

Chapter 2

Cardiovascular CT Imaging: Essentials for Clinical Practice

Patient Selection and Preparation

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2.1 Patient Selection and Indications for Coronary CTA

The current clinical indications for coronary CTA are in evolution and not firmly established.

Patients who are most likely to benefit from coronary CTA are as follows: (1) intermediate risk patients who have undiagnosed chest symptoms and (2) patients with equivocal results from any other noninvasive test.

Following are the published indications for coronary CTA:

1. Detection of CAD: Symptomatic–Evaluation of Intra-Cardiac Structures
Evaluation of suspected coronary anomalies.
2. Detection of CAD: Symptomatic–Acute Chest Pain
Intermediate pre-test probability of CAD with no ECG changes and serial enzymes negative.
3. Detection of CAD with Prior Test Results–Evaluation of Chest Pain Syndrome
Uninterpretable or equivocal stress test (exercise, perfusion, or stress echo).
4. Structure and Function–Morphology
Assessment of complex congenital heart disease including anomalies of the coronary, circulation, great vessels, and cardiac chambers and valves.
Evaluation of coronary arteries in patients with new-onset heart failure to assess etiology.
5. Structure and Function–Evaluation of Intra- and Extra- Cardiac Structures
Evaluation of suspected cardiac mass (tumor or thrombus).
Patients with technically limited images from echo, MRI, or TEE.
Evaluation of pericardial conditions (pericardial mass, constrictive pericarditis, or complications of cardiac surgery).
Evaluation of pulmonary vein anatomy prior to invasive radiofrequency ablation for atrial fibrillation.

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Noninvasive coronary vein mapping prior to placement of biventricular pace-maker.

Noninvasive coronary arterial mapping, including internal mammary artery prior to repeat cardiac revascularization.

6. Structure and Function–Evaluation of Aortic and Pulmonary Disease

Evaluation of suspected aortic dissection or aneurysm.

Evaluation of suspected pulmonary embolism.

Following are the contraindications for coronary CTA:

1. Pregnancy
2. Known contrast allergy
3. Inability to tolerate beta-blockade
4. Creatinine >2.0

2.2 Patient Preparation

Following patient instructions should be given when procedure is scheduled:

1. No food or drink (except clear liquids) for 3–4 h prior to exam.
2. No caffeine products for 12 h prior to exam.
3. Do drink plenty of water prior to exam.
4. No nicotine products for 4 h prior to exam.
5. Take all regular medications the day of exam, especially blood pressure medicines.
6. No Viagra or similar medications for 24 h prior to exam.
7. Diabetic patients should ask their physicians how to adjust their medication for the day of the exam.
8. Metformin (Glucophage) often will be discontinued for 48 h after the scan.

Consent/health history forms should:

1. Include past cardiac surgeries, interventions, risk factors, and current symptoms
2. Include past reactions to contrast agents; other allergic reactions; and issues relating to pregnancy, lung disease, kidney disease, diabetes, or the presence of multiple myeloma.
3. Clearly state that this exam will require an intravenous (IV) injection of contrast material and that the patient may be given cardiac medications for heart rate, rhythm, or vasodilatation as needed [1].
4. Explain any portions of the study that might be used for research and how the patient's privacy will be protected.

Patient preparation includes the following:

Patient preparation should be done by an experienced nurse or nurse practitioner. All employees should be ACLS or BLS trained.

OSHA standards require that radiation safety policy and Hepatitis B viral vaccination be made available to all employees.

2.3 IV Placement

Use short, 20-gauge IV catheters in normal or younger patients, but use an 18-gauge catheter when necessary for more rapid infusion rates (older and hypertensive patients).

Use antecubital veins if available. Alternate sites include the basilica or median veins of the forearm, the cephalic vein lying lateral (thumb side) of the arm, or the large upper cephalic vein above the antecubital space. If necessary, hand veins may be used, generally with a 20-gauge catheter.

The IV catheter tubing should have pressure rating of 300 psi.

No central lines may be used other than those specifically labeled for power injection.

Connect the IV to an extension tubing.

Secure all connections with Op-Site and tape.

2.4 Hydration Policy

The most effective renal protection from IV contrast is adequate hydration both before and after the scan. Patients with diabetes or renal insufficiency or dehydration are at extra risk for contrast-induced nephropathy (CIN) defined as a rise of >0.5 in serum creatinine [2].

Encourage all patients to drink a liter of water prior to arrival. At discharge give the patient a 500 ml bottle of water to drink and instruct them to drink approximately 1500 ml more by the time they go to bed that evening.

Following are the protocols for patients with elevated creatinine levels:

1. For creatinine level between 1.5 and 1.8: aggressive oral hydration pre- and post-administration of nonionic and low osmolar contrast [3]. Patients *may* be premedicated with four doses of Mucomyst 600 mg.
2. For creatinine level between 1.8 and 2.0: 250 cc NS IV hydration immediately post scan plus aggressive oral hydration pre- and post-administration of nonionic and low osmolar contrast. Patient *must* be premedicated with four doses of Mucomyst 600 mg.

Following are the protocols for single kidney and renal transplant patients:

- Creatinine up to 1.5: use protocol (1) above.
- Creatinine of 1.6–2.0: use protocol (2) above.

Do not scan patients with a creatinine level above 2.0.

2.5 Pre-Procedure Patient Medication

Beta-blockade: Oral or IV metoprolol has become the standard because of demonstrated safety in patients with CHF and significant COPD and because of its low cost and reliability [1].

Oral approach: 50 mg of metoprolol is given 12 h before the scan with another 50 mg at the center, or the total 100 mg can be given as a tablet at the center 1 h prior to scanning. If the heart rate is not < 65 , an additional 5 mg IV is given every 5 min to a total of 15 mg. Post-oral beta-blockade requires monitoring for 1 h post-procedure.

IV approach: After the patient is on the cardiac monitor and Blood Pressure (BP) is obtained, 5 mg of IV metoprolol is given as a test bolus with a 1–2 min pause to assess the response. A further 5–50 mg is then given as a slow push of 1 mg per 15 s, carefully monitoring the patients Heart Rate (HR). The average total required dose is 25 mg; however, older patients and smokers often require more dose. BP monitoring continues during the medication delivery, and if it is low (< 100 systolic), 30 cc of Normal Saline (NS) is given between each 5 mg of Lopressor delivered. No post-procedure monitoring is required if the patient is stable post-scanning [4].

Nitrates: Sublingual nitroglycerin (400–800 mcgs sublingual = 1–2 tablets or 1–2 sprays), should be given between 3 and 10 min of scan time unless the BP is low [5].

Lidocaine: After beta-blockade if frequent PVCs are noted, 2% Lidocaine can be administered at 5–100 mg IV over 1–2 min.

Reasons to stop Lidocaine administration include marked bradycardia, evidence of heart block, or any neurological changes such as drowsiness or disorientation.

Atropine: If after maximal beta-blockade, significant beat-to-beat variability is noted, or if the HR is < 40 , Atropine 0.5–1.0 mg can be given.

Breath-hold training :

1. Always practice breath holding and being still.
2. Have patients hold their breath in maximal inspiration.
3. Oxygen or sedation may help.

Patient observation and instruction after the scan [6]:

1. Have patients stand up slowly.
2. Help them walk to a chair and sit with continued IV hydration and observation for 15 min.
3. If oral beta-blockers were given, let them remain at the center for 1 h.
4. Utilize a teaching sheet to remind patients about post-hydration, when they may eat and when to restart their routine medications (including metformin).

2.6 Contrast Issues

1. Image quality is dependent on the signal-to-noise ratio. Optimal images require intra-arterial densities of 250–350 HU (lying well above the background tissues but not substantially overlapping with calcium deposits) [7].
2. Given injection rates of 4–6 cc/s, this is best obtained with iodine concentrations ≥ 350 mg/ml.
3. Patients with high cardiac outputs rapidly dilute out the contrast, resulting in poor image quality. Obese, anemic, hyperthyroid, anxious, and smoking patients will require injection rates of 5–6 cc/s.

4. Total contrast loads should not exceed 100 ccs.
5. Programmable and dual source power injectors that allow smooth transitions to a saline flush optimize contrast delivery [8, 9].
6. A 22-gauge IV delivers 3–4 cc/s, a 20-gauge delivers 4–5 cc/s, and an 18-gauge delivers 5–6 cc/s.
7. Obese and high-output patients will require a full 100 ccs of contrast at 5½–6 cc/s.

Accurately timing the scan to the arrival of the IV contrast in the target structures is a required skill that improves with attention and practice. Timing errors of even 5–10 s can make a substantial difference.

Three strategies are employed to best determine the vein-to-aorta travel time.

1. Fixed “best guess” of 22–25 s.
2. Automatic triggering. A region of interest is selected over the ascending aorta and is sampled every 2 s after the initiation of the contrast bolus. When the density in the aorta rises to preset value (usually 100 HU), the system will automatically tell the patient to take a deep breath and will start scanning.
3. Test bolus with a region of interest placed in the ascending aorta and sampled every 1 s. The contrast travel time can be accurately measured. This strategy offers several advantages: no false starts or delays, identification of contrast dilution problems, checking the quality of the IV, and a chance to observe and practice the patient before the real scan.

Following are the timing bolus protocols:

1. Select the level of the ascending aorta at the bifurcation or the pulmonary artery.
2. Give breath-hold instructions.
3. Inject 20 ml of contrast at 5 ml/s followed by 20 ml of normal saline at 4 ml/s.
4. After images are reconstructed, place a ROI cursor in the aorta.
5. Calculate circulation time from onset to the peak of the aortic curve. Add 8 s to peak aortic time (5 s for the built-in delay in the test injection and 3 s for the time it takes to get contrast into the distal coronary arteries).
6. If the aortic curve peak does not reach 100 HU, consider increasing the flow rate below to 5½ or 6 ml per second.

Injection protocol (for the actual scan) is as follows [10, 11]:

	Flow Rate (ml/s)	Volume (ml)
Pure contrast	5	35
Pure contrast	5	30
Blend 60/40 (contrast to saline)	4	30

Contrast reactions are as follows:

1. Moderate-to-severe itching/flushing/rash: diphenhydramine 12.5–25 mg IV and SoluMedrol 125 mg IV [12].
2. Nausea: Phenergan (promethazine) 12.5 mg IV.
3. Mild respiratory distress such as wheezing: Albuterol inhaler two puffs.
4. Signs of anaphylaxis: call a physician, start aggressive hydration, give diphenhydramine 12.5–25 mg IV, and be ready to administer epinephrine SQ 1 mg of 1:10,000.

Extravasation of contrast [13]:

Initial treatment: Elevate extremity.

Ice pack recommended three times per day and may be alternated with warm soaks.

Notify MD and document the following:

Nonionic contrast extravasation >100 ml

Skin blistering

Altered tissue perfusion

Change in sensation distal to the site of extravasation

Follow up through phone call with the patient next day.

Patient teaching includes the following:

1. Keep arm elevated above your heart for 12 h.
2. Apply ice packs for 15–30 min every 8 h for 1–3 days. Use warm soaks after the first day.
3. For pain, use Tylenol or Motrin as directed.
4. Notify MD of any blistering, redness, skin discoloration, hardness, change in sensation (loss of feeling, numbness, tingling), weakness, or an increase or decrease in temperature in the affected arm.
5. If worsens, go to ER.

2.7 Conclusion

The goal of any imaging center is to obtain the highest quality images with the least risk to and discomfort for the patient.

In general, coronary artery CTA is an elective diagnostic procedure and should be deferred if either the risk to the patient or the chance of an inferior study is increased.

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