Expert Consensus on Coronary CT Angiography Scanning and Report Writing (Postprint)

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Abstract

Coronary CT angiography (coronary computed tomography angiography, CCTA) has become one of the safe and reliable preferred techniques for clinical screening of coronary artery disease. With technological development, a large number of post-64-slice high-end CT equipment have been installed in recent years; however, numerous unreasonable and non-standardized phenomena still exist regarding scanning indications, scanning protocols, and contrast agent usage, and the level of standardized and normalized application of CCTA scanning and report writing needs to be improved. The purpose of formulating this consensus is to establish guiding principles for scanning indications, standardized scanning protocols, and imaging reports that can be commonly followed, in order to promote standardized application nationwide.

Full Text

Expert Consensus on Coronary CT Angiography Scanning and Reporting

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Abstract

Computed tomography coronary angiography (CCTA) has become one of the safe and reliable first-line techniques for clinical screening of coronary artery disease. With technological development, a large number of high-end CT scanners

have been installed clinically in recent years. However, numerous unreasonable and non-standardized practices persist regarding scanning indications, scanning protocols, and contrast agent usage. The standardization of CCTA scanning and reporting urgently needs improvement. This consensus aims to establish common guidelines for standardized indications, scanning protocols, and imaging reports to promote standardized application nationwide.

Keywords: coronary artery; computed tomography angiography; indication; iodinated contrast agent; coronary artery disease-reporting and data system

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1. Indications and Contraindications

1.1 Indications Based on extensive clinical experience and evidence-based medical research, international professional associations including the American College of Cardiology Foundation (ACCF), the Society of Cardiovascular Computed Tomography (SCCT), and the American College of Radiology (ACR) have published multiple consensus statements on CCTA indications, imaging capabilities, and training recommendations [4-10]. Domestic experts have also accumulated substantial experience. Professor Lü Bin from Fuwai Hospital led the publication of the "Expert Consensus on Clinical Application of Cardiac Coronary Multi-detector CT" which proposed indications suitable for China' s national conditions [11]. Building upon this foundation and incorporating recent clinical practice experience, this consensus proposes the following indications:

1.1.1 Coronary Atherosclerotic Heart Disease (Coronary Heart Disease)

Coronary heart disease is defined as atherosclerotic lesions causing 50% luminal stenosis in at least one coronary artery. CCTA is primarily applicable for: 1. Initial screening of coronary artery plaques and stenosis in high-risk populations, and observation of cardiac and vascular anatomical structures 2. Patients with atypical chest pain or breathlessness symptoms, especially elderly patients who cannot undergo or refuse exercise stress ECG testing 3. Patients with chest pain symptoms where exercise stress ECG or nuclear myocardial perfusion results are equivocal or uncertain 4. Screening for coronary heart disease in asymptomatic individuals with multiple coronary risk factors 5. Patients who cannot undergo or refuse invasive coronary angiography 6. Follow-up observation of lesion progression and evolution in patients with known coronary heart disease or atherosclerotic plaques after clinical intervention

1.1.2 Follow-up Evaluation after Angioplasty and Stenting

CCTA is mainly applicable for: 1. Evaluating in-stent restenosis and guiding treatment plans for restenosis patients 2. Assessing stent patency, including stent size selection, feasibility of guidewire passage and balloon dilation 3. Evaluating plaque characteristics in totally occluded lesions, including location and extent of lesions, which provides important basis for guiding intervention

1.1.3 Coronary Artery Bypass Graft Evaluation

Compared with conventional coronary angiography, CCTA is relatively non-invasive and has high negative predictive value. It is mainly applicable for: 1. Preoperative evaluation of internal mammary artery anatomy and ascending aortic wall atherosclerosis, calcification, and wall thickening to determine whether the ascending aorta can be used for grafting 2. Postoperative evaluation of graft patency in symptomatic patients, including whether the graft is open and the cause of recurrent angina symptoms, including native coronary artery lesions

1.1.4 Preoperative Coronary Assessment for Non-Coronary Heart Surgery

CCTA is simple to operate and safe, and can exclude significant coronary artery disease before non-coronary cardiac surgery. It is mainly applicable for: 1. Elderly patients undergoing atrial septal defect closure or mitral valve balloon valvuloplasty who cannot undergo exercise stress ECG testing. In addition to clarifying coronary artery lesions, it can also observe atrial septal morphology, size, location, and whether there is concomitant left atrial thrombus 2. Patients with hypertrophic cardiomyopathy or dilated cardiomyopathy to clarify whether coronary artery disease is the cause

1.1.5 Adult Congenital Heart Disease

For coronary artery anomalies, CCTA can accurately present the anomaly location, type, and relationship with surrounding tissues, which is of great significance for preoperative guidance. It can also comprehensively display pathological changes and has advantages in diagnosing cardiac and vascular anatomical structural abnormalities and valvular lesions.

1.1.6 Preoperative Assessment for Electrophysiological Radiofrequency Ablation

Before atrial fibrillation radiofrequency ablation, CCTA can clarify pulmonary vein anatomy and relationship with surrounding tissues. Before dual-chamber pacemaker implantation, it can delineate cardiac coronary sinus anatomy.

1.2 Contraindications CCTA examination is contraindicated or inappropriate for patients with: 1. Uncured hyperthyroidism 2. Pregnancy or suspected pregnancy 3. History of severe contrast agent allergic reaction 4. Renal insufficiency (serum creatinine concentration >2.0 mg/dl [177 mol/L]) 5. Decompensated heart failure 6. Clinical instability or inability to cooperate with scanning and breath-hold commands (>5 s)

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2. Examination Operation Protocol

2.1 Requirements for Examination Operators Coronary artery examination requires collaboration among multiple medical personnel including tech-

nicians, nurses, and diagnostic physicians. Effective coordination among operators is essential for ensuring smooth and complete examination execution. The required qualifications and skills for each position are summarized as follows:

2.1.1 Main Scanning Operator (Technician)

The main operator must not only possess radiology technician qualifications and certification for large medical equipment, but also: - Master cardiovascular-related basic and clinical knowledge - Be proficient in the complete CCTA examination workflow, including indications and contraindications, related precautions, contrast agent usage protocols, and specific scanning operation methods - Be skilled in guiding patients through proper pre-examination breath-hold training - Understand optimal scanning program and parameter selection settings - Be knowledgeable about cardiovascular anatomy, pathophysiology basics, image post-processing techniques, and image quality assessment methods - Have diagnostic capability for related diseases to help determine whether images meet diagnostic quality requirements

2.1.2 Nurse

Nurses must have nursing practice qualifications and be proficient in: - Venipuncture skills and enhanced examination-related high-pressure injector usage methods - Observation of patient conditions during contrast agent injection and management of adverse reactions - For anxious patients, appropriate sedatives may be administered as over-excitement, anxiety, and pain can increase the risk of adverse reactions or worsen contrast agent-related reactions

2.1.3 Technician and Diagnostic Physician

Physicians involved in CCTA examination require strict standardized training. They should: - Pass cardiovascular imaging certification or American College of Radiology medical specialty testing - Possess certain diagnostic capabilities for cardiac and vascular anatomical structures and valvular lesions - Have appropriate understanding of cardiovascular-related anatomical and pathophysiological knowledge to help ensure successful examination completion - Confirm examination completion and absence of significant abnormalities

2.2 Scanning Equipment Requirements Due to the heart' s unique characteristic of continuous beating, achieving high-quality coronary artery imaging requires high temporal resolution. The ability of the dual-barrel high-pressure injector to reach injection speeds of 4-7 ml/s is an important criterion for evaluating equipment suitability. Currently recommended equipment should have: - Tube rotation time reaching or below 350 ms - Submillimeter spatial resolution - Corresponding post-processing software - Automatic tube voltage and current modulation functions

2.3 Pre-examination Patient Requirements and Preparation Patients require rigorous clinical evaluation and contraindication screening to ensure con-

trollable examination risks. The process includes: 1. Instructing patients and families to sign informed consent forms after detailed explanation of potential examination risks 2. Having patients or families complete examination questionnaires, including basic information such as height and weight to help determine contrast agent usage protocols, and preliminary assessment of cardiac function and heart rate 3. For patients with faster heart rates, recommending pre-administration of heart rate-lowering medication 4. For patients with poor breath-hold capability, abdominal binders may be added 5. For patients with heart disease, sublingual nitroglycerin spray may be administered to achieve coronary vasodilation

2.4 Scanning Process 2.4.1 Pre-scan Preparation

The technician first guides the patient to lie supine in the correct position, connects ECG monitoring, and conducts strict breath-hold training rather than simple instruction. During breath-hold, ECG and heart rate should be monitored. When ECG recognition is poor, timely adjustments should be made, including: - Adjusting electrode position - Improving electrode-skin contact (e.g., moistening skin) - Changing leads

2.4.2 Localization Image and Scan Range

Localization images are acquired from the thoracic inlet to the cardiac diaphragmatic surface. Scanning conditions for localization images (anteroposterior or lateral views) are embedded in equipment defaults and generally require no modification.

2.4.3 Coronary Artery Calcium Scoring Scan

Calcium scoring scan is performed before CCTA. The upper boundary is 1-2 cm below the carina, and the lower boundary reaches the cardiac diaphragmatic surface, with left and right margins exceeding the cardiac border by 1-2 cm. Scan parameter settings are related to calcium score calculation results. Default parameters recommended by manufacturers are recommended for coronary artery calcium scoring.

2.4.4 Scan Mode Selection

Scan modes mainly include prospective and retrospective ECG gating. Three scanning methods are available: 1. **Prospective high-pitch spiral scanning**: Lowest radiation dose (<1 mSv) 2. **Prospective step-and-shoot axial scanning**: Moderate radiation dose (1-3 mSv) 3. **Retrospective ECG-gated spiral scanning**: Highest radiation dose (>3 mSv)

For patients with stable heart rate <70 bpm and regular rhythm, prospective ECG-gated scanning is recommended, especially prospective high-pitch spiral scanning. For heart rate 70-90 bpm with rhythm variation <5 bpm, prospective ECG-gated acquisition is recommended with ECG pulsing window set at 30%-70% R-R interval. For heart rate >90 bpm with regular rhythm, prospective

ECG-gated acquisition is recommended with ECG pulsing window set at 30%-45% R-R interval. For patients with irregular rhythm, prospective step-and-shoot axial scanning may be attempted with ECG pulsing window set at 30%-45% R-R interval or 250-400 ms absolute phase.

For post-stenting and post-bypass patients, coronary artery calcium scoring is not recommended due to interference from metallic implants.

** Different CCTA Scan Mode Selections**

Scan Mode	Heart Rate (bpm)	ECG Pulsing Window
Prospective high-pitch spiral	<70	70% R-R
Prospective step-and-shoot axial	70-90	30%-70% R-R
Retrospective ECG-gated spiral	>90 (regular)	30%-45% R-R
	Irregular rhythm	30%-45% R-R or 250-400 ms

2.4.5 Scan Parameter Setting

Scanning voltage and current parameters can be determined based on patient body habitus, heart rate, and operator experience. Personalized parameter settings are recommended according to specific conditions and clinical requirements. With iterative reconstruction and low kVp techniques, low-volume contrast agent application becomes possible.

2.4.6 Post-examination Considerations

After examination completion, technicians should: - Help patients remove electrodes and related equipment - Guide them out of the examination room - Advise adequate water intake to promote contrast agent excretion - Inform patients to continue withholding metformin for 48 hours, especially those with multiple myeloma, hyperuricemia, and newly diagnosed diabetic patients - Advise patients to check serum creatinine levels after 48 hours and only restart metformin if renal function is unchanged from pre-contrast baseline, under physician guidance

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3. Contrast Agent Injection Protocol

3.1 Preparation Before Iodinated Contrast Agent Use 3.1.1 Patient Informed Consent

Physicians or nurses must inform patients or guardians about: - Contrast agent usage indications - Possible adverse reactions - Emergency management methods for adverse reactions and allergies - Availability of emergency equipment and medications

Patients should be instructed to sign the iodinated contrast agent usage informed consent form.

3.1.2 Contraindications

Inquire about: - Hyperthyroidism (contraindicated if not cured) - History of moderate to severe allergic reactions to iodinated contrast agents - Renal disease, renal surgery, or use of nephrotoxic drugs affecting glomerular filtration rate - Hypertension, gout history, or other drug adverse reactions/allergies - Congestive heart failure

3.1.3 Contrast Agent Warming

Heating iodinated contrast agents to 37°C before use can improve patient tolerance. Studies show heating reduces contrast agent viscosity, making injection easier.

3.1.4 Allergy Testing

Small-dose contrast agent allergy testing is not recommended as it has no predictive value. The test itself may occasionally cause severe or even fatal allergic reactions.

3.2 Injection Protocol Currently, there is no unified expert consensus on contrast agent injection protocols. The coronary artery enhancement depends on the injection protocol and patient body weight. A coronary CT value of 325 HU or higher is required for clinical diagnosis [22].

3.2.1 Contrast Agent Concentration and Injection Rate

The iodine delivery rate (IDR) is the amount of iodine injected per unit time (gI/s), calculated as: IDR (gI/s) = iodine concentration (gI/ml) × injection rate (ml/s). Injection rate has greater impact on IDR than contrast agent concentration. The recommended IDR is 1.4 gI/s, with 1.8-2.2 gI/s being optimal. Low-concentration and high-concentration contrast agents can achieve equivalent coronary enhancement at the same IDR.

For patients weighing 60-80 kg, either: - 0.3 gI/ml concentration at 4-6 ml/s injection rate, or - 0.37 gI/ml concentration at 3.2-4.8 ml/s injection rate

High injection rates may increase the probability of extravasation, therefore injection rate should not exceed 5 ml/s.

** Contrast Agent Dosage for Different Body Weights at Same IDR**

Patient Weight	0.3 gI/ml, 4 ml/s Dose	0.37 gI/ml, 3.2 ml/s Dose
60-80 kg	As listed	As listed

Note: Values are recommended injection rates using 120 kVp. If using iterative reconstruction and lower kVp (e.g., 100 kVp), injection rate can be reduced.

3.2.2 Contrast Agent Dosage

Total iodine load (TIL) (gI) = IDR (gI/s) × injection time (s). The injection time is determined by acquisition parameters including acquisition mode, detector width, and cardiac scan range. Technicians should accurately assess patient weight to determine rational contrast agent dosage.

** Low-Contrast Individualized Injection Protocol**

Note: This protocol uses 0.37 gI/ml contrast concentration with automatic tube voltage modulation.

3.2.3 Delayed Phase Scanning

For intracardiac masses (e.g., cardiac tumors or thrombus), delayed phase scanning can be performed after arterial phase imaging with a delay time of 1-2 minutes to observe lesion blood supply and help differentiate mass nature. Ensure the scan range completely covers the mass.

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4. Reporting Standards

The Society of Cardiovascular Computed Tomography (SCCT), American College of Radiology (ACR), and North American Society for Cardiovascular Imaging have published the Coronary Artery Disease-Reporting and Data System (CAD-RADS) [25]. Based on China' s actual conditions, this consensus proposes the following standardized reporting requirements:

4.1 Main Content of Report

1. Assess image quality and scanning technique
2. Describe coronary artery anatomical variations
3. Describe coronary artery dominance pattern
4. Describe coronary artery dilation or aneurysm size
5. Calculate number of calcified plaques and calcium score
6. Describe distribution of lesions 2 mm diameter by coronary segment, including:
   - Plaque composition (calcified, non-calcified, mixed)
   - Luminal stenosis severity
   - Lesion extent: localized (<1 cm), segmental (1-3 cm), or diffuse (>3 cm)
7. Calculate and describe cardiac function data when required
8. Describe intracardiac lesions (cardiac structure, cardiac tumors, thrombus)
9. Describe pericardial and myocardial conditions
10. Describe extracardiac lesions

4.2 Coronary Artery Segmentation The 18-segment coronary artery segmentation system is recommended: - Segments 1-3: Right coronary artery (proximal, middle, distal) - Segments 4-6: Left main, left anterior descending (proxi-

mal, middle, distal) - Segments 7-9: Diagonal branches - Segments 10-14: Left circumflex (proximal, distal, obtuse marginal branches) - Segments 15-18: Posterior descending and posterolateral branches

4.3 Coronary Atherosclerotic Plaque Assessment Plaques can be classified by CT value: - Non-calcified plaque: <50 HU - Mixed plaque: 50-120 HU - Calcified plaque: >120 HU

Plaque assessment should also evaluate vulnerable plaque features: - Positive remodeling - Spotty calcification - Low-attenuation plaque - Napkin-ring sign

4.4 Coronary Stenosis Assessment Grading System The CAD-RADS classification is recommended, which depends on stenosis severity:

** International Cardiovascular CT Association Luminal Stenosis Grading Scale**

Stenosis Severity	CAD-RADS Category
1-24%	1 (Minimal non-obstructive)
25-49%	2 (Mild non-obstructive)
50-69%	3 (Moderate obstructive)
70-99%	4 (Severe obstructive)
100%	5 (Total occlusion)

** CAD-RADS Classification for Stable Chest Pain Patients**

Category	Management Recommendation
CAD-RADS 0: No plaque or stenosis	Consider non-atherosclerotic causes of chest pain
CAD-RADS 1: Minimal non-obstructive	Consider non-atherosclerotic causes; risk factor modification
CAD-RADS 2: Mild non-obstructive	Risk factor modification; preventive therapy
CAD-RADS 3: Moderate obstructive	Consider functional assessment; symptom-guided anti-ischemic therapy
CAD-RADS 4: Severe obstructive	Consider coronary angiography; functional assessment
CAD-RADS 5: Total occlusion	Recommend coronary angiography; consider myocardial viability assessment

5. Summary

According to national surveys and industry data, the number of CT devices in China exceeds 10,000 units, accounting for a significant proportion of the global market and growing at more than 10% annually. However, a considerable proportion of high-end equipment remains underutilized for cardiac coronary imaging, indicating substantial potential for development in this field in China. This suggests that this consensus will have significant guiding value and broad application prospects. We hope this consensus will receive attention from more readers, and we encourage and welcome timely feedback on any issues identified to ensure timely revision.

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Note: Figure translations are in progress. See original paper for figures.