Canadian Association of Radiologists

Canadian Association of Radiologists/ Canadian Cardiovascular Society Consensus Training Standards for Cardiac CT

The standards of the Canadian Association of Radiologists (CAR) are not rules, but are guidelines that attempt to define principles of practice that should generally produce radiological care. The physician and medical physicist may modify an existing standard as determined by the individual patient and available resources. Adherence to CAR standards will not assure a successful outcome in every situation. The standards should not be deemed inclusive of all proper methods of care or exclusive of other methods of care reasonably directed to obtaining the same results. The standards are not intended to establish a legal standard of care or conduct, and deviation from a standard does not, in and of itself, indicate or imply that such medical practice is below an acceptable level of care. The ultimate judgment regarding the propriety of any specific procedure or course of conduct must be made by the physician and medical physicist in light of all circumstances presented by the individual situation.

Approved: September 2009

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Consensus Statement

Standards for training in cardiac CT have been developed as a consensus of the Canadian Association of Radiologists and Canadian Cardiovascular Society and apply to both radiologists and cardiologists with the mutual goal of optimizing patient care. The training standards pertain to the interpretation of cardiac CT and not to the interpretation of extracardiac findings. The CAR/CCS working group recognizes the need for rigorous training as acquiring expertise in CCT interpretation is a relatively slow process. (1, 2) Regular updates and revisions to these standards will continue to be developed in a collaborative manner. Competence is divided into 3 categories.

The working group is aware of other training guidelines recently published by various professional societies and has elected to use similar designation for levels of training. While the nomenclature is similar, the recommendations are different and have been carefully reviewed and agreed upon by consensus.

Level 1 Training:

Level 1 training constitutes exposure to cardiac CT that is sufficient to understand the strengths and weaknesses of the modality, indications and contraindications. This level of training is not sufficient to independently interpret cardiac CT and generally applies to exposure to cardiac CT during residency training.

Level 2 Training:

Level 2 training constitutes sufficient training for independent performance and interpretation of Cardiac CT exams. The components include acquisition of content knowledge, imaging training, and maintenance of competence.

1. Content Knowledge

The content knowledge suggested for Cardiac CT is included in Appendix A. This knowledge is to be obtained through didactic teaching, courses, or CME.

2. Imaging Training

150 total cases of ECG gated contrast-enhanced thoracic CT of which:

- 75 cases are coronary CTA studies that are directly acquired, reconstructed and interpreted by the trainee. Interpretation must be mentored by an expert cardiac CT reader with Level 3 training and a report must be generated by the trainee.
- 75 gated contrast-enhanced thoracic CT cases that may include cardiac CT or other non-cardiac thoracic CT studies. These may be directly acquired and interpreted or in the case of cardiac CT, drawn from a case library or other teaching resource. Cardiologists will interpret cardiac CT studies. Radiologists may interpret cardiac or other gated thoracic CT studies. However, if non-cardiac gated thoracic CT's are chosen, these must be directly acquired.
- 25 cases out of the total 150 cases must include a non-contrast CT for calcium scoring.

25 cases out of the total 150 cases must be coronary CTA studies with correlation to invasive angiography. These may be acquired by the trainee or read from a case library. However, for cases obtained from a library, the original CTA dataset should be reviewed (not just pre-prepared 3D reconstructions) as well as the invasive angiography. The majority of the cases obtained from the library should be abnormal.

This interpretation must be satisfactory in the judgment of the Level 3 mentor.

This training is not sufficient to independently interpret studies pertaining to congenital heart disease.

3. Maintenance of Competence

Ongoing case volume is required to ensure institutional (nurse, technologist) and physician competence in performance of cardiac CT. Therefore a minimum of 50 cases per reader per year is required to maintain competence. It is also essential that physicians will participate in accredited CME programs to maintain their knowledge in the field.

Level 3 Training:

Level 3 training constitutes expert training in cardiac CT that qualifies the trainee to run a cardiac CT program and serve as a local resource person in cardiac CT. Individuals with level 3 training will usually work in tertiary care centers or academic institutions in which there is active participation of both cardiologists and radiologists. The components include acquisition of content knowledge, imaging training, and maintenance of competence. Level 3 training is not required in order to do CTA, but physicians performing CTA with Level 2 training should have access to a Level 3 trained colleague, either in their own institution or in a tertiary referral centre. These recommendations and standards are meant to describe training and competency requirements for an institution based practice with pre-established radiation protocols in place.

4. Content Knowledge

Level 3 trained individuals should have a more detailed and in depth mastery of the content knowledge outlined in Appendix A (including knowledge of CT imaging of congenital heart disease) than those with Level 2 training:

5. Imaging Training

300 total cases of ECG gated contrast thoracic CT of which:

- 150 cases are coronary CTA studies that are directly acquired, reconstructed and interpreted by the trainee. Interpretation must be mentored by an expert cardiac CT reader with Level 3 training. This interpretation must be satisfactory in the judgment of the Level 3 mentor.
- 150 gated contrast-enhanced cardiac CT cases. These may be directly acquired and interpreted or drawn from a case library or other teaching resource.
- 50 cases out of the total 300 cases must include a non-contrast CT for calcium scoring.
- 50 cases out of the total 300 cases must be coronary CTA studies with correlation to invasive angiography. These may be acquired by the trainee or read from a case library. However, for cases obtained from a library, the original CTA dataset should be reviewed (not just pre-prepared 3D reconstructions) as well as the invasive angiography. The majority of the cases obtained from the library should be abnormal.

In general, Level 3 requirements will be fulfilled as part of a dedicated fellowship in cardiac CT alone or in combination with other modalities (eg. MRI, echocardiography, nuclear cardiology, interventional cardiology).

Level 3 competence is also accorded to currently existing practitioners of cardiac CT who were in active CT practice prior to January 2010 and who, by virtue of their clinical experience, research or teaching contributions to the field are recognized as experts in Cardiac CT.

6. Maintenance of Competence

Ongoing case volume is required to ensure institutional (nurse, technologist) and physician competence in performance of cardiac CT. Therefore a minimum of 100 cases per reader per year is required to maintain competence. It is also essential that physicians will participate in accredited CME programs to maintain their knowledge in the field.

Reporting Standards

The working group endorses the recently published guidelines for the interpretation of coronary computed tomography by the Society of Cardiovascular CT (3).

References

1. Pugliese, F, Hunink M, Gruszczynska K, et al. Learning curve for coronary CT angiography: what constitutes sufficient training? Radiology 2009;251(2):359-368

2. Oevrehus KA, Boettcher M, Larson HM, Boetkaer HE, Noergaard BL. Impact of Procedure Volume and Operator Experience on the Diagnostic Accuracy of Computer Tomographic Coronary Angiography. J Am Coll Cardiol 2009;53(10 Suppl A):A264

3. Raff GL, Leong LH, Abidov A, Achenbach S, Berman DS, Boxt LM, Budoff MJ, Cheng V, DeFrance T, Helinger JC, Karlsberg RP. SCCT Guidelines for the Interpretation and Reporting of Coronary Computed Tomographic Angiography, Journal of Cardiovascular Computed Tomography (2009), doi: 10.1016/j.jcct.2009.01.001

Appendix A
Learning Objectives

Basic CT Physics:

1. How does CT work: Attenuation coefficient; Beer's Law; X-ray detection system
2. Data acquisition and image reconstruction: backprojection; filtering; slip-ring technology; spiral scanning (concept of helical pitch); spiral reconstruction
3. Multislice CT: compared to single slice and elctron-beam CT; importance of scan time; number of detectors; coverage; rotation pitch; slice thickness; volume scanning; 3D reconstruction; maximum intensity projection (MIP); multiplanar reformations (MPRs: sagittal, coronal, curved); surface rendering; 4D cardiac imaging

Multislice CT Imaging:

1. 2D Reconstruction: 2D filtered backprojection (FBP, limitations); 2D spiral reconstruction; conebeam reconstruction; coplanar projection; conebeam artifacts
2. 3D Backprojection and conebeam reconstruction: versus 2D; specific role in cardiac imaging
3. Cardiac reconstruction: importance of immobilizing the heart; rotation speed of CT gantry; heart rate; multi-cycle reconstruction for better temporal resolution; physical constraints (z-axis coverage (pitch and conebeam geometry), cardiac cycles (heart rate and pitch), angular phase (heart rate and gantry rotation speed) of segments); optimal temporal resolution and heart rate; temporal resolution and variable heart rates; optimal phase selection
4. Gating techniques: retrospective, prospective
5. Increasing slices per channel: effect on temporal and spatial resolutions, image acquisition time, radiation dose, slice thickness, length of breath hold

Radiation Dose in CT:

1. Dose importance in CT: tube current; scan rotation time; scan length; tube voltage; tradeoffs between image quality and ionizing radiation dose to the patient
2. Dose units and measurements: absorbed dose (average energy absorbed per unit mass, mGy); effective dose (radiation risk to patient, mSv); CT dose index (average instantaneous dose to the patient, CTDIvol); dose length product (CTDIvol adjusted for scan length, DLP); effective dose (DLP adjusted for region of the body)
3. Typical CT effective dose
4. Dose efficiency (% of x-rays used for imaging): increase with multislice and larger detector slice thickness
5. Dose reduction strategies: dose modulation, automatic current adjustment
6. Operator safety issues

CTA in Daily Practice:

1. At-home patient preparation: known/suspected contrast allergy premedication, hold phosphodiesterase inhibitors (Viagra, Levitra, Cialis, etc.), hold stimulants, maintain rate-control medication (beta-blockers, calcium channel blockers, etc.), determine cardiac rhythm and rate (rapid atrial fibrillation? premedicate as needed), determine renal function (premedicate or postpone/cancel study as needed)
2. Workflow: pre and post CT prep-room monitoring, optimization of scanner use (10 min. in scanner)
3. Onsite patient preparation: intravenous (IV) access (16-18G), oral and IV heart rate-control (if HR>60/min), monitoring for optimal heart rate and surveillance of blood pressure
4. Optimal contrast to noise: Contrast selection, contrast dose and infusion rate on dual injection for saline chase, bolus tracking, tube current and voltage; provisions for graft patients; coverage; slice thickness and increment (pitch)
5. Optimal gating: electrode positioning, ECG changes with position and breath hold, verify ECG tracking, heart rate, arrythmia
6. Review before patient leaves table: adequate coronary and left ventricle filling; LV brighter than RV and coronary arteries brighter than veins; no excessive motion
7. Reconstruction: ECG editing, selection of reconstruction phases, selection of filter (obese patients, stents)

CTA Image Interpretation at the Console:

1. Assessment of image quality; artifacts
2. Interpretation from source axial images
3. Strengths and caveats of maximum intensity projection (MIP), multiplanar reformation (MPR), and volume rendered images
4. Limitations of spatial resolution; accuracy of diameter stenosis measurement in native coronary artery disease
5. Impact of calcifications on diagnostic accuracy
6. Diagnostic accuracy in coronary stents and bypass grafts (saphenous vein and internal mammary artery)
7. Reporting standards

Normal Cardiac Anatomy and Physiology:

1. General orientation: cardiac chambers, valves, great vessels, coronary arteries in axial, sagittal, coronal views, and cardiac long-axis (left 2 chamber, 4 chamber, semi-4 chamber), short-axis views, left ventricle inflow and outflow, right ventricle inflow and outflow views
2. Specific characteristics and anatomical definitions of aortic valve, left ventricle, mitral valve, left atrium, pulmonary valve, right ventricle, tricuspid valve, right atrium
3. General orientation of epicardial coronary arteries in standard coronary angiography views: Left coronary system in LAO-Cranial, RAO-Cranial, LAO-Caudal, RAO-Caudal views; right coronary artery in LAO, AP-Cranial and RAO views

4. Specific characteristics and anatomical definitions of epicardial coronary arteries based on the BARI modification of the CASS definitions, including coronary artery origin, trajectory and dominance
5. Distribution of left ventricular blood supply/perfusion: which coronary artery supplies which left ventricular segment based on the American Heart Association standardized definitions

Congenital Anomalies of Coronary Arteries and Normal Variants:

1. Anomalous origin from a different coronary sinus
2. Anomalous origin from another coronary artery
3. Anomalous origin from a great vessel
4. Arteriovenous communications or communications between coronary artery and cardiac chamber
5. High-risk criteria warranting intervention
6. Myocardial bridges
7. Clinically useful targets (what the clinician wants to know)

Pathophysiology of Atherosclerosis:

1. Vascular biology of atherosclerosis: Pathophysiology, American Heart Association classification, stable versus unstable atherosclerosis
2. Natural history of atherosclerosis and disease progression
3. Disconnect between luminal diameter percent stenosis and atherosclerosis disease burden; Glagov phenomenon
4. Role of obstructive coronary artery disease in predicting angina symptoms but not necessarily acute coronary syndromes; role of non-hemodynamically significant coronary artery disease in acute coronary syndromes; criteria for vulnerable atherosclerosis
5. Strengths and limitations of Hounsfield units as predictors of plaque composition
6. Major modifiable and non-modifiable risk factors for atherosclerosis: diabetes, dyslipidemia, hypertension, smoking, abdominal obesity, sedentary lifestyle, gender, age, and family history of premature coronary artery disease
7. Risk scores including Framingham 10-year risk of coronary event: high/intermediate/low; limitations of risk scores, predictive values, special populations including women and younger adults
8. General basis for systemic therapy: pharmaceutical (antiplatelet, anticoagulant, lipid-lowering, angiotensin-converting enzyme inhibition, etc.) and risk factor modification
9. Special attention to the pathophysiology and significance of vessel wall calcification as a marker of atherosclerosis burden; relationship between calcification and atherosclerosis versus competing vascular disease; lack of correlation between calcium burden and luminal stenosis
10. Calcium scoring methods including Agatston, modified Agatston, etc; strengths and weaknesses; limitations of a fixed Hounsfield unit definition of calcium and overlap
11. Relationship between calcium scoring and other atherosclerosis risk factors

12. Per vessel analysis versus global calcium burden; again the difference between calcium burden and coronary stenosis; single vessel disease versus multivessel disease versus left-main coronary artery disease
13. Fixed cutoffs for atherosclerosis risk versus cutoffs adjusted for age and gender; reporting probability of coronary events at 10 years; integrating clinical risk scores and calcium scoring; current American Heart Association/American College of Cardiology expert consensus and European Society of Cardiology recommendations focusing on asymptomatic intermediate risk patients
14. Evolution of coronary artery calcification: clinically useful or useless in the assessment of disease progression/regression and therapeutic success
15. Clinically useful targets (what the clinician wants to know)

Acute Coronary Artery Disease:

1. Definitions, diagnosis and mechanisms underlying various forms of acute coronary syndrome: ST-elevation myocardial infarction (STEMI), non ST-elevation myocardial infarction (NSTEMI), and unstable angina (UA)
2. Manifestations with special attention to imaging targets of the coronary arteries and cardiac anatomy, function and perfusion
3. Definition and diagnosis of stunned myocardium
4. Acute and chronic complications of acute coronary syndrome
5. General basis for local and systemic therapy: pharmaceutical (thrombolysis, etc.), percutaneous (primary angioplasty, rescue angioplasty, etc.), and surgical (coronary bypass, etc.)
6. Monitoring, drug availability, support staff and staff certification (Advanced cardiac life support certification) recommended for handling patients with acute coronary syndrome
7. Overview, recognition and treatment of potential acute complications
8. Potential role for CT in the diagnosis and risk stratification of the acute coronary syndrome patient presenting at the emergency department
9. Clinically useful targets (what the clinician wants to know, and with what degree of urgency)

Chronic Coronary Artery Disease:

1. Pathophysiology of myocardial perfusion, including O2 supply and demand
2. Definition of hemodynamically significant coronary artery stenosis
3. Difference between anatomical and physiological definition of coronary artery stenosis A basic understanding of competing anatomical methods: quantitative coronary angiography, intravascular ultrasound, virtual histology, coronary angioscopy, magnetic resonance coronary angiography, coronary optical coherence tomography, coronary artery palpography, intravascular magnetic resonance
4. A basic understanding of competing physiological methods: difference between function and perfusion reserve; difference between exercise and pharmacological stress; nuclear SPECT imaging, nuclear PET imaging, echocardiography including contrast-echo and 3D-echo

5. Impact of pre-test probability on accuracy (sensitivity, specificity, positive predictive value, negative predictive value); prevalence of disease; Bayes' theorem; American Heart Asssociation criteria for typical angina versus atypical angina versus non-coronary chest pain; difference between diagnosis of atherosclerosis and diagnosis of obstructive coronary artery disease
6. Definition and pathophysiology of myocardial viability; survival benefits in revascularizing a patient with viable versus nonviable myocardium; selective revascularization of viable myocardial segments
7. Potential role for CT in the diagnosis and risk stratification of the chronic coronary patient; potential role in planning coronary intervention in chronic total occlusion, left main coronary angioplasty, bifurcation lesion angioplasty, and left main coronary artery angioplasty
8. Competing methods in the catheterization laboratory: intravascular ultrasound, virtual histology, fractional flow reserve
9. Strengths and limitations of CT in patients with coronary artery stents
10. Strengths and limitations of CT in patients with coronary bypass: saphenous vein grafts, internal mammary artery grafts
11. Clinically useful targets (what the clinician wants to know)

Non-atherosclerotic Coronary Artery Disease:

1. Pathophysiology, diagnosis and natural history of Kawasaki disease
2. Pathophysiology, diagnosis and natural history of spontaneous coronary artery dissection
3. Clinically useful targets (what the clinician wants to know)

Non-ischemic Cardiomyopathy:

1. Pathophysiology and diagnostic criteria for dilated cardiomyopathy, hypertrophic cardiomyopathy, restrictive cardiomyopathy (focus on amyloidosis, sarcoidosis, hemochromatosis), diabetic cardiomyopathy, arrythmogenic right ventricular dysplasia, and ventricular non-compaction
2. Pathophysiology and diagnostic criteria for myocarditis
3. Pathophysiology and diagnostic criteria for constrictive pericarditis: acute inflammatory, chronic fibrous, effusive-constrictive, adhesive
4. Definitions of ventricular function: right versus left, systolic versus diastolic, global versus segmental. Methods: volumetric versus non-volumetric (geometric assumptions); impact of loading conditions (preload, afterload); impact of including versus excluding papillary muscles from ventricular blood pool. Basic knowledge of competing methods: echocardiography, contrast ventriculography, isotopic ventriculography, magnetic resonance imaging
5. Clinically useful targets (what the clinician wants to know)

Valvular Heart Disease:

1. Definitions and pathophysiology of valvular stenosis and regurgitation; definitions of disease severity; integration with cardiac chamber assessment and clinical markers of severity

2. Assessment of leaflet number, morphology and function
3. Planimetry of valvular orifice area: limitations of anatomical orifice area versus effective (physiological) orifice area
4. Assessment of valvular prosthesis: leaflet mobility
5. Clinically useful targets (what the clinician wants to know)

Congenital Heart Disease:

1. Basic understanding of cardiac embryology and development.
2. Review of situs abnormalities and abnormalities of ventricular morphology and position
3. Assessment for intra-cardiac and extra-cardiac shunts.
4. Assessment of extra-coronary cardiac normal variants (ventricular diverticuli, accessory left atrial appendage…)

Great Vessels and Venous Circulation:

1. Definitions and pathophysiology of aortic dissection and aortic aneurysm; monitoring, drug availability, support staff and staff certification (Advanced cardiac life support certification) recommended for handling patients with aortic dissection; potential acute complications in patient with aortic dissection
2. Definitions and pathophysiology of pulmonary vein stenosis