

10-Step Guide to Performing Cardiac CT

Patient Preparation

1. - No caffeine, chocolate, or green/black tea for 4h before the scan! Make sure that patients continue to take their long-term heart rate lowering medication.
 - Heart rate control: if the initial heart rate is **>50 bpm 1 h** prior to the examination, administer a first dose of oral beta blockade using metoprolol according to the following scheme:

	Heart rate		
	50-60 bpm	>60-70 bpm	>70 bpm
BMI < 25	25 mg	50 mg	100 mg
BMI 25-30	50 mg	75 mg	100 mg
BMI > 30	50 mg	100 mg	100 mg

- If the first oral dose of medication for heart rate control does not result in a heart rate <60 bpm, the administration of a second dose of oral metoprolol according to the above table should be given and an additional wait time of 1 h before proceeding to CT is needed.

- In case of beta blocker contraindications, 2 alternatives exist:

1) First choice: Ivabradine (15 mg orally 2 h before CT scan if heart rate is >60 bpm). In certain cases short-acting esmolol i.v. on the table may be added if necessary and clinically justifiable.

2) Second choice: Calcium channel blockers (verapamil, 240 mg orally 1 h before CT scan. If the first oral dose does not result in a heart rate <60 bpm, the administration of a second dose of oral verapamil and an additional wait time of 1 h is needed).

NOTE: **Do NOT** use **slow release preparations of calcium channel blockers!**

NOTE: **Do NOT** combine oral **calcium channel blockers and i.v. beta blockers!**

- In very anxious patients oral conscious sedation might be considered (e.g., by administering an oral short-acting anxiolytic drug like midazolam)

Examination

2. - Perform non-contrast coronary artery calcium scan (CACS) using 120 kV with the mA as specified for each scanner and potentially automatically adjusted using the scanogram. The trigger delay should be adjusted to the heart rate for each scanner. Determine start and end position of coronary arteries along the Z-axis for subsequent CTA on a thin-slice reconstruction in order to reduce effective dose. Add 15 mm to the upper and lower end position of the coronaries on CACS for the definition of the Z-axis coverage of CTA.

NOTE: **NO** exclusion of patients based on high CACS!

NOTE: If more than 2x15 mm can be added to the upper and lower end positions, add the additional millimetres preferably to the upper end.

3. - Administer i.v. beta blocker on the table according to local practice (in case of initial oral administration of metoprolol or ivabradine) if heart rate is still >55 bpm (to reach the target heart rate for scanning: <60 bpm). Here, the heart rate as recorded during breath hold training (if not available on the scanner console: perform it yourself) is the one that counts.

NOTE: In certain cases short-acting i.v. beta blockers like esmolol **can** be administered even in case of contraindication for beta blockers if clinically justifiable, e.g., in case of asthma that is not severe.

4. - Administer sublingual nitroglycerin (preferably 2 capsules equal to 0.8 mg or 1.0 mg as available or spray [2 puffs, equal to 0.8 mg]) if systolic blood pressure is ≥ 100 mmHg and no further contraindications are present. If systolic blood pressure is between ≥ 90 mmHg and < 100 mmHg, use half the dose (e.g., 1 capsule, equal to 0.4 or 0.5 mg as available or 1 puff of spray, equal to 0.4 mg); in case the heart rate increases > 60 bpm, consider further administration of i.v. betablockers.

NOTE: If available, better use capsules than spray

5. - Perform contrast agent injection for CTA within 5 min after nitroglycerin administration because of the short half-life of nitroglycerin.
 - Select the start and end position for CTA based on CACS (see point 2).
 - Manually adjust mA and kV to weight/BMI of individual patients or automatically adjust mA and kV based on information from the scanogram.

NOTE: Do NOT perform an ultra-low-dose CT! We need to evaluate plaque characteristics!

- Use a contrast agent with a concentration of 350, 370, or 400 mg/ml
- Calculate the amount of pre-heated (37°C) contrast agent to be used according to the following formula:

<p>Total Volume [<i>in ml</i>] of contrast agent to be injected = (Expected scan time given by scanner [<i>in sec</i>] + 10 [<i>constant</i>]) X Flow of contrast agent [<i>in ml/sec</i>] e.g., (8 sec expected scan time + 10) x 5 ml/sec = 90 ml</p>

Use a triphasic injection protocol (if you do not have an injector capable of triphasic injection, use a biphasic protocol)

Example for triphasic injection:

1. Calculate contrast agent volume as described in the above mentioned formula
2. In the first phase administer the total volume *MINUS* 9 ml of contrast agent
3. In the second phase administer the rest of 9 ml of contrast agent mixed with 21 ml of saline (30 ml mix of 30/70%)
4. In the third phase administer 75 ml of saline injected at the same flow as the contrast agent

The flow (=injection rate) of contrast agent, the mix of contrast agent and saline, and pure saline has to be the same and has to be adjusted to the weight of the patient according to this table:

Body weight [kg]	Injection rate [ml/s]
<50	4
50-80	5
>80	6

Thus, the volume and flow of contrast agent is adapted individually.

See the following table for contrast agent amount of the first phase in a triphasic injection protocol depending on injection rate and scan time:

Table: Triphasic injection protocol

	Scan time in [sec]	Injection rate in [ml/s]		
		4	5	6
1. Phase	1	35	46	57
	2	39	51	63
	3	43	56	69
	4	47	61	75
	5	51	66	81
	6	55	71	87
	7	59	76	93
	8	63	81	99
	9	67	86	105
	10	71	91	111
2. Phase	9 ml contrast agent + 21 ml saline			
3. Phase	75 ml saline			

See the following table for contrast agent amount of the first phase in a biphasic injection protocol depending on injection rate and scan time:

Table: Biphasic injection protocol

	Scan time in [sec]	Injection rate in [ml/s]		
		4	5	6
1. Phase	1	44	55	66
	2	48	60	72
	3	52	65	78
	4	56	70	84
	5	60	75	90
	6	64	80	96
	7	68	85	102
	8	72	90	108
	9	76	95	114
	10	80	100	120
2. Phase	75 ml saline			

- Use an 18-gauge cannula for injection of contrast agent into the (preferably) right antecubital fossa. If this is not possible, use a 20-gauge cannula.
 - If available, perform **breath hold training** for **submaximum** inspiration and give breath hold instructions for the actual scan in an automated way. If not available, talk to the patient yourself (including performance of training). For the actual scan, include a **2 sec period of waiting** after the end of breath hold instructions to allow normalization of heart rate after inspiration.
- NOTE:** These 2 seconds are **NOT** part of the CTA scan duration for calculating the total amount of contrast agent to be used
- The **heart rate variability** should be below 10% of the average heart rate during breath hold training. If variability is larger, consider first further i.v.

betablockers or, if this is not sufficient, switch to multisegment reconstruction or do not use single-beat acquisitions.

- According to the site-specific scan protocol, make use of the "test bolus" or the "sure start bolus tracking" approach. Bolus tracking is preferred because of less contrast agent used. For test bolus use the same flow of contrast agent and the same volume (75 ml) and flow of the saline chaser as for the actual CTA scan. For bolus tracking, set the ROI according to local practice (e.g., in the descending aorta) and use an adequate protocol-specific HU threshold for the automatic start.

- Make use of a saline chaser of 75 ml following the contrast agent that is injected at the same rate in ml/sec as the contrast agent.

- Primarily, perform prospective scanning (up to a stable heart rate of ≤ 60 bpm).

NOTE: All scans covering more than 1 beat without complete interruption of exposure are considered retrospective. If only 1 beat is scanned or exposure is interrupted completely between beats, scans are considered prospective.

Reconstruction

In general: if you are able to perform iterative reconstruction (IR), always do both – IR and filtered back projection (FBP) reconstructions (also for the CACS!).

Use FBP to calculate Agatston scores and as a backup reconstruction for CTA and noncardiac structures which will be read by IR primarily.

6. CACS (120 kV and FBP):

- Small field of view (≤ 20 cm) reconstructions with slice thickness of 3 mm and slice increment of 3 mm. Use FBP reconstruction for calculating the Agatston Score.

- 2.5 mm slice thickness and increment are applicable in GE and Philips scanners

CTA:

- Use a small field of view (FOV ≤ 20 cm)

- Use slice thickness ≤ 0.8 mm and slice increment ≤ 0.5 mm

- Reconstruct the phases of the RR interval defined by the motion map approach ("auto best systole and diastole") and perform further reconstructions within the acquisition window in 5% intervals; if necessary, reconstructions can also be made in 1% intervals

7. For noncardiac structures:

- Reconstruct large FOVs (> 20 cm!) to encompass as much as possible of the chest) with a slice thickness of 1 mm and a slice increment of 1 mm

a) For evaluation of the lungs and bone using lung kernel reconstructions from the CACS raw data (e.g., nodules and masses).

b) For vessel and soft tissue evaluation using body kernel reconstructions from the CTA raw data (e.g., aortic dissection, pulmonary embolism)

Reading

8. - Use a workstation that can automatically generate curved MPRs

- For interpretation use: a) axial, coronal, sagittal source images, b) curved MPRs, c) axial, coronal, and sagittal as well as double-oblique thin-slice MIPs

- Note: a non-diagnostic segment (any kind of artifact that may hide an at least 50% stenosis) which is amenable to revascularisation (≥ 2 mm reference vessel

diameter) has to be considered to be positive for the management according to the "CT-based Management of Patients within DISCHARGE" flow chart. For instance a left main or proximal LAD artifact that may hide an at least 50% stenosis is considered high-risk coronary artery disease whereas a relevant artifact in the RCA and LCX is equal to 2-vessel disease for management. Therefore, image quality is so important in order to avoid artifacts to happen frequently.

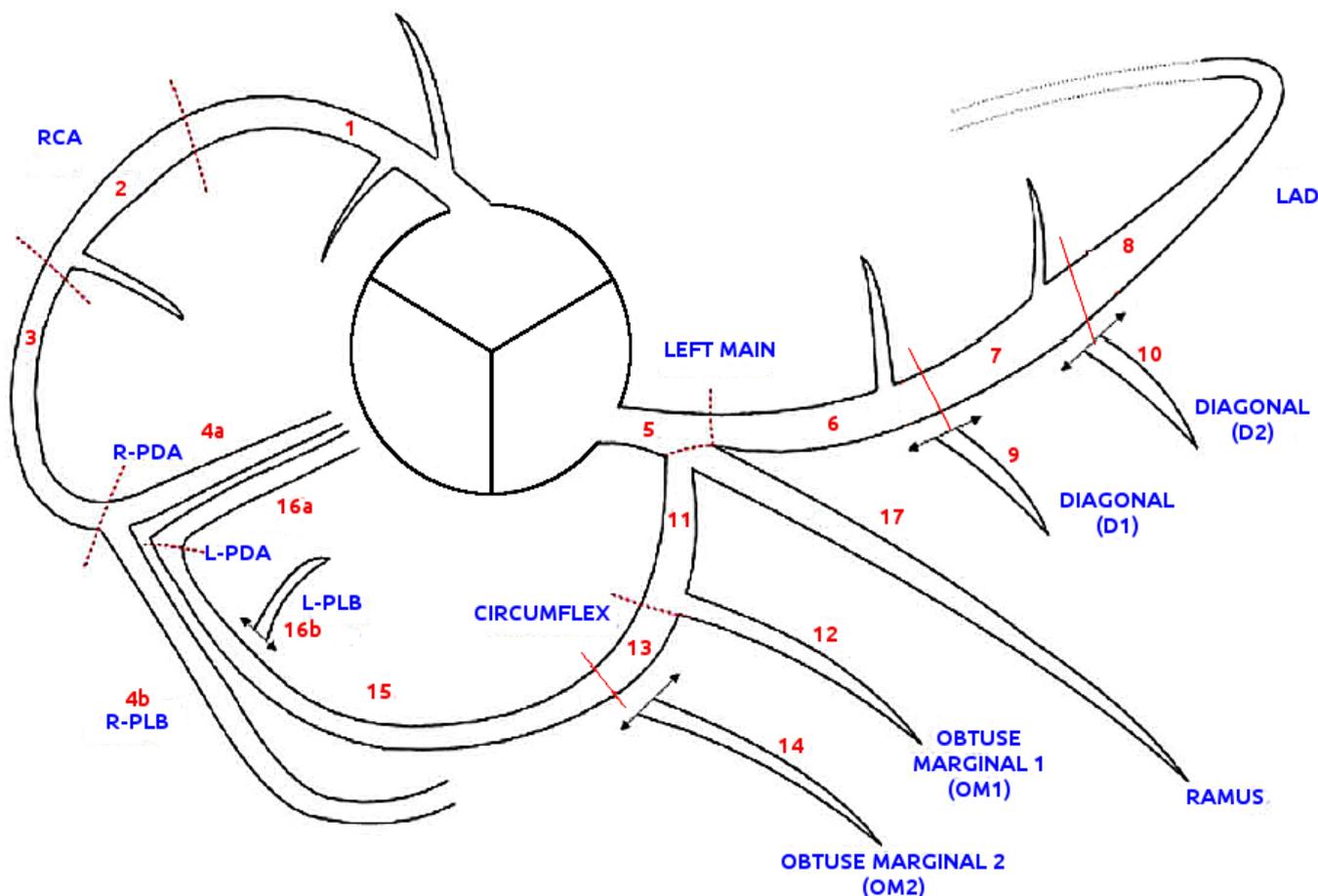
- Manually measure and report each diameter stenosis that is visually >20%.

Reporting

9. - Only vessels with a diameter of ≥ 1.5 mm need to be considered
- We suggest a "modified SCCT Coronary Segmentation Model with 19 segments based on the AHA 17-segment model" (two PDAs can be assigned [from left and right] while the original classification for the LAD is obtained [the first (segment 9) and second (segment 10) diagonal branches divide the LAD into the segments 6, 7, and 8]):

AXIAL CORONARY ANATOMY

(See attached legend)



L = Left, R = Right
 LAD = Left Anterior Descending
 RCA = Right Coronary Artery
 PDA = Posterior Descending Artery
 PLB = Posterolateral Branch
 Ramus = Intermediate Branch

extracted and modified from:
 Raff GL et al. J Cardiovasc Comput Tomogr.
 2009 Mar-Apr;3(2):122-36

Image Storage

10. - Store all images (PACS or dedicated server)
- Send pseudonymized images using FBP and IR of all phases that were used for CACS and CTA reading as well as all images used for noncardiac structure reading to the Charité corelab via AGMEDNET