Differences Between Invasive FFR and FFR_{CT}



On the left is an image of a coronary angiogram obtained in the cath lab in which one of the coronary stenoses in the left anterior descending artery was found to have an FFR value of 0.65. This indicates a flow-limiting stenosis. When an FFR is obtained in the cath lab, the pressures across the stenosis are measured invasively in the coronary artery by using a specialized wire with a pressure sensor at its tip.

On the right are images from the same patient of a coronary CTA and the associated non-invasive FFRCT. With FFRCT, the fractional flow reserve is derived from the Coronary CTA image, and in this case was also calculated as 0.65. Both measurements were taken in the same location and there is a correlation between the invasive FFR and the FFRCT.

Diagnosing Coronary Artery Disease with Coronary CTA + FFR_{CT}

Chapter 2

Jonathon Leipsic chapter script:
Hello, I'm Jonathon Leipsic and I'm a radiologist in Vancouver, British Columbia. I was a past president of SCCT and helped to write the SCCT guidelines for the performance and acquisition of coronary CTA. You will find that many of the concepts we are teaching today come from that publication.

The primary application of CCTA with FFR-CT is in the diagnosis of patients suspected of having coronary artery disease, this is what I will be reviewing in this chapter.

Coronary Artery Disease (CAD)

What is CAD?[1,2]

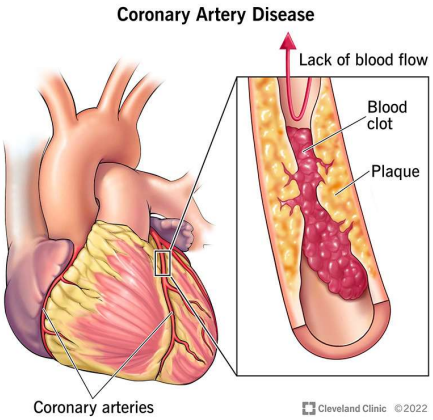
- Common heart condition in which the coronary arteries have become narrowed or blocked due to the buildup of plaque, resulting in diminished flow of blood, oxygen, and nutrients to the heart muscle (myocardium).
- Symptoms can include chest pain (angina), shortness of breath (SOB), pain/discomfort in arm(s), fatigue, and many less typical symptoms, such as neck or jaw pain and nausea.

Prevalence[3]

- Cardiovascular disease is the most common cause of mortality among adults in the US
- CAD is the most common type of heart disease, killing 375,476 people in 2021
- 1 in 20 adults age 20+ have CAD (about 5%)

Impact on healthcare[3]

- Heart disease costs the US ~$239.9 billion each year (data from 2018-2019)



1. Coronary Artery Disease. Mayo Clinic. May 25, 2022. https://www.mayoclinic.org/diseases-conditions/coronary-artery-disease/symptoms-causes/syc-20350613
2. Coronary Artery Disease. Cleveland Clinic. Updated October 13, 2023. https://my.clevelandclinic.org/health/diseases/16898-coronary-artery-disease
3. Heart Disease Facts. Centers for Disease Control and Prevention. Reviewed May 15, 2023. https://www.cdc.gov/heartdisease/facts.htm
4. Mayo Clinic Staff. Heart Attack. Mayo Clinic. October 9, 2023. https://www.mayoclinic.org/diseases-conditions/heart-attack/symptoms-causes/syc-20373106
Image: Coronary Artery Disease. Cleveland Clinic. Updated October 13, 2023. https://my.clevelandclinic.org/health/diseases/16898-coronary-artery-disease

As you know, coronary artery disease, or CAD, is the leading cause of mortality among US adults, and the most common type of heart disease. It is caused by the buildup of fatty deposits, known as plaque in the coronary arteries. This can lead to narrowing or blockage of the arteries resulting in diminished blood flow. Notice the image that shows the buildup of plaque on the endothelium of a coronary artery, that resulted in plaque rupture or erosion causing a blood clot at the site of narrowing. This blood clot can cause a complete obstruction resulting in a heart attack[4]. Coronary artery disease may be asymptomatic; however, if symptoms occur, they commonly manifest as anginal-type chest pain or discomfort, shortness of breath, fatigue, pain, or aching in the arms, particularly the left arm. Angina is chest discomfort associated with physical exertion, or sometimes emotional stress, and alleviated by rest. Sometimes coronary artery disease is associated with neck pain, jaw pain, or nausea. Heart disease has a huge impact on the healthcare system, costing about 239.9 billion dollars each year in the US.

References:

1. Coronary Artery Disease. Mayo Clinic. May 25, 2022. https://www.mayoclinic.org/diseases-conditions/coronary-artery-disease/symptoms-causes/syc-20350613
2. Coronary Artery Disease. Cleveland Clinic. Updated October 13, 2023.

https://my.clevelandclinic.org/health/diseases/16898-coronary-artery-disease
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4. Mayo Clinic Staff. Heart Attack. Mayo Clinic. October 9, 2023. https://www.mayoclinic.org/diseases-conditions/heart-attack/symptoms-causes/syc-20373106

Image:
Coronary Artery Disease. Cleveland Clinic. Updated October 13, 2023. https://my.clevelandclinic.org/health/diseases/16898-coronary-artery-disease

Tests Used to Evaluate for Coronary Artery Disease

One or more of these below tests may be ordered to assess anatomic evidence of coronary artery disease and physiologic significance

	Exercise tolerance /treadmill test (ETT)	Stress Echo-cardiogram	Single-photon emission computed tomography (SPECT)	Positron emission tomography (PET)	Dynamic Myocardial CT perfusion (CTP)	Cardiac magnetic resonance (CMR)	Coronary Computed Tomographic Angiography (CCTA)	CCTA w Heartflow Analysis (FFR_{CT})	Invasive cardiac catheterization / coronary angiography (ICA)	Cardiac CT calcium score (CAC)
			Nuclear perfusion imaging							
Coronary artery stenosis (anatomical diagnosis)	X	X	X	X	✓	X	✓	✓	✓	X
Lesion-specific Ischemia (physiologic diagnosis)	X	X	X	X	X	X	X	✓	✓	X
Myocardial perfusion (physiologic diagnosis)	X	X	✓	✓	✓	✓	X	X	X	X
Non-Invasive	✓	✓	✓	✓	✓	✓	✓	✓	X	✓
Radiation exposure	X	X	✓	✓	✓	X	✓	✓	✓	✓

There are several tests that can be used in the diagnosis of coronary artery disease. This table compares CCTA and FFRCT with other diagnostic tests, for example, exercise tolerance treadmill test, stress echocardiogram, nuclear stress test with SPECT or PET; myocardial CT perfusion, cardiac MRI, invasive cardiac catheterization with coronary angiography, and a calcium score.

All of these tests are noninvasive except for coronary angiography.

The noninvasive tests that can demonstrate coronary anatomy, or visual evidence of CAD, are: CCTA, CCTA with FFRCT, and dynamic myocardial CT perfusion.

The other noninvasive tests are physiologic or functional tests, for example: exercise treadmill, stress echo, nuclear SPECT or PET, or cardiac MRI. These tests detect ischemia by looking for EKG changes, cardiac wall motion abnormalities, or myocardial blood flow; however, they do not directly visualize the coronary arteries.

FFR-CT assesses both anatomy and physiology.

An advantage of FFRCT, exercise tolerance test, stress echo, and cardiac MRI is that there is no radiation exposure, or none added in the case of FFRCT. While coronary

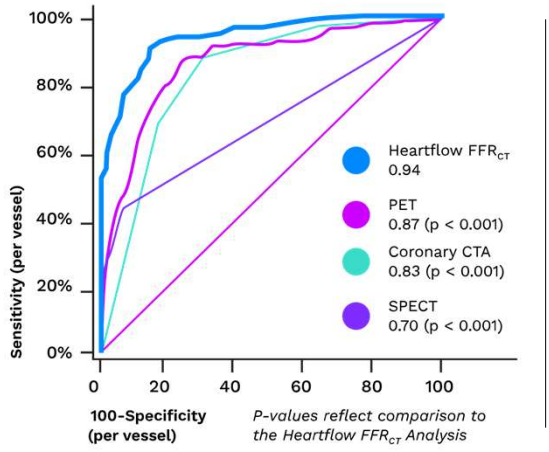
CTA uses radiation, FFR-CT requires no additional exposure to radiation beyond the initial CCTA. Nuclear stress tests have 8-12 milliseverts of radiation while Coronary CT has 1.5-3 milliseverts.

Another test sometimes used for evaluation of CAD is the cardiac calcium scan.[5] That test also uses CT technology but is more limited than a CCTA in the anatomical information provided because it does not use contrast to visualize the coronary arteries. It is usually ordered for patients who do not have symptoms of CAD and is primarily used to screen for risk of CAD. It assesses the presence of calcium in the coronary arteries, and calculates a calcium score, which can range from 0 to over 1000. A score of 100 to 400 means moderate evidence of calcium is present in the coronary arteries. A score of greater than 400 means strong evidence of calcium, and a score of less than 100 means there is little evidence of calcium in the coronary arteries. Calcium alone doesn't tell the whole story for a patient however, and soft plaque may be present but undetected with this test.

References:

1. Mayo Clinic Staff. Coronary Artery Disease. Mayo Clinic. May 25, 2022. https://www.mayoclinic.org/diseases-conditions/coronary-artery-disease/diagnosis-treatment/drc-20350619
2. Coronary Artery Disease. Cleveland Clinic. Reviewed October 13, 2023. https://my.clevelandclinic.org/health/diseases/16898-coronary-artery-disease
3. Nuclear Medicine and Molecular Imaging. Stanford Medicine. 2024. https://stanfordhealthcare.org/medical-clinics/nuclear-medicine-molecular-imaging/types-tests.html
4. Matta M, Harb SC, Cremer P, Hachamovitch R, Ayoub C. *Cleve Clin J Med*. Stress testing and noninvasive coronary imaging: What's the best test for my patient? 2021. 88(9): 501-515. https://www.ccjm.org/content/88/9/502
5. Calcium Score Test. Cleveland Clinic. Reviewed May 3, 2023. https://my.clevelandclinic.org/health/diagnostics/16824-calcium-score-screening-heart-scan
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8. CTP – Dynamic myocardial CT perfusion imaging – state of the art. Eur Radiol. Mar 2023; 33(8): 5509–5525. doi: 10.1007/s00330-023-09550-y

Diagnostic Performance of Common Cardiac Tests



- Beginning with a standard Coronary CTA, the Heartflow Analysis delivers better per-vessel performance than other non-invasive tests.
- CCTA image quality is important for FFR$_{CT}$ accuracy

	PACIFIC FFR$_{CT}$	NXT
Sensitivity	90%	84%
Specificity	86%	86%
Positive Predictive Value (PPV)	65%	61%
Negative Predictive Value (NPV)	96%	95%
Diagnostic Accuracy	**87%**	**86%**
Overall Diagnostic Performance (AUC)	0.94	0.93

Driessen, et al. J Am Coll Cardiol 2019.
Nørgaard, et al. J Am Coll Cardiol 2014.

How accurate are these tests in diagnosing Coronary Artery Disease? One method of reporting the accuracy of a diagnostic test is the AUC curve. AUC stands for area under the curve, where the test with the largest area underneath the curve is best. In this study the non-invasive diagnostic tests were compared to invasive FFR in the cath lab. Coronary CTA combined with FFRCT was found to have the largest area under the curve; demonstrating better per-vessel sensitivity and specificity compared to other non-invasive tests, such as PET or SPECT imaging. Other clinical data also support these findings, for example, the PACIFIC FFRct sub-study and the NXT study reported FFRct diagnostic accuracy of 87% and 86%, respectively. The take-away from this is that with CCTA and FFRCT we can better identify patients who have and don't have coronary artery disease with greater accuracy. One key note though, image quality is very important to ensure this accuracy.

References:

Driessen RS, et al. PACIFIC Substudy. JACC 2019;73(2):161-73. doi.org/10.1016/j.jacc.2018.10.056
Norgaard BL, et al. The NXT Trial. JACC. 2014;63(12):1145-55. doi.org/10.1016/j.jacc.2013.11.043

Coronary Computed Tomographic Angiography (CCTA)

What is Coronary CTA?

- Type of Cardiac CT – cross-sectional images or X-ray slices of the body,[1] focused on the structures and vessels of the heart, using contrast dye
- Noninvasive assessment of coronary artery plaques, stenoses, and other anatomy



How is it different from other diagnostic imaging tests?

- CCTA provides anatomic identification[2] and severity of coronary artery disease by vessel and location
- While stress perfusion testing assesses wall-motion abnormalities/ territory perfusion defects

How is CCTA different from IR CT imaging?

- Interventional Radiology (IR) treats a wide range of conditions in the body and includes using interventional tools (wires, catheters, tubes, stents, biopsy needles, filters, medicines, and cancer treatments) performed by an Interventional Radiologist[3]

1. PET/CT Scan - Stanford Imaging Technology. Stanford Medicine. 2024. https://stanfordhealthcare.org/medical-tests/p/pet-ct-scan.html
2. Matta M, Harb SC, Cremer P, Hachamovitch R, Ayoub C. Cleve Clin J Med. Stress testing and noninvasive coronary imaging: What's the best test for my patient? 2021. 88(9): 501-515. https://www.ccjm.org/content/88/9/502
3. Interventional Radiology. John Hopkins Medicine. https://www.hopkinsmedicine.org/health/treatment-tests-and-therapies/interventional-radiology

Let's dive deeper into coronary CTA now. Remember that coronary CTA is a type of cardiac CT, and that CT creates cross-sectional images.[1] Because coronary CTA is an angiogram, it uses IV contrast dye. CCTA is a noninvasive test used to detect coronary artery plaques, stenoses, and other structures.

Coronary CTA differs from other cardiac diagnostic imaging tests in that it provides anatomic identification[2] and severity of specific coronary artery stenoses, including vessel and location. Nuclear stress tests evaluate myocardial blood flow and wall motion abnormalities, but do not directly identify specific coronary anatomy and stenoses location.

Also, don't confuse CCTA with the type of imaging used in Interventional Radiology. Interventional Radiology procedures involve the treatment of disease. Interventional Radiology procedures are performed by radiologists or other physicians with specialized training, who use imaging combined with interventional tools, such as catheters, stents, biopsy needles, filters, medicines, and cancer treatments.[3]

References:

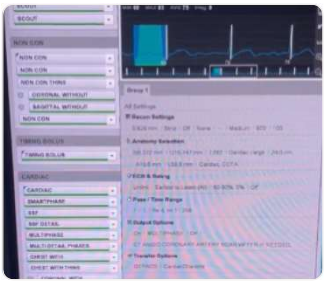
1. PET/CT Scan - Stanford Imaging Technology. Stanford Medicine. 2024. https://stanfordhealthcare.org/medical-tests/p/pet-ct-scan.html

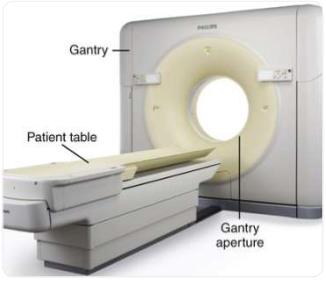
2. Matta M, Harb SC, Cremer P, Hachamovitch R, Ayoub C. *Cleve Clin J Med*. Stress testing and noninvasive coronary imaging: What's the best test for my patient? 2021. 88(9): 501-515. https://www.ccjm.org/content/88/9/502
3. Interventional Radiology. John Hopkins Medicine. https://www.hopkinsmedicine.org/health/treatment-tests-and-therapies/interventional-radiology

CCTA: Terminology and Features

Partnering with your CT technologist to efficiently perform coronary CTAs will go smoother if you understand basic CT fundamentals and related terminology:

- **Patient table or platform:** Where the patient lays and can be moved to slide the patient into the correct position for acquiring images
- **Aperture:** Circular opening of the gantry
- **Gantry:** The large, square-shaped housing that contains the equipment, which rotates around the patient; it contains both the X-ray source and the X-ray detectors from which data for image formation is created
- **Operator console:** The computer used to control variables of the scan such as the thickness of the image slice, mechanical movement of the table, and radiographic factors





1. CT Scan – What you can expect. Mayo Clinic. January 6, 2022. https://www.mayoclinic.org/tests-procedures/ct-scan/about/what-you-can-expect/rec-20393673
2. Harmonay, V. CT Scanner Components: What Does What? Atlantis Worldwide. November 18, 2020. https://info.atlantisworldwide.com/blog/ct-scanner-components-what-does-what#:~:text=The%20gantry%20is%20the%20ring-shaped%20part%20of%20the,The%20aperture%20range%20size%20is%20usually%2070-90%20cm.
3. Computed Tomography. NIH - National Institute of Biomedical Engineering and Bioengineering. March 2022. https://www.nibib.nih.gov/sites/default/files/2022-05/Fact-Sheet-Computed-Tomography.pdf
4. Wright GK, Grey ML. Computed Tomography. Radiology Key. May 4, 2016. https://radiologykey.com/computed-tomography-8/

Image: https://radiologykey.com/wp-content/uploads/2016/02/B9780323069748100165_f16-07-9780323069748.jpg

When performing CCTA, it may help if you understand certain specialized terms regarding CCTA equipment. This image shows a basic CT scanner setup.

The patient table, or platform, is the flat portion where the patient lays. This table can move and will adjust position to slide the patient into the correct position for acquiring images.[1]

The circular-shaped opening is called the aperture. [2] The main equipment of the CT scanner is inside the gantry, which surrounds the aperture. [3] The gantry contains both the source of the X-ray and the X-ray detector, and it rotates around the patient.

The operator console is where the operator controls the equipment and can adjust various controls affecting the scan, such as the thickness of the image slice, settings for the radiation, and movement of the table. [4]

References:
1. CT Scan – What you can expect. Mayo Clinic. January 6, 2022. https://www.mayoclinic.org/tests-procedures/ct-scan/about/what-you-can-expect/rec-20393673
2. Harmonay, V. CT Scanner Components: What Does What? Atlantis Worldwide. November

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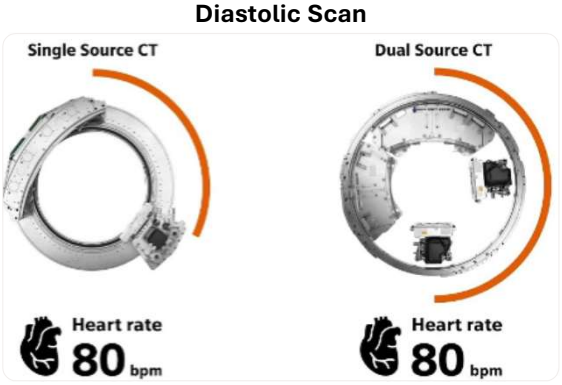
CCTA: Terminology and Features (cont.)

Gating: Acquiring CT images at a specific point in the cardiac cycle

- Prospective gating: Scan is triggered during a specified point in the cardiac cycle
- Retrospective gating: Acquired data are reconstructed after capture to create images at a specific phase of the cardiac cycle

Dual source scanner: Uses two X-ray sources and two X-ray detectors at the same time

Single source scanner: Uses only one X-ray source and X-ray detector



1. Murphy A. Cardiac gating (CT). March 23, 2023. Radiopaedia. https://radiopaedia.org/articles/cardiac-gating-ct?lang=us
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5. Health Jade Team. CT Scan. Health Jade. June 10, 2018. https://healthjade.net/ct-scan/
Image: https://youtu.be/4wSQw4xXR40?feature=shared

Gating refers to acquiring the CT scans at a specified point in the cardiac cycle, based on the patient's ECG. Gating can be prospective, meaning the scan is triggered during a particular portion of the cardiac cycle; or be retrospective, where the acquired data are reconstructed to create images at specific phases of the cardiac cycle.[1]

There are different types of CT scanners, which are suited to different applications. For example, older CT scanners captured a single image or slice at a time. Most CT scanners now are multislice CT scanners, which capture multiple slices at a time. Some CT scanners are helical scanners, which capture slices in a helical or spiral pattern, and can thus be completed in a shorter time. Conventional CT scanners are single source with only one X-ray source[3], whereas dual source CT scanners have two sources of X-ray and two detectors at the same time.[4] Dual source CT provides better images, which is especially useful in coronary CTA for patients with a higher heart rate.

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1. Murphy A. Cardiac gating (CT). March 23, 2023. Radiopaedia. https://radiopaedia.org/articles/cardiac-gating-ct?lang=us
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Image:
https://youtu.be/4wSQw4xXR40?feature=shared

Why Use CCTA to Diagnose Coronary Artery Disease?

CCTA Benefits

- High impact factor in patient management and reassurance to patient and provider with negative tests
  - CCTA has high >95% negative predictive value
- Radiation exposure less than nuclear stress testing
- Noninvasive & convenient
- Diagnostic value = anatomic + hemodynamic; plaque differentiation[1]
- AHA.ACC Chest Pain Guideline recommend CCTA as 1st line diagnostic test for certain patients[2]



Elevates Coronary CTA: The **only** Class 1 noninvasive test with Level A evidence

COR	LOE	Recommendations
		Index Diagnostic Testing
		Anatomic Testing
1	A	For intermediate-high risk patients with stable chest pain and no known CAD, CCTA is effective for **diagnosis** of CAD, for risk stratification, and for **guiding** treatment decisions.

1. Parikh R, Patel A, Lu B, Senapati A, Mahmarian J, Chang SM. Cardiac Computed Tomography for Comprehensive Coronary Assessment: Beyond Diagnosis of Anatomic Stenosis. Methodist Debakey Cardiovasc J. 2020 Apr-Jun;16(2):77-85. doi: 10.14797/mdcj-16-2-77. Gulati M, Levy PD, Mukherjee D, et al. 2021 AHA/ACC/ASE/CHEST/SAEM/SCCT/SCMR
2. Gulati M. et al. Guideline for the Evaluation and Diagnosis of Chest Pain: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines Circulation. 2021;144(22):e368-e454. doi:10.1161/CIR.0000000000001029

One of the benefits of CCTA in the diagnosis of coronary artery disease is that it has a high impact factor in the management of the patient. For patients with no evidence of CAD, CCTA has a high negative predictive value, and can provide reassurance. For patients with evidence of atherosclerotic disease it can help direct treatment plans.

The radiation exposure with CCTA is less than that with nuclear stress testing, with CCTA being about one-third to one-half of the radiation exposure of a typical nuclear stress test. [3]

In addition to being noninvasive, CCTA is relatively convenient. A nuclear stress test typically requires 2 to 4 hours for completion. A CCTA can be completed in 15 to 20 minutes but may take longer if the patient requires medication to slow the heart rate. [4]

It provides anatomic information, and when combined with FFRCT also provides physiologic information.

Furthermore, CCTA can distinguish between different types of plaque,[1] which can aid in determining patient risk and treatment.

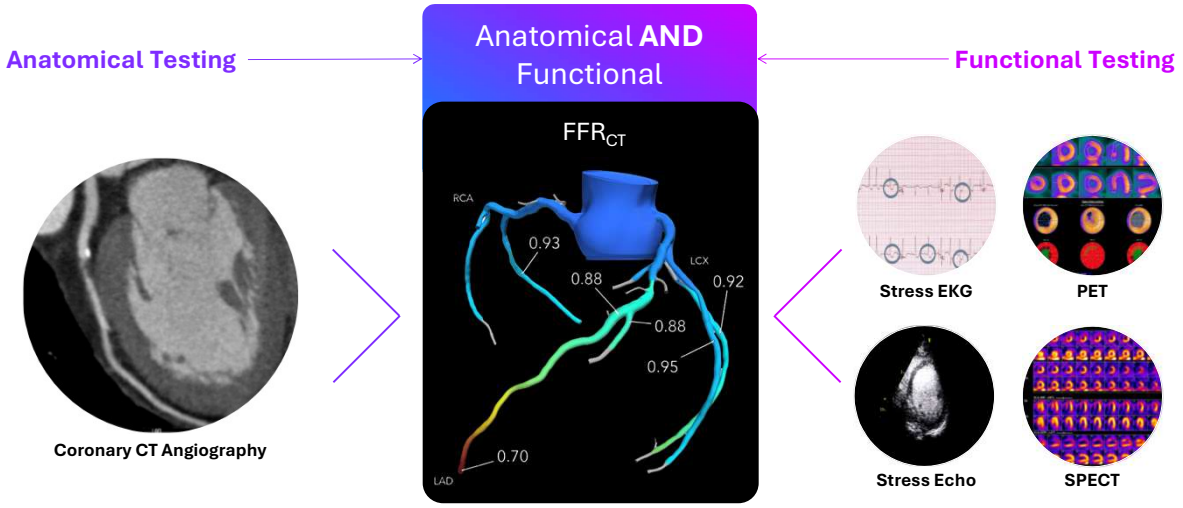
Lastly, the Guidelines for the Evaluation and Diagnosis of Chest Pain issued by the

American Heart Association and American College of Cardiology were updated in 2021, and it recommends CCTA as a first-line diagnostic test for certain patients, we will cover this more in depth later.

References:

1. Parikh R, Patel A, Lu B, Senapati A, Mahmarian J, Chang SM. Cardiac Computed Tomography for Comprehensive Coronary Assessment: Beyond Diagnosis of Anatomic Stenosis. *Methodist Debakey Cardiovasc J.* 2020 Apr-Jun;16(2):77-85. doi: 10.14797/mdcj-16-2-77.
2. Gulati M, Levy PD, Mukherjee D, et al. 2021 AHA/ACC/ASE/CHEST/SAEM/SCCT/SCMR Guideline for the Evaluation and Diagnosis of Chest Pain: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines *Circulation*. 2021;144(22):e368-e454. doi:10.1161/CIR.0000000000001029
3. Abdelrahman, K, Chen, M, Dey, A. et al. Coronary Computed Tomography Angiography From Clinical Uses to Emerging Technologies: JACC State-of-the-Art Review. J Am Coll Cardiol. 2020 Sep, 76 (10) 1226–1243. https://doi.org/10.1016/j.jacc.2020.06.076
4. Understanding Coronary Computed Tomography Angiography (CCTA). Saint Luke's. https://www.saintlukeskc.org/health-library/understanding-coronary-computed-tomography-angiography-ccta

Why Use CCTA + FFR_{CT} to Diagnose CAD?



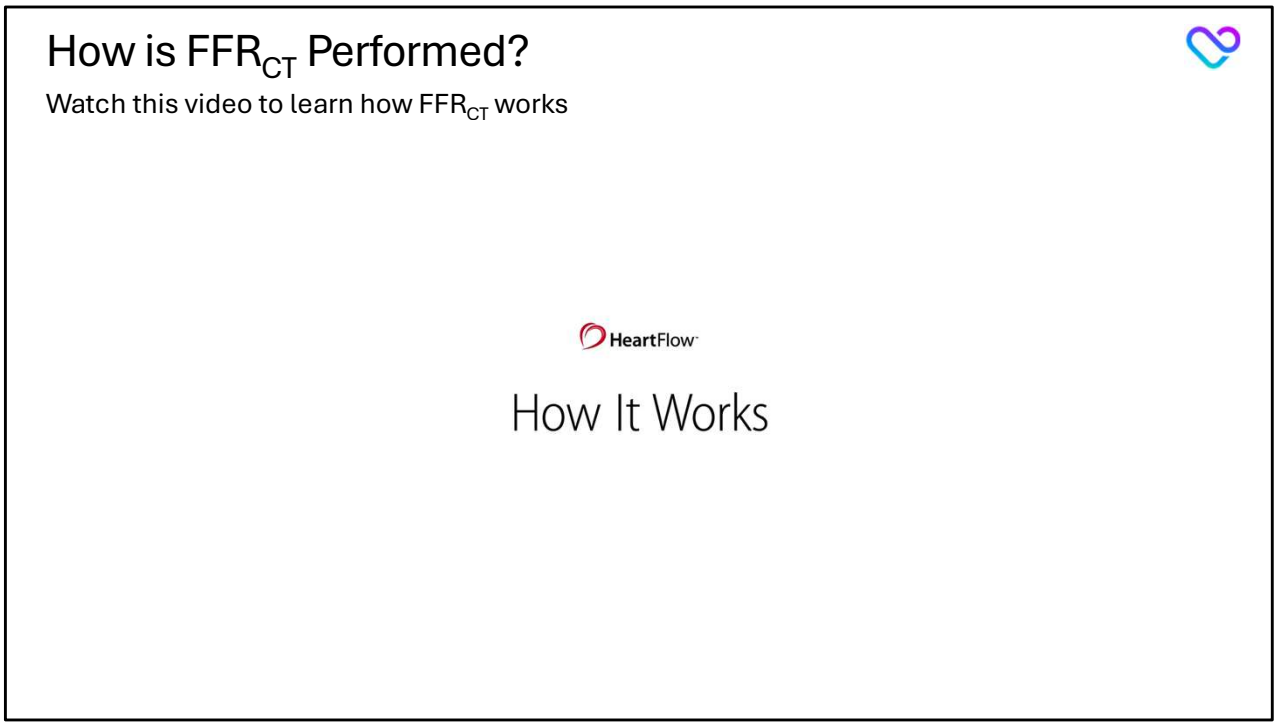
What are the benefits of CCTA <u>combined</u> with FFRCT when diagnosing CAD?

Traditional non-invasive methods of diagnosing heart disease (like treadmill stress EKG, stress echo, MRI and SPECT) demonstrate functional findings and do not provide insight as to the extent, precise location, and severity of disease. They can lead to poor patient outcomes and inefficient care, with 20-30% of patients being sent home with this potentially fatal disease and greater than 50% of patients undergoing unnecessary additional testing.

Coronary CT angiography imaging shows anatomical findings but does not account for the physiologic effects that the disease may be causing. CCTA with FFRCT combines both anatomy and function to provide a more complete picture of coronary artery disease.

How is FFR_{CT} Performed?

Watch this video to learn how FFR_{CT} works

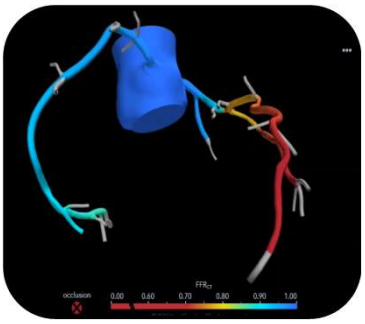


Let's watch a short video explaining how the HeartFlow FFRCT Analysis is obtained in conjunction with coronary CTA.

Why use FFR_{CT} to Diagnose Physiology?

FFR_{CT} Benefits[1]

- CCTA is an excellent anatomic test, but anatomy alone is not enough
- Fractional flow reserve derived from Coronary CTA (FFR_{CT}):
  - creates personalized anatomy and physiology model
  - helps to guide clinical decision-making
  - is noninvasive
  - requires no additional radiation besides that required for CCTA





Includes FFR_{CT}: To guide clinical decisions when CCTA is positive[2]

Non-invasive Physiology

2a	B-NR	For patients with known **coronary stenosis from 40-90% on CCTA**, FFR can be useful for diagnosis of vessel-specific ischemia and to **guide decision-making regarding the use of ICA.**

1. Rajiah P, Cummings KW, Williamson E, Young PM. CT Fractional Flow Reserve: A Practical Guide to Application, Interpretation, and Problem Solving. Radiographics. 2022;42(2):340-358. doi:10.1148/rg.210097
2. Gulati M. et al. Guideline for the Evaluation and Diagnosis of Chest Pain: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines Circulation. 2021;144(22):e368-e454. doi:10.1161/CIR.0000000000001029

Why use FFRCT to diagnose coronary artery disease physiology?

Although Coronary CTA is an excellent anatomic test, defining the coronary anatomy alone is not enough to determine the effects of atherosclerosis. The HeartFlow FFRCT analysis models an individual patient's coronary arteries, simulating how blood moves through the arteries, calculating the impact of any detected blockages on blood flow. This provides the anatomy and physiologic information for specific stenoses to help guide clinical decisions. FFRCT is noninvasive, unlike the FFR obtained in the cath lab. FFRCT requires no additional radiation beyond that required for CCTA.[2]

FFRCT was also introduced into the same AHA / ACC chest pain guidelines previously mentioned as a Class 2A, Level of Evidence B, in patients with a positive Cardiac CT with a stenosis in the 40-90% range; in these patients, FFRCT is endorsed as a next step to guide diagnosis and decision-making regarding the use of invasive coronary angiogram.[1]

References:

1. Rajiah P, Cummings KW, Williamson E, Young PM. CT Fractional Flow Reserve: A Practical Guide to Application, Interpretation, and Problem Solving. *Radiographics*. 2022;42(2):340-

358. doi:10.1148/rg.210097
2. Gulati M. et al. Guideline for the Evaluation and Diagnosis of Chest Pain: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines Circulation. 2021;144(22):e368-e454. doi:10.1161/CIR.0000000000001029

Appropriate Patients for CCTA + FFR_{CT}

Chapter 3

Jonathon Leipsic chapter script:
In this next chapter, we will discuss which patients are appropriate for CCTA with FFRCT.

SCCT 2021 Expert Consensus Document on CCTA

CCTA is appropriate as a first-line diagnostic test in patients with:

- No known CAD and stable typical or atypical chest pain or anginal equivalent
- Known CAD and stable typical or atypical chest pain or anginal equivalent
- Coronary anomalies
- Prior coronary artery bypass graft (CABG) surgery, particularly if graft patency or location of LIMA is the primary objective



Journal of Cardiovascular Computed Tomography

Guidelines

SCCT 2021 Expert Consensus Document on Coronary Computed Tomographic Angiography: A Report of the Society of Cardiovascular Computed Tomography

Jagat Narula, Y. Chandrashekhar, Amir Ahmadi, Suhny Abbara, Daniel S. Berman, Ron Blankstein, Jonathon Leipsic, David Newby, Edward D. Nicol, Koen Nieman, Leslee Shaw, Todd C. Villines, Michelle Williams, Harvey S. Hecht

ARTICLE INFO

1. Introduction: scope of the document

Narula J, Chandrashekhar Y, Ahmadi A, et al. SCCT 2021 Expert Consensus Document on Coronary Computed Tomographic Angiography: A Report of the Society of Cardiovascular Computed Tomography. J Cardiovasc Comput Tomogr. 2021;15(3):192-217. doi:10.1016/j.jcct.2020.11.001

Coronary CTA is an appropriate test for many types of patients. An expert consensus document from the Society of Cardiovascular Computed Tomography focused on patients with coronary artery disease was published in 2021. It listed the indications for CCTA and states that CCTA was considered appropriate as a first-line diagnostic test in patients with stable chest pain or anginal equivalent in patients with or without known CAD. It was also considered appropriate as a first-line diagnostic test for evaluating patients with coronary anomalies or prior coronary artery bypass graft surgery if evaluating graft patency or location of the left internal mammary artery was the primary objective.

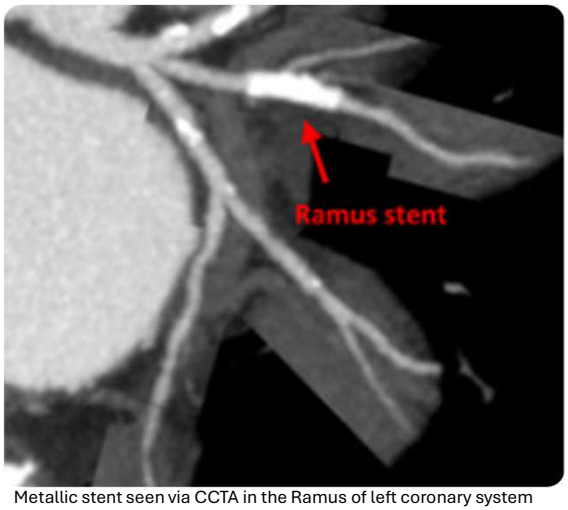
Reference:

Narula J, Chandrashekhar Y, Ahmadi A, et al. SCCT 2021 Expert Consensus Document on Coronary Computed Tomographic Angiography: A Report of the Society of Cardiovascular Computed Tomography. *J Cardiovasc Comput Tomogr.* 2021;15(3):192-217. doi:10.1016/j.jcct.2020.11.001

SCCT 2021 Expert Consensus Document on CCTA

CCTA is appropriate/reasonable in patients with:

- An inconclusive functional test, to obtain more precision regarding diagnosis and prognosis
- Coronary stents >3.0 mm
- Proximal, non bifurcation thin strut stents <3.0 mm
- Younger patients with low-intermediate probability of CAD prior to noncardiac surgery
- Suspected dissection of the aorta to evaluate anatomy
- CCTA may be appropriate/reasonable for patients with other clinical scenarios



Metallic stent seen via CCTA in the Ramus of left coronary system

Narula J, Chandrashekhar Y, Ahmadi A, et al. SCCT 2021 Expert Consensus Document on Coronary Computed Tomographic Angiography: A Report of the Society of Cardiovascular Computed Tomography. J Cardiovasc Comput Tomogr. 2021;15(3):192-217. doi:10.1016/j.jcct.2020.11.001

CCTA was also considered appropriate and reasonable for several other types of patients, including those with an inconclusive functional test, coronary stents with a diameter larger than 3.0 mm, certain types of smaller stents, for assessment of CAD in younger patients with a low-to-intermediate probability of CAD prior to noncardiac surgery, and those with suspected dissection of the aorta, to evaluate anatomy. You do not need to know these indications; we've listed these to provide an understanding of the types of patients that may have a CCTA test ordered.

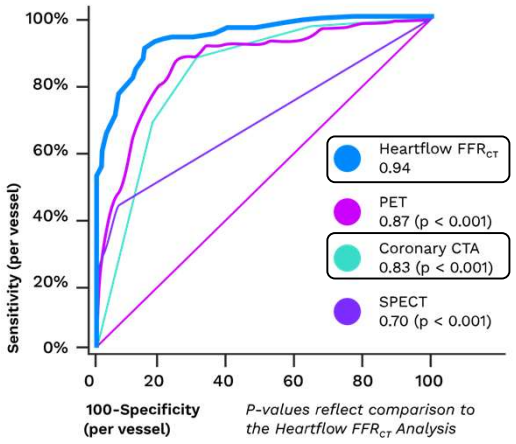
Reference:

Narula J, Chandrashekhar Y, Ahmadi A, et al. SCCT 2021 Expert Consensus Document on Coronary Computed Tomographic Angiography: A Report of the Society of Cardiovascular Computed Tomography. *J Cardiovasc Comput Tomogr.* 2021;15(3):192-217. doi:10.1016/j.jcct.2020.11.001

SCCT 2021 Expert Consensus Document on FFR_{CT}

Recommendations for FFR_{CT}

- Adding FFR_{CT} to CCTA increases specificity, positive predictive value, and diagnostic accuracy over regular CCTA alone
- **FFR_{CT} may be appropriate** to evaluate the functional significance of intermediate stenoses on CTA (30-90% diameter stenosis) particularly in the setting of multivessel disease to help guide invasive coronary angiography (ICA) referral and revascularization treatment planning



1. Narula J, Chandrashekhar Y, Ahmadi A, et al. SCCT 2021 Expert Consensus Document on Coronary Computed Tomographic Angiography: A Report of the Society of Cardiovascular Computed Tomography. J Cardiovasc Comput Tomogr. 2021;15(3):192-217. doi:10.1016/j.jcct.2020.11.001
2. Driessen, R.S, et al. J Am Coll Cardiol. 2019;73(2):161-73

The SCCT expert consensus document also acknowledged that the addition of FFR-CT to CCTA increases the diagnostic value and accuracy of the test compared to CCTA alone.

It acknowledged that FFRCT may be appropriate to evaluate the functional significance of intermediate stenoses in the 30% to 90% range, especially in the setting of multivessel disease, to help guide plans for invasive coronary angiography and revascularization.

References:

1. Narula J, Chandrashekhar Y, Ahmadi A, et al. SCCT 2021 Expert Consensus Document on Coronary Computed Tomographic Angiography: A Report of the Society of Cardiovascular Computed Tomography. *J Cardiovasc Comput Tomogr.* 2021;15(3):192-217. doi:10.1016/j.jcct.200.11.001
2. Driessen, R.S, et al. J Am Coll Cardiol. 2019;73(2):161-73

2021 AHA/ACC Chest Pain Guideline

Elevates Coronary CTA: The **only** Class 1 noninvasive test with Level A evidence

COR	LOE	Recommendations
		Index Diagnostic Testing
		Anatomic Testing
		For patients with **acute** chest pain:
1	A	For intermediate-risk patients with acute chest pain and no known CAD eligible for diagnostic testing after a negative or inconclusive evaluation for ACS, CCTA is useful for **exclusion of atherosclerotic plaque and obstructive CAD**.
		For patients with **stable** chest pain:
1	A	For intermediate-high risk patients with stable chest pain and no known CAD, CCTA is effective for **diagnosis** of CAD, for risk stratification, and for **guiding** treatment decisions.

COR, class of recommendation; LOE, level of evidence.

Gulati M, Levy PD, Mukherjee D, et al. 2021 AHA/ACC/ASE/CHEST/SAEM/SCCT/SCMR Guideline for the Evaluation and Diagnosis of Chest Pain: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines Circulation. 2021;144(22):e368-e454. doi:10.1161/CIR.0000000000001029

The next set of guidelines are even more exciting! In 2021, after the publication of the SCCT consensus document, the American Heart Association and American College of Cardiology issued guidelines on the evaluation and diagnosis of chest pain. The AHA/ACC guidelines are **clinical practice guidelines**, which are evidence-based, and therefore have a stronger scientific base than expert consensus recommendations. These guidelines were **strictly focused on the evaluation of patients with chest pain**. In these, CCTA was given a Class 1A recommendation as the first-line diagnostic test of choice with specific types of patients. A Class IA recommendation is a strong recommendation, backed by the highest quality evidence.

The AHA-ACC 2021 Chest Pain Guideline has caused a shift to a CT-first strategy in 2 sets of patients:

- First, those patients with **acute** chest pain, such as those presenting to the emergency department, who are at intermediate-risk of a major adverse cardiovascular event and who have no known coronary artery disease, after evaluation for acute coronary syndrome has been negative or inconclusive. In this case, the indication is to exclude atherosclerotic plaque and obstructive CAD.
- Second, patients with **stable** chest pain, who are at intermediate-to-high risk of a major adverse cardiovascular event, such as those who might be evaluated in an

outpatient clinic and who have no known coronary artery disease. In this instance, CCTA is effective for diagnosis of CAD, for risk stratification, and for guiding treatment decisions.

Reference:
Gulati M, Levy PD, Mukherjee D, et al. 2021 AHA/ACC/ASE/CHEST/SAEM/SCCT/SCMR Guideline for the Evaluation and Diagnosis of Chest Pain: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *Circulation*. 2021;144(22):e368-e454. doi:10.1161/CIR.0000000000001029

2021 ACC/AHA Recommendations for FFR_{CT}

COR	LOE	Recommendations
For patients with **acute** chest pain and no known CAD:		
2a	B-NR	For intermediate-risk patients with acute chest pain and no known CAD, with a **coronary artery stenosis of 40% to 90% in a proximal or middle coronary artery on CCTA**, FFR_{CT} can be useful for the diagnosis of vessel-specific ischemia and to guide decision-making regarding the use of coronary revascularization.
For patients with **acute** chest pain and known CAD:		
2a	B-NR	For intermediate-high risk patients with acute chest pain and **coronary artery stenosis of 40% to 90% in a proximal or middle coronary segment on CCTA**, FFR_{CT} can be useful for diagnosis of vessel-specific ischemia and to guide decision-making regarding the use of coronary revascularization.
For patients with **stable** chest pain:		
2a	B-NR	For intermediate-high risk patients with stable chest pain and known coronary stenosis of **40% to 90% in a proximal or middle coronary segment on CCTA**, FFR_{CT} can be useful for diagnosis of vessel-specific ischemia and to guide decision-making regarding the use of coronary revascularization.

COR, class of recommendation; LOE, level of evidence.

Gulati M, Levy PD, Mukherjee D, et al. 2021 AHA/ACC/ASE/CHEST/SAEM/SCCT/SCMR Guideline for the Evaluation and Diagnosis of Chest Pain: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines Circulation. 2021;144(22):e368-e454. doi:10.1161/CIR.0000000000001029

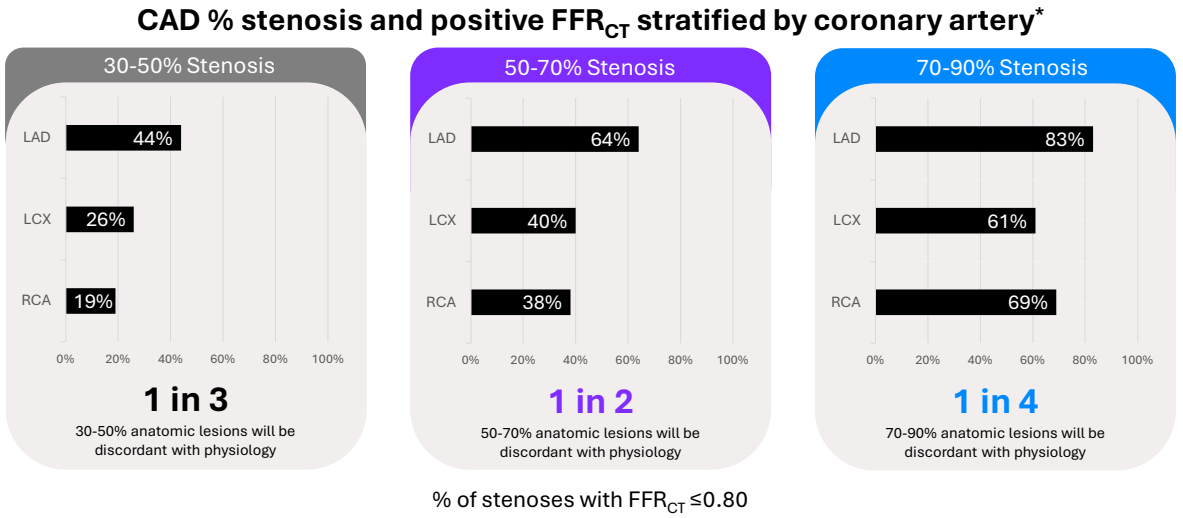
As a sequential or add-on diagnostic test, the guidelines also give Class 2a, level of evidence B, support for FFR-CT in patients who had a CCTA and were found to have a 40% to 90% stenosis in the proximal or mid-portion of a coronary artery.

FFR-CT is endorsed as a next step to guide diagnosis of vessel-specific ischemia and to guide decision-making regarding possible cardiac catheterization and revascularization.

These 3 recommendations are for patients with acute chest pain and **no** known CAD, acute chest pain and **known CAD**, and **stable** chest pain.

Reference:
Gulati M, Levy PD, Mukherjee D, et al. 2021 AHA/ACC/ASE/CHEST/SAEM/SCCT/SCMR Guideline for the Evaluation and Diagnosis of Chest Pain: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *Circulation*. 2021;144(22):e368-e454. doi:10.1161/CIR.0000000000001029

Physiology Cannot be Assumed via Anatomy



Fairbairn TA, et al. Eur Heart J. 2018:39(41):3701-3711. doi:10.1093/eurheartj/ehy530
*FFR$_{CT}$ values ≤0.80 were deemed physiologically significant in the ADVANCE Registry.

To further support the need for anatomy and physiology to appropriately diagnose and make clinical decisions regarding CAD, there are large registries that also support this practice on top of the guidelines. The largest of these registries to date is the ADVANCE Registry, with approximately 5000 patients studied.

The ADVANCE registry found that in patients with a 70% to 90% (severe) stenosis by CCTA, 1 in 4 of these patients had a normal, nonsignificant, FFR-CT, meaning that those patients went unnecessarily to the cath lab and had an invasive angiogram. And in patients with a 50% to 70% moderate stenosis on CCTA, about half of these patients had an abnormal FFR-CT and half did not – basically a flip of the coin on whether a patient's moderate lesion significantly impairs flow. And among patients with a 30% to 50% stenosis on CCTA, about one-third of these patients had an unexpectedly abnormal FFR-CT, meaning the stenosis that looked mild on CCTA was actually causing more significant loss of blood flow than expected. The findings also varied based on which coronary artery was involved. Thus, a large proportion of

patients had anatomic stenoses that were discordant with physiology.

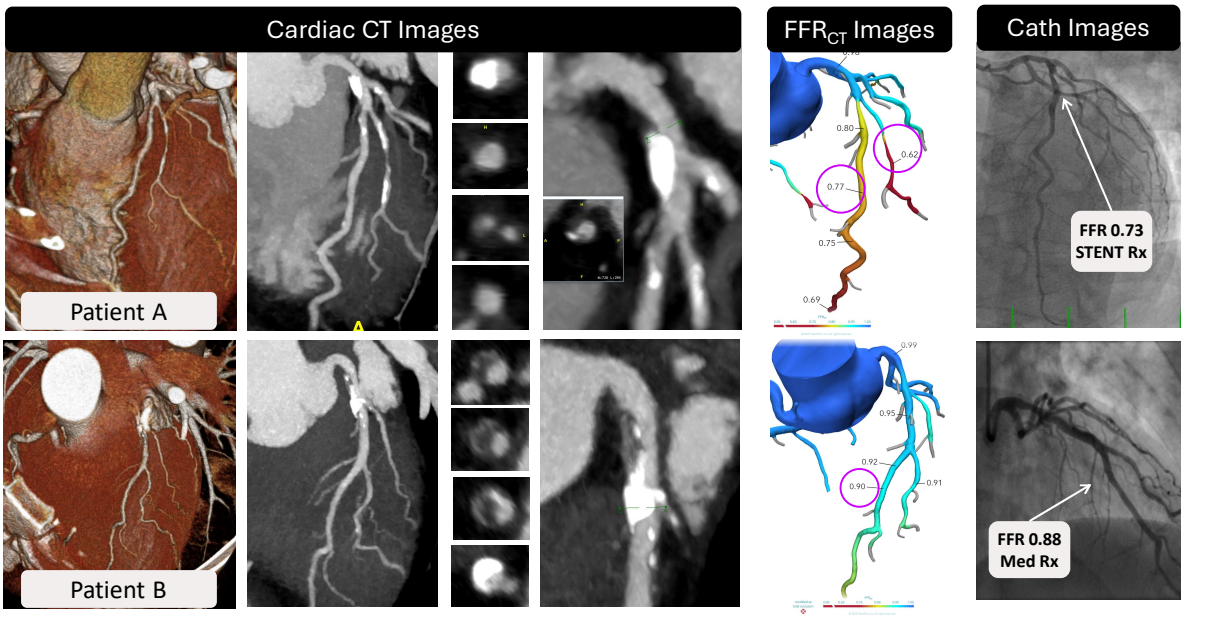
These data from the ADVANCE registry illustrates the importance of appropriate guideline-driven patient selection. The data from ADVANCE was cited in the 2021 chest pain guidelines. It formed an important part of the evidence base that led the expert scientific committee to recommend FFR-CT for further physiologic evaluation of 40% to 90% coronary stenoses found on coronary CTA.

Let's walk through some cases to better understand this important data and understand why physiology cannot be assumed via anatomy alone.

Reference:
Fairbairn et al. Real-world clinical utility and impact on clinical decision-making of coronary computed tomography angiography-derived fractional flow reserve: lessons from the ADVANCE Registry. Eur Heart J 2018 Nov 1;39(41):3701-3711. doi: 10.1093/eurheartj/ehy530.

(Table based on Figure 1 of the above reference: i.e. LAD 30-50% is 666+521=1187. ischemia significant lesions of 521/1187 = 43.89%)

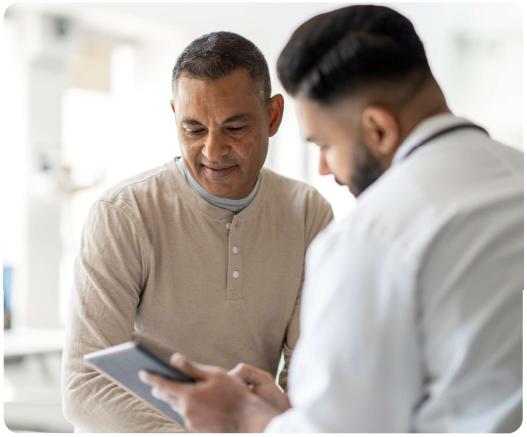
≥70% Stenosis in 2 patients: Similar but Different



These case examples display two male patients in their mid-50s presenting with chest pain, and they both underwent a CT-first diagnostic strategy. Their CT images, in similar projections, are shown here and illustrate the Left Anterior Descending artery in the proximal to mid segment having calcified plaque. Taking a closer look at the extent of disease with more precise cross-sectional imaging, you can see extensive narrowing which is greater than a 70% stenosis. The FFRCT findings are very different for these two patients. Patient A has a positive FFRCT with a value of 0.77 distal to the stenosis and 0.62 in the diagonal artery, meaning blood flow is limited in both arteries. While patient B has an FFRCT value of 0.90 suggestive of the absence of flow limiting disease. The pictures on the right display very different heart catheterizations. Patient A had a positive invasive FFR with a value of 0.73 (that correlated with the FFRCT) and he underwent PCI with stent placement. While patient B had an invasive FFR value of 0.88, also correlating with the FFRCT, and was treated medically. These two cases display the benefit of FFRCT in clinical decision-making.

Ideal Patient Population for FFR_{CT}

- Patients with an appropriate indication for CCTA
- Who are found to have a 40% to 90% stenosis in the proximal or middle segment of a coronary artery on CCTA, to diagnose vessel-specific ischemia and to guide decision-making regarding the use of coronary revascularization
- No patient features likely to make images non-diagnostic



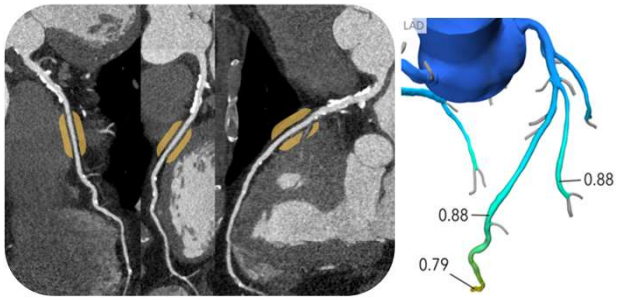
Let's summarize then who is the ideal candidate for this CCTA-first, plus FFRCT diagnostic pathway. First, the patient should have the appropriate indication for CCTA. Then, those patients who are found to have a 40% to 90% stenosis in the proximal or mid-segment of a coronary artery on CCTA can receive the FFRCT. Patients should have no features likely to make the FFR-CT images non-diagnostic – examples of these will be covered.

Common Misconceptions About CCTA + FFR_{CT}

Due to modern scanner capabilities, many patients can now benefit from CCTA + FFR_{CT} who would not have been candidates in the past.

This includes patients with[1,2]

- Coronary artery calcium scores (CACS) > 400
- Body mass index (BMI) > 35
- Coronary anomalies
- Impaired renal function



CCTA and FFR_{CT} successfully performed in patient with CAC score = 2063

Additionally, cardiac CTA on modern CT scanners exposes patients to less radiation than a standard nuclear heart scan, also known as myocardial perfusion imaging (MPI) with single photon emission CT (SPECT).[3,4]

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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002
2. Rajiah P, Cummings KW, Williamson E, Young PM. CT Fractional Flow Reserve: A Practical Guide to Application, Interpretation, and Problem Solving. Radiographics. 2022;42(2):340-358. doi:10.1148/rg.210097
3. Stocker TJ, Deseive S, Leipsic J, et al. Reduction in radiation exposure in cardiovascular computed tomography imaging: results from the PROspective multicenter registry on radiaTion dose Estimates of cardiac CT angIOgraphy iN daily practice in 2017 (PROTECTION VI). Eur Heart J. 2018;39(41):3715-3723. doi:10.1093/eurheartj/ehy546
4. Einstein AJ, Pascual TN, Mercuri M, et al. Current worldwide nuclear cardiology practices and radiation exposure: results from the 65 country IAEA Nuclear Cardiology Protocols Cross-Sectional Study (INCAPS). Eur Heart J. 2015;36(26):1689-1696. doi:10.1093/eurheartj/ehv117

In the past, several categories of patients were thought not to be good candidates for CCTA with FFR-CT. However, with modern, state-of-the-art CT scanners and improved protocols to control heart rate, those patients are no longer excluded, and they can undergo CCTA with FFR-CT. In fact, it's now very routine to scan patients with a calcium score above 400, and not uncommon to scan patients with calcium scores over 1000.

In the past, it was common to also exclude patients with a body mass index greater than 35 from coronary CTA. But nowadays, it is common practice to scan patients with BMI over 35. However, proper attention to scanning strategies and techniques are necessary, which we will explain.

For patients with chronic kidney disease, it is important to use good clinical judgment when deciding on the best imaging modality, as use of IV contrast dye carries some risk of additional kidney injury. However, with newer scanners and strategies, lower doses of IV contrast can be used, which lessens the risk of further damage to the kidneys, or of developing acute kidney injury.

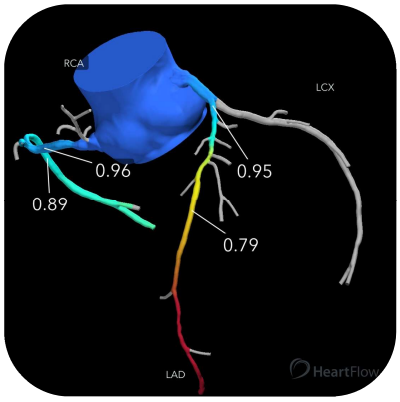
Lastly, studies have shown that modern CT scanners expose patients to significantly less radiation than a standard nuclear heart scan like SPECT or PET.

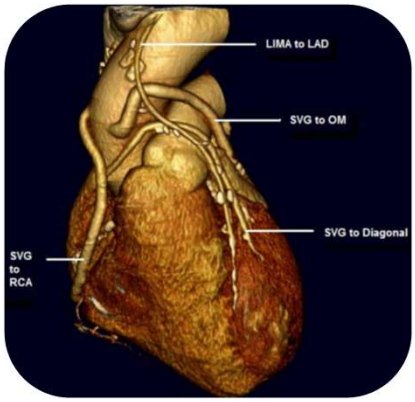
References:

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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002
2. Rajiah P, Cummings KW, Williamson E, Young PM. CT Fractional Flow Reserve: A Practical Guide to Application, Interpretation, and Problem Solving. *Radiographics*. 2022;42(2):340-358. doi:10.1148/rg.210097
3. Stocker TJ, Deseive S, Leipsic J, et al. Reduction in radiation exposure in cardiovascular computed tomography imaging: results from the PROspective multicenter registry on radiaTion dose Estimates of cardiac CT angIOgraphy iN daily practice in 2017 (PROTECTION VI). *Eur Heart J*. 2018;39(41):3715-3723. doi:10.1093/eurheartj/ehy546
4. Einstein AJ, Pascual TN, Mercuri M, et al. Current worldwide nuclear cardiology practices and radiation exposure: results from the 65 country IAEA Nuclear Cardiology Protocols Cross-Sectional Study (INCAPS). *Eur Heart J*. 2015;36(26):1689-1696. doi:10.1093/eurheartj/ehv117

FFR_{CT} Potential Limitations

- Vessels with stents are not analyzed
- The Heartflow FFR_{CT} Analysis has not been evaluated for patients with prior coronary artery bypass graft (CABG) surgery
- High / variable heart rate





Lastly, let's review a few situations in which use of a coronary CTA plus FFR-CT pathway may be limited. Patients who previously underwent percutaneous coronary intervention with one or more coronary stents placed are unable to have FFRCT values calculated for the coronary vessels where the stents were previously placed. Importantly, FFRCT values can be calculated in the coronary artery anatomy without the stent. In this case, you can see that the left circumflex artery is grayed out, signifying that a stent is in this vessel. Yet, the FFRCT values are shown for the left anterior descending coronary artery and the right coronary artery.

Patients with prior bypass surgery cannot have FFR-CT analysis because FFR-CT has not been evaluated and validated in patients with prior bypass grafts. These patients can certainly undergo coronary CTA testing, just not the FFR-CT analysis. CCTA is an excellent imaging test to assess the location, characteristics, and patency of bypass grafts. In this image, you can see that the CCTA shows 4 bypass grafts.

The third group of patients in which FFR-CT may be limited are those with a high or variable heart rate, as heart rate and rhythm can affect image quality. Quality CCTA images for FFRCT are obtained in patients with a low and steady heart rate, ideally below 60 beats per minute.

We will review heart rate control to obtain high-quality cardiac CTA scans in greater detail in a future chapter . We will discuss standardized imaging protocols and how they may be adapted for various types of patients, including those with variations in heart rate, rhythm, or regularity. To obtain high-quality images with CCTA, imaging teams must develop the skill sets and protocols needed to accommodate a broad range of patients.

References:

1. Maroules CD, Rybicki FJ, Ghoshhajra BB, et al. 2022 use of coronary computed tomographic angiography for patients presenting with acute chest pain to the emergency department: An expert consensus document of the Society of cardiovascular computed tomography (SCCT): Endorsed by the American College of Radiology (ACR) and North American Society for cardiovascular Imaging (NASCI). *J Cardiovasc Comput Tomogr*. 2023;17(2):146-163. doi:10.1016/j.jcct.2022.09.003

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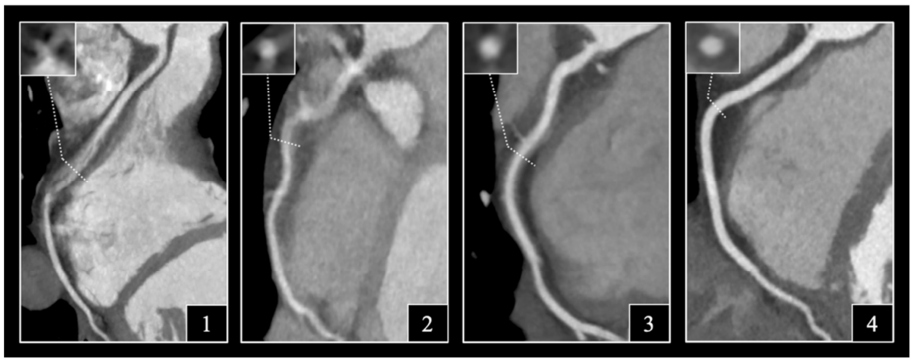
Patient Factors that can Affect Image Quality

Chapter 4

Sara Wallace chapter script:
Hello, I'm Sara Wallace and I am the Program Coordinator and Nurse Navigator for Cardiac Imaging at Cone Health Heart and Vascular Center in Greensboro, North Carolina. In this chapter, we will discuss how individual patient factors can affect the image quality of coronary CTA studies.

Patient Factors that can Affect Image Quality

- Cardiac rate and rhythm, and ability to tolerate medication to lower heart rate
- Patient's ability or inability to hold breath during scan
- Mental status
- Severe obesity
- Poor IV access
- Coronary stents
- Significant coronary calcium burden



Representative curved multiplanar reconstructions and corresponding cross-sectional images demonstrating examples of the 4-point Likert scale describing motion artifacts: (1), non-diagnostic image quality precluding the evaluation of the right coronary artery; (2), moderate image quality merely allowing the exclusion of obstructive stenosis; (3), good image quality with minor artifacts and (4), excellent image quality with no artifacts present

The most important factors that may affect CCTA image quality are listed here. Although these are considerations the healthcare providers must consider, many of these can be managed to optimize the scan.

Coronary CTA is sensitive to motion artifact, and therefore, a slow and steady heart rate is ideal for obtaining CCTA images.[1] Medications, such as beta-blockers, calcium-blockers, or ivabradine are often used to achieve a slower heart rate. If the patient is not able to tolerate those medications, then it may not be possible to achieve satisfactory scans.[1] The sensitivity to motion is also why patients need to be able to hold their breath during portions of the study to minimize chest wall motion. If a patient is unable to hold their breath, or if their mental status is diminished such that they are unable to follow instructions to hold their breath or to remain still during image acquisition, good CCTA images may not be obtained. [1]

Patients who are severely obese are more likely to have false negative studies,[2] in that it is more difficult to visualize the coronary arteries through a large chest wall.

CCTA requires the injection of intravenous contrast dye to visualize the coronary arteries. Proper IV access is crucial for obtaining satisfactory images. If the IV access is compromised, then the IV contrast material may leak or extravasate around the IV

site, resulting in suboptimal imaging and potential skin irritation.[3] Poor contrast enhancement may result in inadequate visualization of the coronary arteries.

Coronary stents can affect CCTA image quality with blooming artifact,[4] and FFR-CT is not performed in stented vessels.

And finally, patients with greater coronary calcium burden are more likely to have false positive studies due to various artifacts.[1]

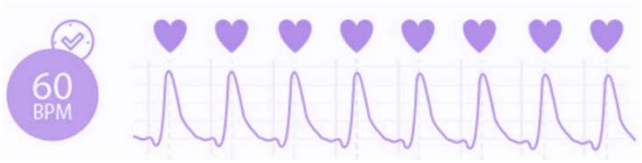
One of these factors alone may not rule out a patient from getting a CCTA, however a combination of these could. Each scanning site will have protocols for the CCTA. Let's dig into each of these further.

References:

1. Ghekiere O, Salgado R, Buls N, et al. Image quality in coronary CT angiography: challenges and technical solutions. Br J Radiol. 2017;90(1072):20160567. doi: 10.1259/bjr.20160567.
2. Lowenstern A, Ng N, Takagi H, et al. Influence of Obesity on Coronary Artery Disease and Clinical Outcomes in the ADVANCE Registry. Circ Cardiovasc Imaging. 2023;16(5):e014850. doi:10.1161/CIRCIMAGING.122.014850
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Heart Rate Management for CCTA

- Ideal heart rate is regular and < 60 BPM
- Heart rate is one of the most important factors to manage and where nursing judgement can have the most impact:
  - **Can this patient's heart rate be reduced safely?**
  - **What medications can be given?**
- Some arrythmias can be managed
  - Atrial Fibrillation and PACs: scanners can predict rhythm and accommodate
  - PVCs: require medication
  - Pacemakers/ICDs: require industry rep to manage



Maroules CD, Rybicki FJ, Ghoshhajra BB, et al. 2022 use of coronary computed tomographic angiography for patients presenting with acute chest pain to the emergency department: An expert consensus document of the Society of cardiovascular computed tomography (SCCT): Endorsed by the American College of Radiology (ACR) and North American Society for cardiovascular Imaging (NASCI). J *Cardiovasc Comput Tomogr*. 2023;17(2):146-163. doi:10.1016/j.jcct.2022.09.003
Image: Vecsey-Nagy, M. et al. Heart rate-dependent degree of motion artifacts in CCTA adquired by a novel purpose-built cardiac CT scanner. J. Clin. Med. 2022. https://doi.org/10.3390/jcm11154336

Let's talk first about heart rate. This is an area in which the nurse's judgment can most affect the outcome of the test. The ideal heart rate for a CCTA is regular and less than 60 beats per minute.

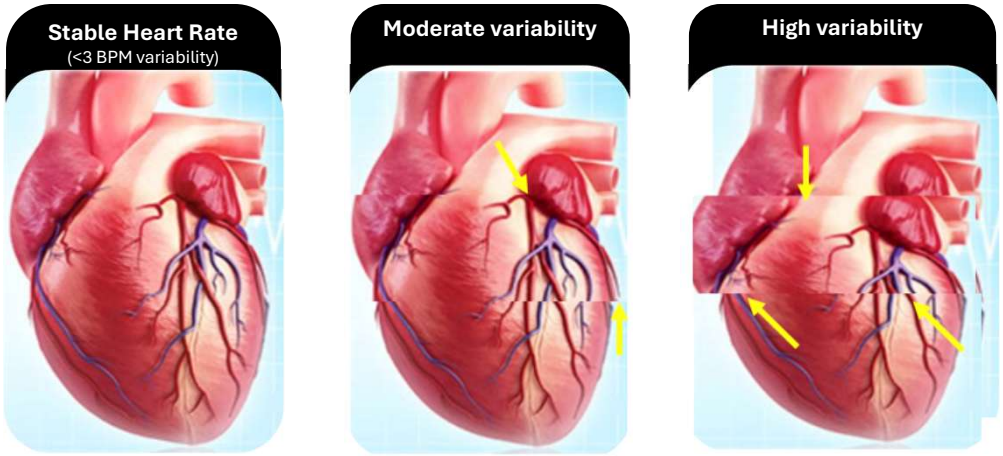
Most patients will have a heart rate above 60 beats per minute when they arrive for their scan. Therefore, the heart rate may need to be reduced prior to CCTA utilizing medications like metoprolol. The first question to consider is "Can this patient's heart rate be reduced safely?" In some patients, it may not be safe to reduce the heart rate. For example, if the patient is waiting to have a pacemaker placed due to sick sinus syndrome or second- or third-degree heart block, then it will not be safe to slow the heart rate. Patients with decompensated heart failure, hypotension, or severe aortic stenosis are other examples of patients in whom lowering the heart rate should be avoided.

The second question to consider is : "What medications can be given to slow the heart rate?" If the patient has asthma or history of significant wheezing, or even moderate to severe chronic obstructive pulmonary disease, a beta-blocker would be contraindicated. However, the patient might be able to tolerate a calcium-channel blocker instead.

Many patients presenting for a CCTA scan will have some sort of arrhythmia. Depending on the scanner being used, many of these arrhythmias can be managed satisfactorily such that the scan can proceed.[1] PVCs, if frequent, might require suppression with medication. Most patients with atrial fibrillation or PACs can undergo a CCTA scan, and the scanners are capable of accommodating to the rhythm. If the patient has a pacemaker or implantable cardioverter defibrillator, then an industry representative from the device company will likely be needed to manage the device. For example, if the pacemaker's base rate is set at 70, there is no way the heart rate will drop below 70 unless the device rep reprograms or temporarily disables the device while the CCTA scan is being performed.

Reference:
Maroules CD, Rybicki FJ, Ghoshhajra BB, et al. 2022 use of coronary computed tomographic angiography for patients presenting with acute chest pain to the emergency department: An expert consensus document of the Society of cardiovascular computed tomography (SCCT): Endorsed by the American College of Radiology (ACR) and North American Society for cardiovascular Imaging (NASCI). J *Cardiovasc Comput Tomogr*. 2023;17(2):146-163. doi:10.1016/j.jcct.2022.09.003
Image:
Vecsey-Nagy, M. et al. Heart rate-dependent degree of motion artifacts in CCTA adquired by a novel purpose-built cardiac CT scanner. J. Clin. Med. 2022. **https://doi.org/10.3390/jcm11154336**

Effect of Heart Rate Variability



In addition to reducing heart rate, it is important to reduce variability in heart rate. Even if a patient's heart rate is hovering around 60, it may be beneficial to give a single modest dose of oral metoprolol. The reason for doing this is not to slow the heart rate, but to reduce heart rate variability and avoid reflex tachycardia from either the anxiety of the scan or from injection of contrast dye. Many scanners acquire images of the heart during 3 or more rotations of the xray tubes and detectors. The scanner then takes those 3 slices of data and stitch them together to create one image.

This slide shows images with a stable heart rate on the left, moderate variability in the center, and high variability on the right. Those with modest or high variability are distorted due to misalignment, or "stair step artifact". Heart rate variability can impact the quality of the scan by creating misalignment, which results in challenges to anatomical assessment of the coronary arteries.

High BMI or Severe Obesity

- BMI cutoffs will depend on scanner protocols
- BMI can affect:
  - Image quality – difficult to examine coronaries through great amounts of adipose tissue1
  - Radiation exposure is higher
  - IV access – high BMI patient require larger bore IVs (which can be difficult to place) to allow for larger contrast doses
  - Ability to hold breath or lay flat
- BMI > 50 should be reviewed for appropriateness

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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002
2. Maroules CD, Rybicki FJ, Ghoshhajra BB, et al. 2022 use of coronary computed tomographic angiography for patients presenting with acute chest pain to the emergency department: An expert consensus document of the Society of cardiovascular computed tomography (SCCT): Endorsed by the American College of Radiology (ACR) and North American Society for cardiovascular Imaging (NASCI). *J Cardiovasc Comput Tomogr*. 2023;17(2):146-163. doi:10.1016/j.jcct.2022.09.003

In patients with a high body mass index or severe obesity, several things must be considered. Each scanner will have its own recommended cutoff for weight or BMI.[1] It is important to know the technical capacity and limitations of the scanners in your institution.

The reason that BMI is so important is that it is more difficult to visualize the coronary arteries through great amounts of adipose tissue. Higher radiation doses are needed in obese persons.[1-2] Plus, a larger dose of contrast may be required, necessitating placement of a larger bore IV, and these can be difficult to place, particularly in obese persons. [1-2]

Very obese persons may have more difficulty with laying flat or holding their breath long enough to acquire satisfactory images, due to the greater metabolic demands on the body, or due to other comorbidities.

Most of these issues can be overcome. However, if the patient's BMI is over 50, it may be necessary to reconsider or review the case for appropriateness of CCTA scanning. Looking at previous x-ray or CT scans may help you assess adipose tissue distribution and help determine if CCTA is an appropriate modality for that patient.

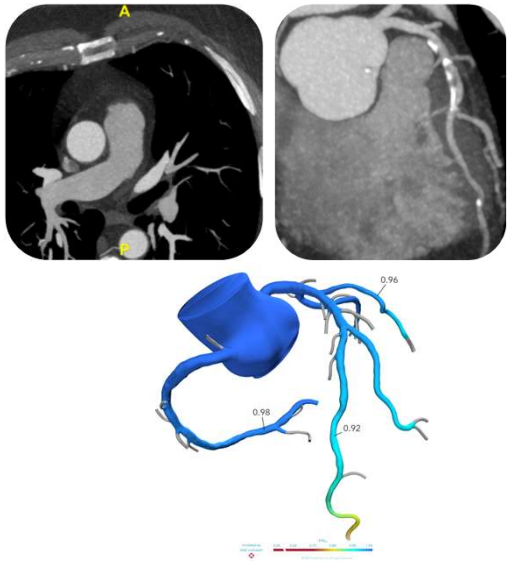
References:

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2. Maroules CD, Rybicki FJ, Ghoshhajra BB, et al. 2022 use of coronary computed tomographic angiography for patients presenting with acute chest pain to the emergency department: An expert consensus document of the Society of cardiovascular computed tomography (SCCT): Endorsed by the American College of Radiology (ACR) and North American Society for cardiovascular Imaging (NASCI). *J Cardiovasc Comput Tomogr*. 2023;17(2):146-163. doi:10.1016/j.jcct.2022.09.003

Case Example: Coronary CTA in Obesity

60-year-old male, BMI 41 (5'8", 268 lbs) with fatigue and shortness of breath

- Improvements in CT scanner hardware and software have enabled high quality images, even in patients with severe obesity
- Wide detector and dual source imaging scanners now allow for successful imaging of patients with challenging anatomy
- Several publications address the diagnostic performance of coronary CTA in obese patients
- The ADVANCE registry indicated that high BMI was not a statistically significant predictor of CCTA quality rejection; many patients with BMI > 39 had successful and accurate FFRCT analysis although stacking multiple factors that can affect image quality should be considered



See notes for list of references

To explain this concept further, let's review a case study. Here are the CCTA images of a male patient with a body mass index of 41, or 268 lbs. He was being evaluated for symptoms of fatigue and shortness of breath. There is extensive soft tissue in the image on the left. Using a CT scanner with modern hardware and software enabled this patient to have a CCTA that produced high-quality images, seen on the right. The image shows significant calcium deposits in the proximal Left Anterior Descending artery. Interestingly, the FFR-CT, was negative, indicating no flow-limiting blockages. This allowed the patient to avoid multiple "layered" stress tests and to avoid invasive cardiac catheterization.

One of the technical advances that has made successful imaging possible for patients with challenging anatomy is the use of wide detector CT scanners, which may have up to 320 detector rows, allowing acquisition of CCTA images in less than 1 second of time. Another technological innovation is the use of dual source scanners. Most of these use two x-ray sources instead of just one.

Several publications address the issue of diagnostic performance of CCTA in obese patients. The ADVANCE Registry demonstrated that high BMI was not a predictor for CCTA image quality rejection.

If a patient is markedly obese AND has other factors that could affect image quality, this should be considered in the preassessment of the patient.

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6. Lowenstern A, Ng N, Takagi H, et al. Influence of Obesity on Coronary Artery Disease and Clinical Outcomes in the ADVANCE Registry. *Circ Cardiovasc Imaging.* 2023;16(5):e014850. doi:10.1161/CIRCIMAGING.122.014850

IV Access

- Appropriate IV access is needed for CCTA; facility-specific protocols should be followed
- IV cannula size (i.e. 18 gauge) and location of IV (i.e. right antecubital vein) should be adequate for the required flow rate
- IV patency and flow should be ascertained prior to injection of contrast dye
- Obese patients may require a larger contrast dose and thus a larger gauge IV
- Poor IV access results in:
  - extravasation/leakage of IV contrast around the IV site
  - inadequate contrast to visualize coronary arteries



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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002
Image = https://www.bd.com/en-ca/products-and-solutions/products/product-families/bd-nexiva-diffusics-closed-iv-catheter-system

Adequate IV access is crucial for obtaining satisfactory CCTA images. Each facility will have its own protocol regarding IV access. It is necessary that the gauge of the IV and location of the IV site is adequate for the required flow rate of contrast. The 2016 SCCT guidelines recommend an 18 gauge IV in most adult patients, although a 20 gauge IV might be satisfactory in small patients. And newer fenestrated catheters allow a smaller gauge to be used while still allowing a faster injection rates, this may be beneficial for smaller patients.

These guidelines recommend the right antecubital vein to be used, and second choice would be the left antecubital vein. Hand veins should be avoided unless no other access is available.

Prior to the injection of IV contrast, IV patency and flow should be ascertained.

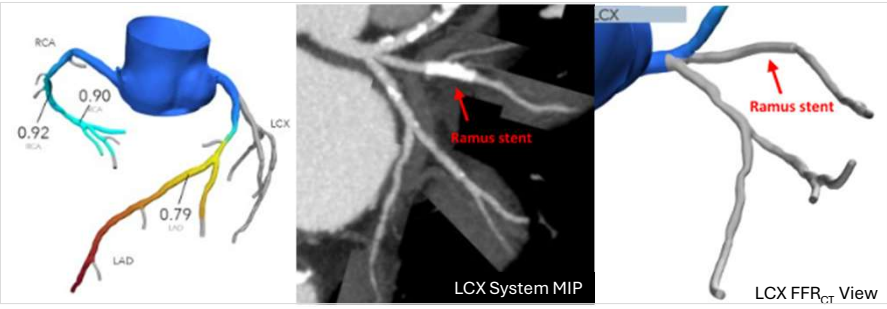
Obese patients may require a larger gauge IV because of a need for a larger dose of IV contrast.

If IV access is inadequate, the result may be extravasation of contrast around the IV site and inadequate contrast to visualize the coronary arteries. Skin irritation from the extravasated contrast may also develop.

Reference:
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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002
Image = https://www.bd.com/en-ca/products-and-solutions/products/product-families/bd-nexiva-diffusics-closed-iv-catheter-system

Coronary Stents

- Patients with stents can have a CCTA safely, with some caveats
- Patients with stents > 3 mm can be scanned but cannot be evaluated for in-stent stenoses
  - Advise that CCTA can be performed in patients with no more than 1 stent
- Stents can cause artifact called "blooming" making it difficult to interpret imaging
- FFR_{CT} cannot be performed in coronary arteries with stents



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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002

CCTA can be performed in patients with coronary stents, however, there are some caveats. The 2021 AHA.ACC guidelines for the evaluation of chest pain indicate that CCTA can be performed to evaluate stent patency for stents 3 mm or larger in diameter. Although it can assess for stent patency, it cannot evaluate in-stent stenoses. It can visualize blood flow distal to the stent, but visualization inside the coronary stent is limited.

Coronary stents cause various types of artifact on CCTA, and these impact the accuracy of images obtained with CCTA. One type of artifact is called “blooming,” which can obscure up to 55% of the lumen within the stented segment. Accuracy of CCTA is significantly reduced if the stent diameter is less than 3 mm.

The best images will likely be obtained in patients with no more than one coronary stent. Vessels with stents will not have an FFRCT analysis and will appear grey.

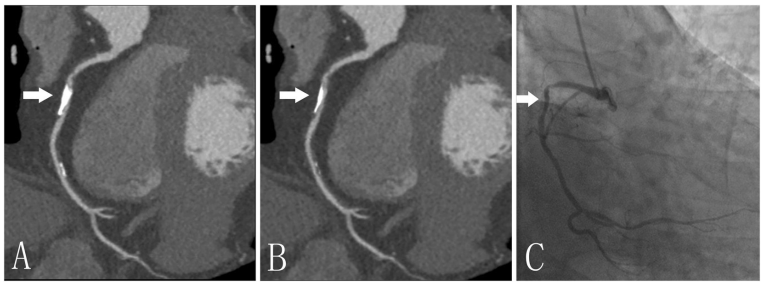
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doi:10.1016/j.jcct.2016.10.002

Significant Calcium Burden

- Patients with elevated calcium scores >400 can still undergo CCTA
- Calcified coronary arteries are prone to artifact
- Modern CT scanners compensate for artifact using a variety of technical modifications
- With modern scanners, sensitivity and specificity of CCTA is high even with elevated calcium scores >1000
- Important to avoid further motion-related artifact: achieve suitable heart rate, ensure patient can comply with breath holding instructions



A) 77-year-old man with calcified plaque (arrow) of the right coronary artery (RCA). A and B) Curved planar reformation (CPR) images without (A) and with (B) de-blooming algorithm show the volume reduction of calcified plaque and improvement of lumen evaluation by using this algorithm; (C) Invasive coronary angiography (ICA) confirms mild stenosis in the RCA. Without de-blooming algorithm, the RCA was almost occluded; while with use of de-blooming algorithm, the RCA was almost 50% stenosis, consistent with findings from ICA.

1. Ghekiere O, Salgado R, Buls N, et al. Image quality in coronary CT angiography: challenges and technical solutions. *Br J Radiol*. 2017;90(1072):20160567. doi:10.1259/bjr.20160567
2. den Dekker MA, de Smet K, de Bock GH, Tio RA, Oudkerk M, Vliegenthart R. Diagnostic performance of coronary CT angiography for stenosis detection according to calcium score: systematic review and meta-analysis. Eur Radiol. 2012;22(12):2688-2698. doi:10.1007/s00330-012-2551-x
Image = https://www.nature.com/articles/s41598-018-25352-5/figures/3

Heavily calcified coronary arteries are one of those patient-related factors that can impact image quality. Patients with a greater coronary calcium burden are more likely to have false positive tests due to various artifacts, like streak and blooming artifacts, which are related to the high-density of the structures. All major CT manufacturers have devised their own solutions for mitigating problems with artifact. These are largely technical solutions your CT Technologist partner will manage.

A meta-analysis of 27 CCTA studies found that sensitivity of CCTA remained quite high even with coronary calcium scores more than 1000, but specificity was reduced, particularly for those with a calcium score in the 400 to 1000 range. However, with more modern CT scanners in use today, specificity remained high, such that there is no need for a calcium score cutoff criteria for performance of CCTA.

In patients with an elevated calcium score, it is very important to minimize any further motion-related artifact, so achieving a suitable heart rate, and complete compliance with breathholding instructions is very important in these patients.

So while a patient with a coronary calcium score of 800 may have a satisfactory CCTA scan, another patient with a calcium score of 800 who has severe obesity, coronary stents, frequent PVCs, and an inability to tolerate a beta-blocker may need to undergo

a different type of diagnostic test. Let's look at a patient case example to better understand.

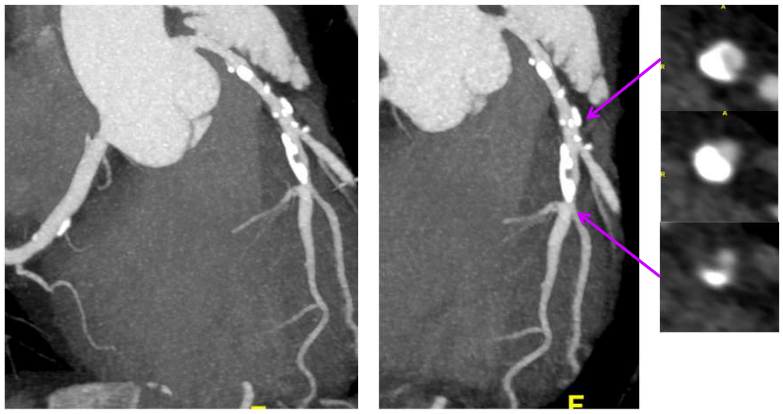
References:

1. Ghekiere O, Salgado R, Buls N, et al. Image quality in coronary CT angiography: challenges and technical solutions. *Br J Radiol*. 2017;90(1072):20160567. doi:10.1259/bjr.20160567
2. den Dekker MA, de Smet K, de Bock GH, Tio RA, Oudkerk M, Vliegenthart R. Diagnostic performance of coronary CT angiography for stenosis detection according to calcium score: systematic review and meta-analysis. Eur Radiol. 2012;22(12):2688-2698. doi:10.1007/s00330-012-2551-x

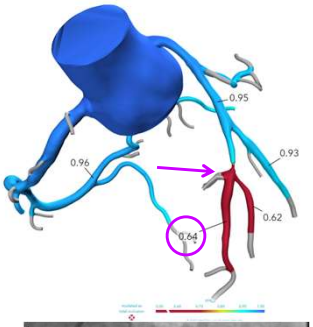
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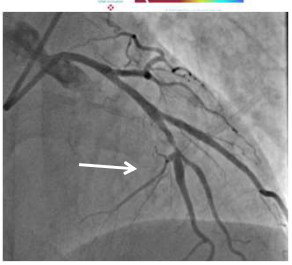
Case Example 2: Calcification and FFR_{CT}

57-year-old male with CAC 474, exertional chest tightness



CTA: LAD 50-70% stenosis; heavy focal calcification





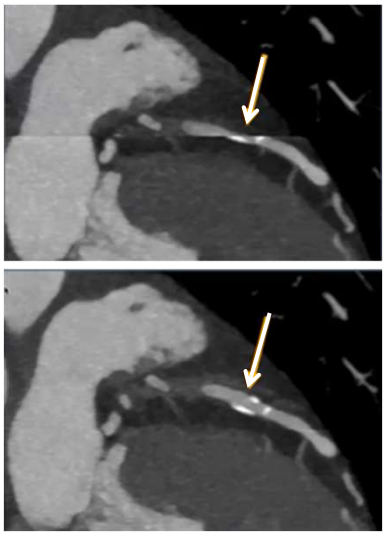
Cath: LAD mid 80-90% stenosis; PCI performed

This patient case example shows images of a 57-year-old male with a coronary artery calcium score of 474 and exertional chest tightness. This is a very common scenario, and with proper scanning parameters, CTA with FFRCT is a very accurate and an important diagnostic tool.

The coronary CTA images demonstrate extensive calcification in the proximal to middle segments of the Left anterior descending artery, with a 50-70% stenosis. FFRCT was performed, which revealed a markedly positive value of 0.64 in the LAD distal to the stenosis. The invasive angiography confirmed a 90% stenosis, and the patient was treated with percutaneous coronary intervention.

Breath-holding and Mental Status

- For optimal images, motion-related artifact must be eliminated
- To achieve this, patients must hold their breath during CCTA for 10-30 second breath-holds
- Patient medical history should be reviewed to ensure patient can lay flat and hold their breath
- Patients with heart failure or severe pulmonary issues may have difficulty
- Patients with dementia, confusion, or altered mental status are unlikely to be able to cooperate with instructions to hold their breath



Ghekiere O, Salgado R, Buls N, et al. Image quality in coronary CT angiography: challenges and technical solutions. Br J Radiol. 2017;90(1072):20160567. doi: 10.1259/bjr.20160567.

For optimal images, motion-related artifact must be eliminated. For this reason, the patient is instructed to hold their breath during critical portions of the scan. You can see in this example the first scan of this patient resulted in a misalignment artifact because the patient didn't hold their breath correctly. The trouble with this image is that we do not know if there is a significant stenosis in the proximal portion of the Left Anterior Descending artery. When the scan was repeated with correct breath holding technique, we can see what the correct arterial anatomy.

The patient will need to be able to hold their breath for 10 to 30 seconds. Some patients may have trouble holding their breath while laying flat. For this reason, it is important to review the patient's medical history prior to the scan.

Patients with heart failure or with moderate or severe pulmonary issues are the most likely to have difficulty with holding their breath while laying down.

Patients with dementia, those who are confused, and patients with altered mental status are unlikely to cooperate with instructions to hold their breath.

Reference:
Ghekiere O, Salgado R, Buls N, et al. Image quality in coronary CT angiography:

challenges and technical solutions. Br J Radiol. 2017;90(1072):20160567. doi: 10.1259/bjr.20160567.

Patient Disease States and How They Can Affect Scanning

Chapter 5

Rachael Grant chapter script:
Now we are going to talk about various patient situations or disease states and how that might impact scanning.

Patient Disease States and Situations that can Affect Scanning

- Severe chronic obstructive pulmonary disease (COPD) / asthma
- Heart failure (acute versus chronic)
- Severe aortic stenosis / severe left ventricular outflow tract (LVOT) obstruction
- Renal compromise (acute versus chronic)
- Contrast dye allergy
- Pregnancy

For example, patients who have severe Chronic Obstructive Pulmonary Disease, or COPD; or asthma, heart failure, severe aortic stenosis, renal compromise, a contrast dye allergy, or are pregnant may have complications, considerations, or contraindications to having Coronary CTA performed. Let's dig into each one.

Severe COPD / Asthma

- Respiratory concerns: Can the patient lie flat for scan and comply with breath holds?
- Heart rate lowering concerns: Can the HR be lowered to <60bpm effectively and safely?
  - Beta blockers are contraindicated due to bronchoconstriction
  - Consider calcium-channel blocker or ivabradine instead of metoprolol
- Appropriateness: Is there alternative testing?



Lopressor. Package Insert. US Food and Drug Administration. Revised February 2008. https://www.accessdata.fda.gov/drugsatfda_docs/label/2008/017963s062,018704s021lbl.pdf
Image = https://zwangerpesiri.com/services/ct/coronary-ct-angiography/

With severe COPD or asthma patients, a primary concern regarding Coronary CTA is whether the patient can lie flat for a scan and can comply with breath-holding instructions.
Another concern is whether the heart rate can be safely lowered to the target range of less than 60 beats per minute.
In these patients, beta-blockers are contraindicated because they can cause bronchoconstriction. Alternative medications would be a calcium-channel blocker or ivabradine.
If a patient with severe COPD or asthma cannot lie flat, hold their breath, or have their heart rate safely lowered, then an alternative test might be considered.

Reference:
Lopressor. Package Insert. US Food and Drug Administration. Revised February 2008. https://www.accessdata.fda.gov/drugsatfda_docs/label/2008/017963s062,018704s021lbl.pdf
Image = https://zwangerpesiri.com/services/ct/coronary-ct-angiography/

Heart Failure (Acute versus Chronic)

Acute: patients with new or worsening heart failure often have…

- Orthopnea typical symptom of heart failure
- High heart rate to compensate for a weak heart: cannot safely give HR lowering medications

Chronic:

- Review ability to take heart rate lowering medications
- Review respiratory status to ensure can comply with breath holds and lying flat
- Respiratory compromise: difficulty with breath holds and lying flat

Patients with acute heart failure may not be able to lie flat either, as orthopnea is a typical symptom in these patients. Also, patients with decompensated heart failure often have an elevated heart rate, which is needed to support the cardiac output with a heart that is not efficiently pumping. In this type of patient, decreasing the heart rate would not be safe with any medication.

Patients with chronic heart failure may be able to undergo a Coronary CTA scan depending on their ability to tolerate heart-rate lowering medications. It would be important to assess this carefully. If they have a relatively low blood pressure, as many patients with heart failure do, there may not be margin for reducing the heart rate. It is also important to assess their ability to lay flat and comply with breath holds. Some patients may sleep on 2 pillows every night and simply cannot lay flat.

Severe Aortic Stenosis / Severe Left Ventricular Outflow Tract (LVOT) Obstruction

Similar patient management for both during CCTA

- Blood flow from the heart is reduced
- Patients need a balance of blood pressure that is not too high or too low
- Nitroglycerin (NTG) is generally contraindicated in these patients
  - NTG is considered essential for optimal CCTA image quality and thus accurate diagnosis
  - If NTG cannot be given, procedure may need to be reconsidered or aborted



1. Takx RA, Suchá D, Park J, Leiner T, Hoffmann U. Sublingual Nitroglycerin Administration in Coronary Computed Tomography Angiography: a Systematic Review. *Eur Radiol*. 2015;25(12):3536-3542. doi:10.1007/s00330-015-3791-3
2. 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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002

Patients with severe aortic stenosis or severe left ventricular outflow tract obstruction have a similar physiology. Blood flow, ie, cardiac output, is restricted by the narrowing of the aortic valve or the obstruction of the left ventricular outflow tract. Careful management of blood pressure is required in these patients, therefore reducing blood pressure in these patients may not be safe.
For this reason, nitroglycerin is generally contraindicated in such patients.

During a Coronary CTA scan, use of sublingual nitroglycerin is standard practice to produce maximal blood flow to the coronary arteries. Nitroglycerin increases the diagnostic accuracy of coronary CTA,[1] and is considered essential for optimal image quality and an accurate diagnosis.[2] In patients with severe aortic stenosis or severe left ventricular outflow tract obstruction who cannot take nitroglycerin, the image quality with Coronary CTA may be compromised, and so the procedure may need to be reconsidered.

References:

1. Takx RA, Suchá D, Park J, Leiner T, Hoffmann U. Sublingual Nitroglycerin Administration in Coronary Computed Tomography Angiography: a Systematic Review. *Eur Radiol*. 2015;25(12):3536-3542. doi:10.1007/s00330-015-3791-3
2. 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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002

Renal Compromise (Acute versus Chronic)

Acute:

- Contrast is cautioned in patients with acute renal failure/kidney injury
- Serial GFR/creatinine lab tests should show improved renal function prior to scan

Chronic:

- Pre-test glomerular filtration rate (GFR) is not required, but should be performed for patients at increased risk (i.e., age, low BMI, and history)
  - Stable patients with GFR > 30 (stage 3 CKD) – well hydrated, avoid NSAIDs and diuretic
  - GFR < 30 (stage 4 CKD) – nephrology consult and follow policies
- Dialysis patients
  - Ensure dialysis within 24 hours
  - Prone to fluid overload – ensure patient can lie flat and comply with breath holds

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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002
2. Davenport MS, Perazella MA, Yee J, et al. Use of Intravenous Iodinated Contrast Media in Patients With Kidney Disease: Consensus Statements from the American College of Radiology and the National Kidney Foundation. *Kidney Med*. 2020;2(1):85-93. doi:10.1016/j.xkme.2020.01.001

IV contrast administration can be associated with kidney damage. For this reason, patients with acute kidney failure or injury will likely not undergo Coronary CTA until their renal function tests are showing significant improvement, perhaps back to their baseline levels.

Chronic kidney disease is relatively common. The guidelines support that many patients in this category can undergo a Coronary CTA if they are stable. If a patient has chronic renal insufficiency, the risks versus benefits of the test must be carefully weighed. Some factors that can increase the likelihood of developing contrast-induced nephropathy include cardiomyopathy, diabetes, elderly and those with low body mass index. If a patient is dehydrated or volume-depleted, has hypotension, or is on NSAIDS, they may also have a higher risk. Patients at higher risk should be screened for kidney function prior to the scan. They should be well-hydrated, avoid NSAIDS for 48 hours before the test and hold their diuretic the day before the test if possible. Local protocols for pre-scan hydration should be developed and followed.

If the patient's GFR is less than 30 [ml/min/1.73 ml], meaning they are in at least stage 4 chronic kidney disease, then particular care needs to be taken, and a nephrology consult may be required. Each hospital or scanning site will likely have their own policy regarding these patients.

Patients who are already on dialysis can undergo Coronary CTA if they can have dialysis within 24 hours of the scan. These patients are prone to fluid overload, so the ability to lay flat and hold their breath should also be assessed.

References:

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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002
2. Davenport MS, Perazella MA, Yee J, et al. Use of Intravenous Iodinated Contrast Media in Patients With Kidney Disease: Consensus Statements from the American College of Radiology and the National Kidney Foundation. *Kidney Med.* 2020;2(1):85-93. doi:10.1016/j.xkme.2020.01.001

Contrast Dye Allergy

- CCTA is not advised if prior anaphylactic reaction to IV contrast
- Review iodine allergies and whether topical or with IV contrast dye
- If history of mild contrast dye allergy (hives, itching), ask if patient was able to undergo CT with IV contrast and premedication (steroids and antihistamine) in the past without breakthrough reaction
- Follow premedication for contrast allergies per the facility protocols; consider physician oversight
- Driver may be needed to drive patient home if Benadryl is used
- Know procedure for handling patients who develop significant allergic reaction to IV contrast
- Be familiar with emergency services available at imaging location



1. Schabelman E, Witting M. The relationship of radiocontrast, iodine, and seafood allergies: a medical myth exposed. *J Emerg Med*. 2010;39(5):701-707. doi:10.1016/j.jemermed.2009.10.014
2. Bruen R, Stirling A, Ryan M, Sheehan M, MacMahon P. Shelling the myth: allergies to Iodine containing substances and risk of reaction to Iodinated contrast media. *Emerg Radiol*. 2022;29(1):67-73. doi:10.1007/s10140-021-01989-0
3. Ledford DK. Povidone iodine (Betadine) allergy and radiocontrast hypersensitivity. American Academy of Allergy, Asthma, and Immunology. March 10, 2016. https://www.aaaai.org/allergist-resources/ask-the-expert/answers/old-ask-the-experts/povidone-iodine-betadine

Another important issue related to Coronary CTA is allergy to IV contrast dye. If a patient has had a previous anaphylactic reaction to IV contrast dye, Coronary CTA is not advised.
Prior to the scan, the patient should be asked about any prior history of reaction to IV contrast dye or to iodine, since the dye is iodine-based, and to clarify whether it was topical iodine such as Betadine, or with IV contrast dye. If it was topical iodine or Betadine, the Coronary CTA test can still proceed, as there is no known connection between reaction to topical iodine and IV contrast.

If they have a history of a mild reaction, such as rash, itching, or hives, ask if the patient was able to undergo CT with IV contrast with pretreatment of steroids and antihistamine, and without breakthrough reaction in the past. Patients who were successfully able to undergo CT (or a similar procedure) with IV contrast and premedication may be good candidates, if they have appropriate premedication.

Each facility may have their own protocol for pretreatment for allergy to IV contrast dye, which should be followed. Also, to provide additional safety, consider scanning patients with known contrast allergies at a location where there are resources to manage a breakthrough reaction.

If an antihistamine such as Benadryl is administered to the patient, then it is advisable that another driver be available to drive the patient home following the test, due to the drowsiness induced by Benadryl.

Personnel at the imaging lab should be familiar with the procedure for handling patients who develop a significant allergic reaction to IV contrast dye. The supervising radiologist or designee should be notified, and depending on the clinical circumstances and hospital protocol, a rapid-response team might be called, or the patient might be taken to the emergency department of the hospital for stabilization and treatment.

References:

1. Schabelman E, Witting M. The relationship of radiocontrast, iodine, and seafood allergies: a medical myth exposed. *J Emerg Med*. 2010;39(5):701-707. doi:10.1016/j.jemermed.2009.10.014
2. Bruen R, Stirling A, Ryan M, Sheehan M, MacMahon P. Shelling the myth: allergies to Iodine containing substances and risk of reaction to Iodinated contrast media. *Emerg Radiol.* 2022;29(1):67-73. doi:10.1007/s10140-021-01989-0
3. Ledford DK. Povidone iodine (Betadine) allergy and radiocontrast hypersensitivity. American Academy of Allergy, Asthma, and Immunology. March 10, 2016. https://www.aaaai.org/allergist-resources/ask-the-expert/answers/old-ask-the-experts/povidone-iodine-betadine

Pregnancy

- CCTA is generally contraindicated due to the risk of radiation exposure to the fetus
- All imaging facilities should have policies and procedures to identify pregnant patients prior to imaging (recommendation per American College of Radiology)
- Risks to the fetus from radiation and/or contrast in comparison with potential benefits of CCTA should be considered



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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002

Lastly, Coronary CTA is generally contraindicated during pregnancy due to the risk of radiation exposure to the developing fetus. All imaging facilities should have policies and procedures to identify pregnant patients prior to imaging, according to the American College of Radiology.

In addition to the risk of radiation, the risk to the fetus of any planned contrast material must be considered, as well as the potential clinical benefit of the CCTA test. The iodine in the contrast can affect the thyroid function of the developing fetus.

Reference:

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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002



Sara Wallace chapter script:
Patient education is an important and necessary part of preparing a patient for a CCTA scan. Following the scan, patients may need additional instructions. Let's review the key facets of patient education.

Patient Education: Pre-CCTA Scan Instructions

- Hydration – patient should be well-hydrated prior to scan
  - Protects kidneys from IV contrast, eases establishment of venous access, and to avoid post-procedure hypotension
  - Patient may drink water or clear fluids without caffeine up until time of exam
- Caffeine – none for 12 hours prior to scan (non-acute setting)
- Food – no solid food for 4 hours prior to scan
- Tobacco – none for 4 hours prior to scan



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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002
2. Ramjattan NA, Lala V, Kousa O, et al. Coronary CT Angiography. [Updated 2024 Jan 19]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK470279/
3. Mayo Clinic Staff. CT Coronary Angiogram. Mayo Clinic. May 6, 2022. https://www.mayoclinic.org/tests-procedures/ct-coronary-angiogram/about/pac-20385117
4. Benowitz NL, Burbank AD. Cardiovascular toxicity of nicotine: Implications for electronic cigarette use. *Trends Cardiovasc Med*. 2016;26(6):515-23. doi: 10.1016/j.tcm.2016.03.001.

The patient needs to be given specific instructions and education prior to the CCTA for a successful outcome. While every institution may have its own policies regarding preparation of patients for a CCTA scan, several principles are generally applicable.

1) Patients should be instructed to hydrate well prior to the scan.([1] Hydration helps to protect the kidneys from IV contrast dye, facilitates ease in establishing IV access, and helps to avoid post-procedure hypotension. Patients can drink water or clear, non-caffeinated fluid up until the time of the procedure.([1]

2) In the non-acute setting, the patient should avoid caffeine for 12 hours prior to the scan as caffeine may elevate the heart rate.([1-3] It may also exacerbate PVC's or other arrhythmias and has a dehydrating effect. This may not be possible in the acute care setting, such as the emergency department.

3) Solid food is usually held for 4 hours prior to the scan.([1-3]

4) The patient should abstain from tobacco for 4 hours prior to the scan. Nicotine[4] increases the heart rate, constricts coronary arteries, and decreases coronary blood flow—these are effects undesirable for a quality CCTA scan. Nicotine has a half-life of about 2 hours,([4] so by abstaining from nicotine for 4 hours prior to the

scan, most of the substance will have cleared the body.

References:

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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002
2. Ramjattan NA, Lala V, Kousa O, et al. Coronary CT Angiography. [Updated 2024 Jan 19]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK470279/
3. Mayo Clinic Staff. CT Coronary Angiogram. Mayo Clinic. May 6, 2022. https://www.mayoclinic.org/tests-procedures/ct-coronary-angiogram/about/pac-20385117
4. Benowitz NL, Burbank AD. Cardiovascular toxicity of nicotine: Implications for electronic cigarette use. *Trends Cardiovasc Med*. 2016;26(6):515-23. doi: 10.1016/j.tcm.2016.03.001.

Patient Education: Pre-scan Instructions

Medications to hold:

- PDE-5 inhibitors must be held for 48 hours prior to scan due to nitroglycerin administration during scan

Brand name for PDE-5 Inhibitors for erectile dysfunction	Generic name	Brand name for PDE-5 Inhibitors for pulmonary hypertension
Viagra	sildenafil	Revatio, Liqrev
Cialis	tadalafil	Adcirca, Alyq, Tadliq
Levitra/Staxyn	vardenafil	

- Hold diuretics the day before the scan if safe; can take after scan is complete
- If impaired renal function, avoid nonsteroidal anti-inflammatory drugs (NSAIDS) and other nephrotoxic drugs for 48 hours before

Ramjattan NA, Lala V, Kousa O, et al. Coronary CT Angiography. [Updated 2024 Jan 19]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK470279/
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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002

The patient also needs to be instructed about what medications to take, and NOT TO TAKE.

Because nitroglycerin is often going to be administered to maximize blood flow through the coronaries and increase diagnostic accuracy, Phosphodiesterase type 5 inhibitor medications, such as Viagra and Cialis must be held for a minimum of 48 hours prior to the scan. The generic name for Viagra is sildenafil, which is also marketed for pulmonary hypertension under the brand names of Revatio and Liqrev. The trade name for Cialis is tadalafil, and it is marketed under several different names for pulmonary hypertension. Another PDE-5 inhibitor is vardenafil. These medications must be held for 48 hours prior to administration of nitroglycerin. If these are taken it can lead to severe hypotension once nitroglycerin is administered, therefore the patient may be sent home and rescheduled.

It is best to also hold diuretics, such as Lasix or spinronolactone, the day prior to the scan, if that is safe to do so, for 2 reasons—to increase hydration and volume status, and to minimize hypotension with the administration of nitroglycerin.

In patients with renal dysfunction in which a CCTA is planned, the patient should be instructed to avoid nonsteroidal inflammatory drugs such as Advil or Motrin for 48

hours prior to the scan, as well as other nephrotoxic drugs.

References:

1. Ramjattan NA, Lala V, Kousa O, et al. Coronary CT Angiography. [Updated 2024 Jan 19]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK470279/
2. 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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002

Patient Education: Pre-scan Instructions

Medications taken for the scan:

- Metoprolol tartrate (short-acting oral beta-blocker) or ivabradine is usually administered 60 to 120 minutes prior to scan; patient may feel tired
- During the scan, further medications may be administered:
  - Nitroglycerin (NTG) 5 minutes prior to scan
  - IV medication to further slow the heart rate
- Any premedication required for allergy to IV contrast dye
- Driver not required unless taking Benadryl for contrast dye allergy



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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002

Medications prescribed to slow the heart rate—typically metoprolol tartrate or ivabradine—are usually taken about 60 to 120 minutes prior to the scan. Patients may feel tired after taking the medication. Some physicians may also prescribe oral beta-blockers the night before and morning of, this will be a protocol set up by your institution.
During the scan, while the patient is on the CT table, sublingual nitroglycerin may be administered approximately 5 minutes before the scan to vasodilate the coronary arteries and therefore increase artery visibility. The patient should also be aware that further medications to slow the heart rate may be given via IV.

Patients should know to take required premedication like prednisone or Benadryl for allergy to contrast dye. Another driver will not be required unless the patient needs to take Benadryl.

Reference:
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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002

Patient Education: At the Scan

- EKG monitoring
  - EKG pads placed on chest to monitor heart rate during scan
  - Heart rate affects timing and dose of contrast administration, which is synchronized with imaging
- IV Placement, usually in the right arm
- Vitals taken during prep, prior to NTG administration, after scan, and prior to sending patient home
- Additional meds (IV) may be given before or during scan
- IV Contrast administration based on heart rate
- IV Contrast can make the patient feel warm and have a full bladder sensation

Prior to and during the scan, the nurse or technician should explain the patient experience.

- EKG pads are placed on the chest to monitor the heart rate and rhythm during the scan. The timing of contrast administration is coordinated with breathholding and is synchronized with imaging of the heart. The heart rate can also affect how much contrast is administered.
- An IV is placed, preferably in the right antecubital space because the right arm is more of a straight shot to the heart than the left.
- Vital signs are taken during preparation, prior to administration of nitroglycerin, following the scan, and before sending the patient home.
- If additional heart rate lowering medications are required, it will be given by IV before or during the scan.
- IV contrast is injected once the heart rate is in the desired range and during the appropriate timing.
- When the contrast is injected, the patient will likely feel warm and have the sensation of a full bladder.

Explaining the procedure along the way, helps the patient with anxiety and can improve the efficiency and experience for everyone.

Patient Education: Post Scan

Instructions the nurse should provide the patient when going home:

- Hydrate to flush contrast out of body
- Take diuretics if prescribed
- Caffeine OK and can mitigate possible headache due to vasodilation of NTG
- Metformin – hold for 48 hours post-scan



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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002

Following the scan, the patient should be instructed to hydrate well and to drink plenty of fluids to flush the contrast out of the body. Diuretic medication, if prescribed, should be resumed.

The patient can drink caffeinated beverages, which may in fact help to alleviate possible headache from vasodilation caused by the nitroglycerin.

The 2016 SCCT guidelines state that "It is reasonable to suspend metformin for at least 48 hours after contrast administration. Metformin itself is not nephrotoxic but is exclusively cleared by the kidneys. If renal failure is precipitated by iodinated contrast, a toxic accumulation of metformin may result, which can induce lactic acidosis. There is no evidence that withholding metformin before a contrast procedure is protective although this approach has been adopted by some in the past."([1])

Reference:

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*

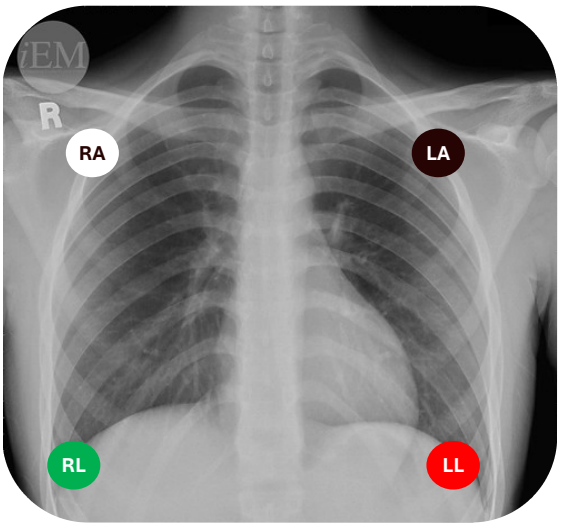
Cardiovasc Comput Tomogr. 2016;10(6):435-449. doi:10.1016/j.jcct.2016.10.002



Rachael Grant chapter script:
Let’s now move on to patient management for CCTA.

ECG Monitoring

- Correct placement of ECG pads is needed
  - Avoid field of scanning
- Placement of upper leads should be somewhat medial due to arm raising, and placement of lower leads should be somewhat lateral
- Observe for cardiac rhythms that affect scanning – full ECG review not required
- May need to clean skin with alcohol and shave at the site of electrode placement



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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002

ECG pads should be correctly placed, this is typically a 4-lead set up based on the site protocol. The ECG leads should be placed outside of the field of scanning, and this may vary somewhat depending on which scanner is used.([1]) Because the patient will have their arms overhead during the CCTA scan, the placement of the upper leads should be somewhat medial, or closer to the patient's center line. To trial upper lead displacement, it may be beneficial to have the patient place their arms above their head and lay them down. The placement of the lower leads should be somewhat lateral to avoid the field of scanning.

The patient's cardiac rhythm will be observed during the test, particularly to note any arrhythmia that might affect scanning, such as atrial fibrillation or PVC's. A full 12-lead ECG review is not required.

It may be necessary to clean the skin with alcohol and shave at the site of electrode placement to ensure sufficient electrode-to-skin contact. [1]

Reference:

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

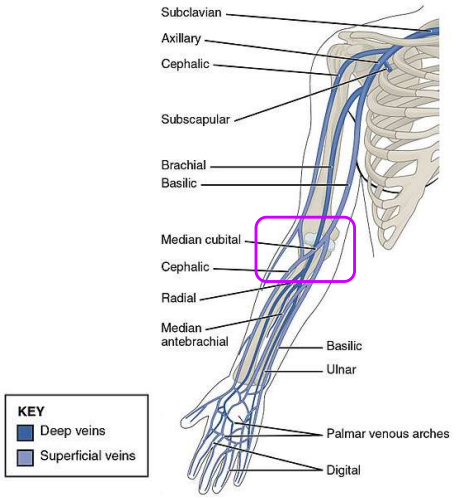
American Society for Cardiovascular Imaging (NASCI). *J Cardiovasc Comput Tomogr*. 2016;10(6):435-449. doi:10.1016/j.jcct.2016.10.002

Image:
https://www.flickr.com/photos/iem-student/44046768961/in/photolist-Lmo1JM-27mrHN7-2a34o6S-Lmu7nt-291VpzL-MYNXVh-291SChq-291xNps-2a7gcR4-MYNtTq-2a36VRw-291UCLY-291y4E7-28JdTE2-JWZG14-27ecHd4-27ewe4k-27ewe3Z-2gk9z3f-2gk9GJp-27eanVR-Lt4BpA-28wxGPW-JX5TPz-2i2LKk1-27T5r7w-JWZGzk-287xBRW-2btDJu4-27T5r2b-KjB2Dg
Used in article: https://iem-student.org/how-to-read-chest-x-rays/

IV Size and Placement

- Need larger bore IVs because of high flow rate needed for contrast injection
- Size (gauge) – see chart
- Location – preferably right antecubital
- Warming of contrast – lowers viscosity of the contrast so it can be administered at higher injection rates with lower injection pressures for optimal timing of the images
- Remove IV post-scan

BMI	Angiocath	Diffusics
<24	20 g	20 g
25-30	18 g	20 g
31-50	16 g	18 g
>50	N/A	18 g



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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002
2. Oda S, Utsunomiya D, Nakaura T, et al. Basic Concepts of Contrast Injection Protocols for Coronary Computed Tomography Angiography. *Curr Cardiol Rev*. 2019;15(1):24-29. doi:10.2174/1573403X14666180918102031

Image - https://wtcs.pressbooks.pub/nursingadvancedskills/chapter/1-3-iv-access/

Another important aspect of patient management is the IV catheter. With Coronary CTA, the injection of contrast is timed with the acquisition of images, and the ideal images are obtained with high contrast flow rates, oftentimes ranging from 4 to 7 milliliters per second,[1] and lasting 10 to 20 seconds.[2] For this reason, the size and location of IV are very important.

In smaller patients, a short 20-gauge IV catheter may be adequate, but an 18-gauge catheter is typically necessary in most adults to achieve rapid infusion rates. There are also some newer high flow IV catheters[1] that allow use of a smaller bore while maintaining high flow rates.

Regarding the location of IV, a right antecubital vein is preferable,[1] as it provides the most direct route to the heart. A left antecubital vein is an alternative if the right cannot be accessed. Hand veins should be avoided, unless no other suitable access can be established. Hand veins require a 20 gauge or smaller catheter and slower flow rates. Central lines should not be used unless specifically labeled for power injection.[1]

Warming of the contrast agent lowers the viscosity of the contrast and allows higher injection rates at lower injection pressures for optimal timing of the images.[1]

Of course, following completion of the coronary CTA scan, the IV will be removed before the patient goes home.

References:

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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002
2. Oda S, Utsunomiya D, Nakaura T, et al. Basic Concepts of Contrast Injection Protocols for Coronary Computed Tomography Angiography. *Curr Cardiol Rev*. 2019;15(1):24-29. doi:10.2174/1573403X14666180918102031

Image - https://wtcs.pressbooks.pub/nursingadvancedskills/chapter/1-3-iv-access/

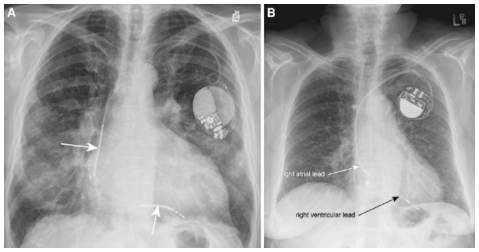
Vital Signs / Pacemakers and ICDs

Heart Rate and Blood Pressure

- During prep to determine if additional meds are required
- Prior to NTG administration
- Post-scan
- Prior to discharge

Pacemakers and ICDs

- Adjustments to programmed rates for permanent pacemakers (PPMs) and implantable cardioverter-defibrillators (ICDs) must be performed by an industry representative in conjunction with the reading provider (cardiologist or radiologist); some devices can be adjusted remotely
- A process for identifying PPM/ICD patients and how to secure industry rep expertise is vital to scanning these patients



Radiographic appearance of an implantable cardioverter defibrillator (ICD) (A) and cardiac pacemaker (B). The only reliable way to differentiate an ICD from a pacemaker is presence of shocking coil(s) (indicated by arrows) in the right ventricle and sometimes in the superior vena cava. These appear as sections of the lead which are wider and more radio-dense.

Image: Can J Anesth/J Can Anesth (2012) 59:394–407. DOI 10.1007/s12630-012-9678-8. https://www.researchgate.net/figure/Radiographic-appearance-of-an-implantable-cardioverterdefibrillator-ICD-A-and-a_fig2_221877154

The patient's heart rate and blood pressure are assessed during the preparation phase to see if additional medications are required to slow the heart rate and determine if it is safe to give additional medications.

Heart rate and blood pressure are also checked prior to administration of nitroglycerin and following the scan. In addition, a final measurement of heart rate and blood pressure should be taken prior to discharge from the imaging facility.

For patients with a permanent pacemaker or implantable cardioverter defibrillator (ICD), the underlying rate of the device must be adjusted by an industry representative, in conjunction with the radiologist or cardiologist who will be reading the scan. To scan these patients, there should be a process at your site for identifying patients with a pacemaker or ICD and for securing the expertise of the appropriate industry representative.

Image: Can J Anesth/J Can Anesth (2012) 59:394–407
DOI 10.1007/s12630-012-9678-8.
https://www.researchgate.net/figure/Radiographic-appearance-of-an-implantable-

cardioverterdefibrillator-ICD-A-and-a_fig2_221877154



Jonathon Leipsic chapter script:
In this section we will briefly touch on the medications commonly used in conjunction with CCTA. We won't review all the information in the charts for each medication, but you will be able to have this information in your accompanying transcript from this training.

Metoprolol Tartrate

Used for	Heart rate (HR) management (oral best, but can be give IV prior to scan to adjust HR)
Mechanism of Action	Beta-blocker. Short acting beta 1-selective adrenergic receptor blocker that reduces HR and BP
Contraindications & Warnings	Sinus bradycardia, cardiogenic shock, acute HF, reactive airway disease due to bronchoconstriction (asthma/COPD); recent methamphetamine or cocaine use
Adverse Effects (patient education)	Fatigue, weakness, dizziness, shortness of breath, decreased exercise tolerance
Dosage & Administration	Use local protocol; most protocols commonly use 50 to 100 mg orally 1 hour prior to scan, with supplemental IV dose just prior to scan as needed for HR

https://www.webmd.com/drugs/2/drug-8814-2372/metoprolol-succinate-oral/metoprolol-succinate-extended-release-capsule-oral/details
https://www.drugs.com/pro/metoprolol.html
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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002

For lowering the heart rate in patients undergoing a CCTA scan, metoprolol tartrate is most often used. This would be the short-acting form of metoprolol, also known as Lopressor. Most protocols specify administration of 50 to 100 mg of metoprolol orally 1 hour prior to the scan. If the heart rate is not sufficiently lowered with oral medication, then supplemental doses of beta-blocker can be administered via IV prior to the scan. Patients with sinus bradycardia, acute heart failure or bronchospastic disease cannot take beta-blockers.

References:

https://www.webmd.com/drugs/2/drug-8814-2372/metoprolol-succinate-oral/metoprolol-succinate-extended-release-capsule-oral/details

https://www.drugs.com/pro/metoprolol.html

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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002

Ivabradine

Used for	HR management in patients unable to take metoprolol or in addition to metoprolol tartrate for patients with higher HRs (>80 BPM)
Mechanism of Action	Blocks the channel responsible for the cardiac pacemaker current, I(f), which regulates HR prolonging diastolic time and reducing HR without reducing BP
Contraindications & Warnings	Concomitant use of verapamil or diltiazem, decompensated HF, conduction abnormalities
Adverse Effects (patient education)	Fatigue, dizziness, decreased exercise tolerance
Dosage & Administration	Possible regimens include: 7.5 to 15 mg orally 1 hour before scanning

1. Corlanor Prescribing Information. US Food and Drug Administration. Revised April 2019. https://www.accessdata.fda.gov/drugsatfda_docs/label/2019/206143s007lbl.pdf
2. 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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002
3. Manz M, Reuter M, Lauck G, Omran H, Jung W. A single intravenous dose of ivabradine, a novel I(f) inhibitor, lowers heart rate but does not depress left ventricular function in patients with left ventricular dysfunction. *Cardiology*. 2003;100(3):149-155. doi:10.1159/000073933

Ivabradine is a unique medication that slows the heart rate but with less effect on blood pressure than beta-blockers or calcium-channel blockers. It is FDA-approved for patients with heart failure,[1] and has been studied as an adjunctive medication with patients undergoing CCTA. It is CONTRAINDICATED with verapamil or diltiazem due to a known drug interaction, having to do with the cytochrome P450 system.[1] Ivabradine is also contraindicated with decompensated heart failure or with sick sinus syndrome, sinoatrial block or third-degree heart block unless a pacemaker is present, severe bradycardia, pacemaker dependence, or clinically significant hypotension.[1]

Reference:

1. Corlanor Prescribing Information. US Food and Drug Administration. Revised April 2019. https://www.accessdata.fda.gov/drugsatfda_docs/label/2019/206143s007lbl.pdf

References for dosage & administration:

2. 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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002
3. Manz M, Reuter M, Lauck G, Omran H, Jung W. A single intravenous dose of ivabradine, a novel I(f) inhibitor, lowers heart rate but does not depress left ventricular function in patients with left ventricular dysfunction. *Cardiology*. 2003;100(3):149-155. doi:10.1159/000073933

Nitroglycerin (Sublingual)

Used for	Prevention of angina pectoris due to coronary artery disease; Vasodilation of the coronary arteries for better imaging
Mechanism of Action	Relaxation of vascular smooth muscle and dilation of peripheral arteries and veins
Contraindications & Warnings	Early MI, severe anemia, increased intracranial pressure; patients with aortic stenosis or left-ventricular outflow obstruction; concurrent use with PDE-5 inhibitors (sildenafil, tadalafil, vardenafil hydroxide) for erectile dysfunction; or pulmonary hypertension
Adverse Effects (patient education)	Fatigue, dizziness, weakness, hypotension, headaches
Dosage & Administration	Administer 400-800 mcg sublingual tablets or spray 5 minutes prior to CCTA, with 800 mcg being the preferred dose

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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002
https://www.accessdata.fda.gov/drugsatfda_docs/label/2016/021134s008lbl.pdf

Administration of sublingual nitroglycerin is an important standard protocol with coronary CT angiogram unless contraindicated. Nitroglycerin helps to dilate the coronary arteries to provide better visualization on the images. The usual dosage is 400 to 800 micrograms, sublingually, in either tablets or spray. The 800-mcg dosage is the preferred dosage if the patient can tolerate it. It is important to check the patient's blood pressure before administering nitroglycerin and reassess following the scan. Nitroglycerin would be contraindicated if a patient has taken a PDE-5 inhibitor (sildenafil, tadalafil, or vardenafil) within 48 hours prior to the scan.

Reference for dosage and administration:

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;10(6):435-449. doi:10.1016/j.jcct.2016.10.002

https://www.accessdata.fda.gov/drugsatfda_docs/label/2016/021134s008lbl.pdf

Diltiazem

Used for	Patients with atrial fibrillation when HRs vary by >25 BPM
Mechanism of Action	Calcium channel blocker, anti-arrhythmic
Contraindications & Warnings	Concurrent use of ivabradine for lowering HR (may exacerbate bradycardia/conduction disturbances); sick sinus syndrome or second- or third-degree AV block with no functioning ventricular pacemaker, severe hypotension or cardiogenic shock, atrial fibrillation or atrial flutter associated with an accessory bypass tract such as in WPW syndrome or short PR syndrome, ventricular tachycardia
Adverse Effects (patient education)	Bradycardia, dizziness, fatigue, headache
Dosage & Administration	Oral diltiazem is available in 30, 60, 90, and 120 mg. IV diltiazem (1 mg/ml) is supplied in vials of 125 or 250 ml.

Diltiazem Hydrochloride in Dextrose Injection Prescribing Instructions. US Food and Drug Administration. Revised October 2021. https://www.accessdata.fda.gov/drugsatfda_docs/label/2021/215252s000lbl.pdf
Cardizem Prescribing Instructions. US Food and Drug Administration. Revised November 2014. https://www.accessdata.fda.gov/drugsatfda_docs/label/2014/018602s065lbl.pdf
Diltiazem Hydrochloride in Dextrose Injection Prescribing Instructions. US Food and Drug Administration. Revised October 2021. https://www.accessdata.fda.gov/drugsatfda_docs/label/2021/215252s000lbl.pdf

Most healthcare providers are familiar with the calcium channel blocker, diltiazem. If a patient cannot tolerate metoprolol, for example, and have severe asthma, then diltiazem is an option. Remember, however, that if you give diltiazem then use of ivabradine is excluded and vice-versa. Diltiazem is contraindicated with sick sinus syndrome, second-or third-degree heart block without a functioning pacemaker, severe hypotension or cardiogenic shock, and in patients with atrial fibrillation or flutter with Wolff-Parkinson-White syndrome or short PR syndrome, because it can accelerate the heart rate to dangerous rates. It can also cause hemodynamic deterioration in patients with wide complex tachycardia of ventricular origin, ie, ventricular tachycardia. [1]

Reference for additional contraindications other than ivabradine:

1. Diltiazem Hydrochloride in Dextrose Injection Prescribing Instructions. US Food and Drug Administration. Revised October 2021. https://www.accessdata.fda.gov/drugsatfda_docs/label/2021/215252s000lbl.pdf

References for how supplied:

2. Cardizem Prescribing Instructions. US Food and Drug Administration. Revised November 2014. https://www.accessdata.fda.gov/drugsatfda_docs/label/2014/018602s065lbl.pdf

3. Diltiazem Hydrochloride in Dextrose Injection Prescribing Instructions. US Food and Drug Administration. Revised October 2021. https://www.accessdata.fda.gov/drugsatfda_docs/label/2021/215252s000lbl.pdf

Sample Protocol for Heart Rate Control with CCTA

Heart-rate control
• Prescribe heart rate-lowering medication, if appropriate, with the intent to achieve a stable target heart rate ≤60 beats/min • Sample institutional protocol: 1. **Oral metoprolol**: give 30–60 min prior to imaging, then reassess; systolic blood pressure >90 mmHg • Baseline HR 55–60: give 25 mg • Baseline HR 61–65: give 50 mg • Baseline HR > 66: give 100 mg 2. **IV metoprolol**: while patient is on the scanner table, give 5 mg over slow IV push every 5 min, up to 20–25 mg total; systolic blood pressure >90 mmHg 3. **Ivabradine**: • Oral ivabradine 15mg or 7.5 mg (in chronic beta blockade) 75 min prior to imaging 4. **IV diltiazem**: not recommended first-line for heart rate control unless there is contraindication to beta-blockers; do not combine with beta-blockers; systolic blood pressure >90 mmHg • Give 5 mg IV over 2 minutes; re-dose every 10 minutes to a max dose of 30 mg

Maroules CD, et al. 2022 Use of CCTA for patients presenting with acute chest pain to the ED: An expert consensus document of the SCCT. Endorsed by ACR and NASCI. JACC 2023(17)146-163. DOI: 10.1016/j.jcct.2022.09.003

You can find an example of a heart rate control protocol in the Expert Consensus document of the Society of cardiovascular computed tomography which was also endorsed by the American College of Radiology and the North American Society for cardiovascular Imaging. Your facility will likely have a protocol of it its own that will be to follow.

Reference:

Maroules CD, et al. 2022 Use of CCTA for patients presenting with acute chest pain to the ED: An expert consensus document of the SCCT. Endorsed by ACR and NASCI. JACC 2023(17)146-163. DOI: 10.1016/j.jcct.2022.09.003

Sample Protocol for Nitroglycerin with CCTA

Coronary vasodilation
• Sample protocols: 1. Apply ½ inch nitropaste to chest 60 min prior to imaging 2. Give 0.4–0.8 mg sublingual nitroglycerin (tabs or spray) 5 min prior to contrast • Omit nitroglycerin in patients with contraindications (ie aortic stenosis, recent intake of phosphodiesterase inhibitors, etc)

Maroules CD, et al. 2022 Use of CCTA for patients presenting with acute chest pain to the ED: An expert consensus document of the SCCT. Endorsed by ACR and NASCI. JACC 2023(17)146-163. DOI: 10.1016/j.jcct.2022.09.003

In that same document, it also mentions a sample protocol for nitroglycerin use with coronary CTA. Again, recall that 800 mcg of nitro is preferred if the patient can tolerate this.

Reference:
Maroules CD, et al. 2022 Use of CCTA for patients presenting with acute chest pain to the ED: An expert consensus document of the SCCT. Endorsed by ACR and NASCI. JACC 2023(17)146-163. DOI: 10.1016/j.jcct.2022.09.003

The Cardiac Nurse Navigator Role

Chapter 9

Rachael and Sara to both record full chapter script:
This chapter will review the role of a cardiac nurse navigator with respect to Coronary CTA. Not all locations have this role and as Coronary CTA programs grow, this role may become more common.

The Cardiac Nurse Navigator Role: Best Practices

- Nurse Navigator provides clinical support between Cardiology and Radiology teams to maintain throughput and optimize image quality by enhancing communication throughout the patient process:
  - Appropriateness
  - Patient safety
  - Scan quality
  - Operational efficiencies
- As volume grows, ensuring appropriateness and preparing patients properly for the scan becomes more important.

The role of the nurse navigator is to serve as a clinical liaison between the cardiology and radiology teams to maintain patient flow, efficiency, and efficacy for the entire Coronary CTA process. Communication with the patient and the various team members is an integral part of the role.

The responsibilities of the nurse navigator include reviewing the appropriateness of the order based on the patient's clinical history, ensuring patient safety, taking measures to optimize scan quality, and achievement of operational efficiencies.

As the volume of Coronary CTA increases, ensuring appropriateness becomes more challenging. Oftentimes, patients who don't meet the ideal profile can still undergo a Coronary CTA scan. However, they will need to be properly prepared for the scan, and the protocol for the scan may need to be adapted for the patient.

If a patient arrives at the imaging facility to undergo a scan, but then for some reason cannot have the scan at that time, resources are wasted, including scanner time, CT technologist time, and RN time. Therefore, having a nurse navigator ensure that these essential functions are carried out promotes operational efficiencies.

Appropriateness

- Not all patients are ideal candidates for coronary CTA
- Proper preparation and individualization of the protocol may be needed for non-ideal candidates
- Communication is key across departments!
- Ordering HCPs may not be aware of:
  - CCTA indications/contraindications
  - Patient selection and appropriate preparation for scan
  - Scanners with different capabilities

Some patients simply cannot undergo a Coronary CTA scan, and if so, the ordering physician should be notified and alternative arrangements for a different diagnostic test can be made. For some patients, the Coronary CTA may be necessary despite one or more relative, but not absolute, challenges. And other patients may have a disease or condition that, with respect to the CCTA can be managed with proper preparation and individualization of the protocol. The nurse navigator's role is to sort this out, and if necessary, have discussions with the ordering physician, CT technologists, and radiologist or interpreting cardiologist if needed.

Some ordering healthcare providers may not be aware of all the subtleties regarding indications and contraindications for Coronary CTA scans, and oftentimes there may be referrals from outside hospital systems or from facilities that do not have Coronary CTA scanner capability. With this lack expertise in knowing which patients should or should not undergo a Coronary CTA scan, the nurse navigator role is even more important. Another complicating factor is that different scanners may have different capabilities, so it is important to know the capabilities of the scanner or scanners in your system.

Patient Safety

- Clinical liaison between Cardiology and Radiology to communicate relevant information about patient prior to scan:
  - Limitations/concerns for scan (IV contrast dye allergy, renal function, ECG abnormalities, etc.)
  - Medications concerns
- Works with ordering provider, schedulers, CT technologists, CT RNs, and readers to ensure “right scan, right time, right location/scanner”

Of course, patient safety is paramount. Whether the patient has an allergy to IV contrast dye, impaired renal function, severe obesity, ECG abnormalities, or severe asthma, the nurse navigator should be able to evaluate possible safety concerns prior to the scan. The concern for safety also extends to the use of medications to lower heart rate, with beta-blocker, ivabradine, calcium channel blocker, and to use of nitroglycerin to dilate the coronary arteries.

The nurse navigator will coordinate and communicate any necessary information with other members of the team, including ordering and interpreting physicians, schedulers, CT technologists, and radiology nurses to ensure that the right scan is performed with the right timing, at the right location, and with the right CT scanner.

Scan Quality

- Ensure effective patient preparation based on clinical considerations and scan requests
- Clarify imaging request from ordering provider
  - Review complex cases with reader to determine scan protocols
  - Communicate scan protocols and requests with CT technologists and RNs to ensure correct scan

To ensure high-quality scans, it is necessary to prepare the patient through education and application of the clinical protocols. Preparation needs to be adapted to the unique considerations for each patient.

If necessary, the nurse navigator will clarify the imaging request with the ordering provider. For example, if the patient has a previous history of anaphylaxis to IV contrast, then a coronary CTA is contraindicated, and the physician should consider ordering a different cardiac test. Or if a patient has complex issues, like severe obesity, a coronary stent, or renal insufficiency—it may be necessary to review the imaging protocol with the reading physician.

Then, these protocols should be communicated with the CT technologist and radiology nurse to ensure that necessary measures are taken to ensure scan quality. For example, a patient with renal insufficiency, may need to have his GFR reassessed, and should be well-hydrated. Depending on his GFR, he may need to arrive early for IV fluids. We might also need an iso-osmolar or low osmolar contrast agent. The radiologist or interpreting cardiologist may want the CT technologistss to call before putting the patient on the scanner so they can communicate directly regarding special instructions for the technical portion of the CT scan, such as amount of contrast,

radiation dose, and timing of images. These concerns must be communicated and the Radiology nurse, or nurse navigator will likely manage this process.

Operational Efficiencies

- Patient-specific details of the scan are arranged before arrival to reduce delays in care:
  - Medications
  - Scan protocols
- Maximize scan appointments – minimize cancellations
  - This equals more patients to be scanned per day and increased productivity
- Nurse navigator review of appropriateness helps ensure patients can receive diagnostic imaging

All details of the scan should be arranged before the patient arrives in the imaging suite. With proper preparation, there will be fewer delays in the imaging process, and the CT or imaging department can be more productive.

If a scan is cancelled at the last minute, it is difficult to fill the time slot due to insurance authorization requirements, travel time, and need for patient preparation.

The review for appropriateness helps to ensure that patients who arrive at the imaging suite can proceed with the test that was ordered.

Patient Case Studies Quiz

Quiz

So now let’s move into some patient case studies to quiz your knowledge.

Case Study 1: Renal Compromised

Scenario:

- 75-year-old female patient with chronic kidney disease (Stage III) and SOB on exertion
- GFR 42 (labs drawn 2/5/25)
- BMI 21
- Respiratory function within normal limits
- No IV contrast dye allergy
- HR 75, BP 120/74

In this first case study quiz question, your patient is a 75-year-old female. She has stage III chronic kidney disease with an estimated GFR of 42 and consistent shortness of breath on exertion. The GFR was obtained recently. The patient is 5 feet, 4 inches and weighs 122 pounds, so has a normal body mass index of 21. There is no known allergy to IV contrast dye, and no history of pulmonary disease. The most recent resting heart rate was 75 and blood pressure was 120/74.

What are your appropriate nursing interventions?

Question #1 – Choose the Best Answer

1. What are appropriate nursing interventions in this scenario as the radiologic nurse?
    A. Perform a patient chart review
    B. Contact the ordering provider to discuss patient's renal status, and recheck of GFR and creatinine prior to, and following the scan
    C. Contact the cardiac Reading physician to discuss institutional policies for scanning patients with low GFR
    D. Request orders to repeat the GFR/Creatinine prior to the scan
    E. Provide scheduling and patient instructions to the schedulers
    F. Call the patient regarding pre-scan instructions
    G. All of the above

Question #2 – Choose the 4 Best Answers

2. In this patient with a GFR of 42 ml/min/1.73 m^2, which of the following nursing interventions is most appropriate to reduce the risk of kidney injury with CCTA?

   A. Arrange for the patient to receive IV normal saline by bolus and infusion starting 1 hour prior to the scan and continuing for 8 hours post-scan.

   B. Instruct the patient regarding the importance of being well hydrated prior to the scan to protect the kidneys from further damage.

   C. Discuss with the patient the implications of impaired renal function post-CCTA

   D. Discuss with the patient the possibility the scan may need to be cancelled if GFR is below permitted range

   E. Instruct the patient to not take any NSAIDS for 48 hours prior to the scan

   F. Arrange for dialysis and repeat GFR for the day after the scan.

   G. Instruct the patient to hold metformin for 48 hours prior to the scan.

Answer #2

- Correct Answer: **B, C, D, E. Instruct the patient regarding the importance of being well hydrated prior to the scan to protect the kidneys from further damage and to avoid taking NSAIDs for 48 hours prior to the scan. Discuss with the patient the possibility the scan may need to be cancelled if GFR is below permitted range and the possible implications of impaired renal function post-CCTA.**
- Explanation. The patient has chronic kidney insufficiency, stage 3. The intervention most likely to decrease the patient's risk of developing contrast induced nephropathy is adequate oral hydration prior to the scan.
- **A** is incorrect because her GFR is above 30, and thus does not require IV fluids.
- **F** is incorrect because short-term dialysis is not known to improve the outcome of patients with renal insufficiency following administration of IV contrast. And obtaining a repeat GFR after the scan has no direct effect on decreasing the risk of injury during CCTA.
- **G** may be an appropriate action, however oral prehydration has a stronger impact on decreasing risk for contrast-induced nephropathy (CIN) than holding metformin. If the patient does develop CIN while on metformin, she is at risk for developing lactic acidosis.

Case Study 2: BMI = 45

Scenario:

- 65-year-old male patient
- 5’10” tall, 317 lbs, BMI of 45
- Previous inconclusive nuclear stress test and still experiencing Chest Pain
- Renal and respiratory function within normal limits
- No contrast allergies
- HR 85, BP 160/90

In our next case study quiz your patient is a 65-year-old male who is 5 feet, 10 inches tall, and weighs 317 pounds. His BMI is 45. His cardiologist ordered the Coronary CTA scan because he had a previous inconclusive nuclear stress test and is still experiencing occasional chest pain. His kidney function is normal. He has no respiratory disease, and no known allergy to IV contrast. His most recent resting heart rate was 85 beats per minute, and his blood pressure was 160/90. What are your concerns for obtaining a high-quality scan for this patient?

Question #3 – Choose the 3 Best Answers

3. What are your concerns for obtaining a high-quality scan for this patient?
    A. IV access can be difficult in obese patients
    B. A high heart rate can decrease image quality and pre-medications will be required
    C. Kidney function due to the use of contrast
    D. Choosing a CT scanner that may be better suited for an obese patient

Answer #3

- **Correct Answer:** A, B, D. You are concerned with ensuring the CT scanner selected can not only hold the patient on the table but also perform the best scan. Some CT scanners may be better than others, so you may consider send the patient to a different scanner due to his size. IV access can be difficult in obese patients, and this patient would need a large dose of contrast and a large bore IV. The patient also has a high heart rate therefore pre-medications, like metoprolol will be required. The patient's renal function is normal; therefore, you are not concerned about the use of contrast.

Question #4 – Choose the One Best Answer

4. For this patient with severe obesity, you discuss hydration during the pre-scan prep phone call. Why is oral hydration particularly important prior to the scan for him specifically?

   A. To protect the kidneys.

   B. Increased water volume promotes visualization of the coronary arteries.

   C. To promote easier large bore IV access.

   D. It improves viscosity of the IV contrast, thus facilitating the IV contrast injection.

   E. Administration of IV fluids would likely be difficult.

Answer #4

- Correct Answer: **C. To promote easier large bore IV access.**
- Explanation: Patients with obesity require larger volumes of IV contrast due to their larger body size and because of the layers of adipose tissue that must be traversed by the X-ray beams. To accommodate the larger amount of contrast, they will require a relatively larger gauge IV. IV access is often difficult in obese patients. Satisfactory hydration results in fuller veins, thus making it easier to obtain IV access.
- **A** is incorrect. Oral hydration protects the kidneys but in an obese patient with normal kidney function, this is not the most important reason to encourage hydration prior to the scan.
- **B** is not the best answer. Although increased volume may promote visualization of the coronary arteries when IV contrast is administered, the more important concern in obese patients is adequate IV access.
- **D** is incorrect. Warming the IV contrast improves its viscosity. Oral hydration doesn't affect contrast administration.
- **E** is incorrect because although administering IV fluids is difficult in obese patients, obtaining adequate IV access is the main challenge.

Question #5 – Choose the One Best Answer

5. What pre-medications will likely be given to this patient with a high BMI and high heart rate prior to the scan?
    A. The pre-medications will likely be determined based on the facility's protocol
    B. The pre-medications will likely include 100 mg of oral metoprolol 1 hour prior to the scan, provided at the facility
    C. The provider may also prescribe oral metoprolol to be taken at home the evening before the scan
    D. The patient may also receive 15 mg of Ivabradine 1 hour prior to the scan if their heartrate is still high (i.e. >80 bpm)
    E. All of the above

Answer #5

- Correct Answer: **E. All of the above.**
- Explanation: Patients with obesity and a higher heartrate of 85 and no concerning medical history or contraindications to metoprolol tartrate will likely be given a higher dose of metoprolol prior to the scan. The physician's protocol may also include metoprolol to be taken the day before, and ivabradine may also be administered in case the heart rate is still high.

Question #6 – Choose the 2 Best Answers

6. Nitroglycerin is typically provided during CCTA to improve image quality. What is the preferred dosage and timing for administration?
   - A. 5 minutes prior to scan
   - B. 0.4 - 0.8 mcg sublingual or spray, with 0.8mcg preferred
   - C. 1 minute prior to scan
   - D. 0.2 mcg nitro paste
   - E. None of the above

Answer #6

- Correct Answer: **A and B**
- Explanation: Based on expert consensus guidelines Nitrogylcerin is typically provided 5 minutes prior to the CCTA scan to improve image quality in the dosage of 0.4 - 0.8 mcg sublingual or spray, with 0.8mcg preferred.

Case Study: Heart Failure

Scenario

- 60-year-old female patient
- History of heart failure
- 5’6”, 248 lbs, BMI 40
- HR 70, BP 100/75
- No history of renal compromise or contrast dye allergy

In case number 3, your patient is a female with heart failure. She is 60 years of age, and is 5 feet, 6 inches, and weighs 248 pounds with a calculated body mass index of 40. Her last resting heart rate was 70 beats per minute, and blood pressure was 100/75. She has no history of renal issues or contrast dye allergy. She has been having consistent chest pain over the last 6 months and is unable to do an exercise stress test. Her cardiologist ordered the Coronary CTA. During your chart review, you identify some questions to ask the patient about her heart failure symptoms prior to the scan. What are your concerns that you want to investigate with the patient?

Question #7 – Choose the 3 Best Answers

7. During your chart review, you identify some questions to ask the patient about her heart failure symptoms prior to the scan. What are your concerns that you want to investigate with the patient?

   A. Ask her if she's been evaluated for valve disease

   B. Assess the patient's ability to lay flat for 15 minutes and hold her breath for 10 to 20 seconds while laying flat.

   C. Tell the patient she will require IV Lidocaine prior to and during the CCTA scan and ask her if she has an allergy to it.

   D. Confirm the medications and dosages she is on currently

   E. Assess the patient's respiratory status and if there are current exacerbations of symptoms

Answer #7

- Correct Answers: **B, D, and E.** Patients with heart failure often have difficulty with dyspnea and orthopnea, so they may not be able to hold their breath for 10-20 seconds while laying down flat. The CCTA test is very sensitive to motion artifact, and the patient's ability to hold their breath while laying on the table is vital for obtaining high quality images. You also want to confirm the medications she is taking so you can ensure appropriate pre-medications and dosages are given to regulate HR, but don't also drop the blood pressure too low.

Question #8 – Choose the One Best Answer

8. This patient shows up at the scan and tells you they are on a beta-blocker (i.e. carvedilol/Coreg or Toprol XL). You call the interpreting physician and ordering cardiologist and discuss these topics:
   A. With her blood pressure already being low and having heart failure, should the scan take place.
   B. The need for additional heart rate control to lower it less than her current rate of 70
   C. Prescribing Ivabradine pre-scan to reach desired heart rate of less than 60
   D. All of the above

Answer #8

- Correct Answer: **D. All of the above…….**
- Explanation: Treatment guidelines for patients with heart failure include beta-blockers and therefore medications provided before and during the CCTA scan are important to consider. A quality CCTA scan requires a low heart rate and in this patient there is concern that lowering her heart rate may exacerbate her heart failure, therefore the appropriateness of the test should be considered.

More than likely, she is already on a beta-blocker like carvedilol, ie, Coreg, or perhaps she is on Toprol XL. Can she be given an oral dose of short-acting metoprolol? Would she be able to tolerate ivabradine, and would that be sufficient to achieve the desired heart rate? Diltiazem might also cause hypotension or might be relatively contraindicated since she is already on a beta-blocker. Those issues should be discussed with the interpreting physician. If it is decided that she could not have metoprolol or diltiazem, but could probably tolerate ivabradine, what is the likelihood that she could achieve the desired heart rate with ivabradine? If she is unlikely to achieve the desired heart rate with ivabradine, then perhaps the scan should be reconsidered.

Possible question: What questions would the nurse have about this patient's heart failure?
answer: HR management and ability to lie flat for scan
rationale; patient's HR 85 and borderline BP limit the

ability to give rate controlling meds; Heart failure diagnosis and presentation should make the nurse question ability to lie flat and comply with breath holds

Question #9 – Choose the One Best Answer

9. Let's take another patient case with a resting heart rate of 75 beats per minute, blood pressure of 130/85, and **no concerning comorbidities**, what is the most appropriate option for lowering the heart rate for CCTA?

   A. Ivabradine 7.5 to 15 mg orally 4 hours before scanning

   B. Oral metoprolol 50 to 100 mg 1 hour prior to the scan.

   C. Oral diltiazem 30 to 60 mg administered 90 minutes prior to the CCTA scan.

   D. IV Lidocaine 50 mg bolus and 2 mg/min infusion prior to the CCTA scan.

   E. IV atropine 0.5-1.0 mg administered 5 minutes prior to the scan.

Answer #9

- Correct Answer: **B. Oral metoprolol 50 to 100 mg 1 hour prior to the scan.**
- Explanation: In patients without contraindication, the first-line drug of choice to lower the heart rate prior to CCTA is metoprolol.
- **A** is not the best answer. Ivabradine is useful for lowering the heart rate prior to CCTA scan, and has the benefit of causing less effect on blood pressure compared to other heart rate-lowering medications. However, it is not the first drug of choice and would not be administered 4 hours before the scan if needed.
- **C** is not the best answer. Diltiazem is useful for lowering heart rate for CCTA in patients who cannot tolerate a beta-blocker. However, in patients with no contraindication to beta-blocker, metoprolol would be the first choice.
- **D** is incorrect because Lidocaine is not used to reduce heart rate. It is useful as an antiarrhythmic drug and may help to suppress PVCs in patients undergoing CCTA.
- **E** is incorrect. Atropine **increases** the heart rate. This patient requires heart rate reduction prior to CCTA.

Case Study 4: Patient with Dementia

Scenario

- 70-year-old male patient
- History of mild dementia
- No history of renal or respiratory dysfunction
- BMI 32
- HR 65, BP 120/80

In our last case study, the patient has dementia, reportedly mild. He is 70 years old, has normal renal and respiratory function, a body mass index of 32, a resting heart rate of 65 beats per minute and his last blood pressure was 120/80. He's been complaining of chest discomfort and the cardiology physician's assistant ordered the Coronary CTA.

Question #10 – Choose the Best Answer

10. In this patient with dementia, you call the caregiver and patient to investigate his dementia symptoms and discuss the ability of the patient to:
    A. Follow instructions before and during the scan
    B. Comply with breath holds
    C. Comply with lying flat
    D. Best time of day for compliance to scan instructions to occur
    E. All of the above

Answer #10

- Correct Answer: **E. All of the above.**
- Explanation: Patients with dementia, who are experiencing symptoms of dementia during the scan may move or not comply with instructions and quality images may not be obtained. Preparing the patient and the staff to provide the best environment possible during the scan will be important.

Question #11 - Matching

11. In this patient with dementia, it is extremely important to explain how they may feel with the medications and contrast given during the scan. Match the medication to the feeling the patient may experience.

100mg of metoprolol 1 hour prior to the scan	tired/drowsy
IV contrast	warm, full bladder feeling of needing to urinate
800 mcg sublingual Nitroglycerine tablet	taste, post scan headache

Answer #11

- Correct Answer:
- 100mg of metoprolol 1 hour prior to the scan may make the patient feel a little tired or drowsy. The IV contrast may give the patient a warm, full bladder feeling of needing to urinate. The 800-mcg sublingual Nitroglycerine tablet may not taste great and cause a post scan headache.

Question #12 – Choose the Best Answer

12. One last question to test your knowledge! In a patient with moderate-to-severe bronchospastic COPD, heart rate of 68 beats per minute and blood pressure of 104/72, which is the best medication for reducing the heart rate to 50-60 beats per minute prior to CCTA?

    A. Oral metoprolol 50 to 100 mg 1 hour prior to the scan.

    B. Ivabradine 7.5 to 15 mg orally 1 hour before scanning

    C. Oral diltiazem 30 to 60 mg administered 90 minutes prior to the CCTA scan.

    D. IV lidocaine 50 mg bolus and 2 mg/min infusion prior the the CCTA scan.

    E. IV esmolol per protocol.

Answer #12

- Correct Answer: **B. Ivabradine 7.5 to 15 mg orally 1 hour before scanning**
- Explanation: In patients who cannot tolerate a beta-blocker, both ivabradine and diltiazem are options for reducing the heart rate prior to CCTA. However, diltiazem has a negative inotropic effect and causes a modest fall in blood pressure. This patient's blood pressure is 104/72. Further reduction in blood pressure might be detrimental. The patient will also be receiving nitroglycerin, which also reduces blood pressure. In this case, ivabradine may be the better choice for reducing heart rate as it has less effect on blood pressure than diltiazem.
- **A** is contraindicated because beta-blockers can precipitate bronchospasm and should be avoided in patients with known bronchospastic disease.
- **C** is not the best answer, as ivabradine is the better choice for this patient (see explanation).
- **D** is incorrect because lidocaine is not used to reduce heart rate prior to CCTA.
- **E** is incorrect because esmolol is an IV beta-blocker and contraindicated in patients with bronchospasm.

Additional Resources

Please find additional resources here that may be helpful to you regarding this topic.

Additional General CCTA Resources

- Standardized medical terminology for cardiac computed tomography 2023 update: An Expert Consensus Document of the Society of Cardiovascular Computed Tomography
- SCCT guidelines for the performance and acquisition of coronary computed tomographic angiography: A report of the Society of Cardiovascular Computed Tomography Guidelines Committee
- SCCT 2021 Expert Consensus Document on Coronary Computed Tomographic Angiography: A Report of the Society of Cardiovascular Computed Tomography
- Use of Intravenous Iodinated Contrast Media in Patients: Consensus Statements from the American College of Radiology and the National Kidney Foundation
- Society of Cardiovascular Computed Tomography website
- 2022 use of coronary computed tomographic angiography for patients presenting with acute chest pain to the emergency department: An expert consensus document of the Society of cardiovascular computed tomography (SCCT) Endorsed by the American College of Radiology (ACR) and North American Society for cardiovascular Imaging (NASCI)

Additional Resources Specific to Chest Pain

- 2021 AHA/ACC/ASE/CHEST/SAEM/SCCT/SCMR Guideline for the Evaluation and Diagnosis of Chest Pain: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines
- 2022 use of coronary computed tomographic angiography for patients presenting with acute chest pain to the emergency department: An expert consensus document of the Society of cardiovascular computed tomography (SCCT)



We hope you enjoyed this training and we thank you for your attention!

The Heartflow Analysis technology is an AI-based medical device software for the clinical quantitative and qualitative analysis of previously acquired Computed Tomography (CT) DICOM data for patients with suspected coronary artery disease. It provides anatomic data for luminal assessment of coronary arteries, plaque identification, quantification, and characterization, as well as the calculations of $FFR_{CT,}$ a coronary physiological simulation, computed from simulated pressure, velocity and blood flow information obtained from a 3D computer model generated from static coronary CT images.

Heartflow Analysis consists of four main functions; FFR_{CT}, Planner, Roadmap, and Plaque. All four functions are cleared for clinical use in 43 countries/regions, including the United States, United Kingdom and Europe. Only FFR_{CT} and Planner functions are cleared for clinical use in Canada, and Japan. Please see Heartflow Analysis Indications for Use and Instructions for Use for more information.

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