Clinical Practice Guidelines

Guidelines on Cardiac CT in Singapore (2006)

Writing Committee (listing of members on the last page)

Introduction

The heart is difficult to image because of its complex wall motion and variability of the cardiac cycle. Recent advances in 16 and 64-slice computed tomography (CT) technology such as thin detector collimation and fast gantry rotation allow the heart to be scanned in a single breath-hold.

This paper deals primarily with coronary artery calcium assessment and coronary artery CT angiography (CTA). The principles relating to the use of cardiac CT in the evaluation of cardiac masses, pericardial diseases and congenital heart diseases are similar, but will not be elaborated upon as they are infrequently encountered in routine clinical practice.

Calcium score is useful given a negative CT test as atherosclerotic plaque, including unstable plaque and significant luminal obstructive disease is unlikely. The incremental value of calcium scores over traditional multivariate risk-assessment models however, has not yet been established.

Coronary CTA has been shown to be accurate in the detection and quantification of haemodynamically significant stenosis. The sensitivity and specificity of 16-detector row CT in evaluating haemodynamically significant stenosis has been shown to be between 92% to 95% and 86% to 93% respectively when compared with conventional catheter angiography, with less than 10% of the coronary arteries deemed to be non-assessable. Coronary CTA also provides additional information about cardiac and extra-cardiac anatomy and has shown promising results in the assessment of stent and graft patency. With the advent of 64-slice CT technology, there is potential to improve the accuracy of CT coronary angiography.

At the time of writing, the American College of Cardiology Foundation, in conjunction with the American Heart Association, has issued a Clinical Competence Statement on cardiac CT, as has the American College of Radiology.

This document represents a joint effort between the College of Physicians and College of Radiologists in Singapore to:

1) Summarise the existing body of medical literature on cardiac CT. By definition of existing knowledge, areas under active research, and areas still unknown at the time of writing, it is hoped that clarity will emerge and facilitate the appropriate use of this technology for the benefit of patients. Where there is little clinical data, physicians will need to evaluate the benefits and risks for each patient in order to optimise the usefulness of this new technology.

2) Make suggestions regarding training standards for physicians intending to participate in the field. The criteria have been formulated according to prevailing practices and conditions in Singapore. As with all rapidly evolving fields in medicine, physicians are reminded to update their knowledge in order to deliver the highest level of care to their patients.

Indications

Coronary Artery Calcium Assessment

Since the advent of the electron beam CT (EBCT) scanner, a considerable amount of data obtained from clinical trials and meta-analysis have been collected over the past 17 years. As multi-detector CT (MDCT) is a relatively new modality, the amount of data pertaining to the newer technique is limited, and much of the understanding with regard to calcium scoring is thus based on EBCT data.

Overall, there appears to be clear evidence that a strong correlation exists between the presence of calcium deposits in the coronary arteries, and the presence of coronary atherosclerosis. This strong correlation makes calcium scoring potentially a useful technique in the non-invasive detection of coronary artery disease. However, knowledge of a pathophysiologic relationship does not immediately translate into a consensus on clinical indications, since any new technique needs to be compared to previously established methods and ideally shown to add value to established clinical practice. Moreover, there is a paucity of randomised trials comparing the clinical outcome of different diagnostic strategies even for previously established methods. As with any relatively new modality, the exact clinical role of calcium scoring and the specific indications for its use as an alternative or adjunct to older, well-established techniques (such as stress testing, stress imaging or risk factor assessment) are still undergoing study. There is a range of opinions regarding its optimal clinical role and specific guidelines on clinical indications are not widely agreed upon. Nevertheless, calcium scoring

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appears to be increasingly used clinically.

Accepted knowledge of CT coronary artery calcium scoring can be summarised as follows, in keeping with the American College of Cardiology/American Heart Association expert consensus:

- A negative calcium score makes the presence of atherosclerotic plaque, including unstable plaque, very unlikely.
- A negative test is highly unlikely in the presence of significant luminal obstructive disease.
- Negative tests occur in the majority of patients who have angiographically normal coronary arteries.
- A negative test may be consistent with a low risk of a cardiovascular event within the next 2 to 5 years.
- A positive test confirms the presence of a coronary atherosclerotic plaque.
- The greater the amount of calcium, the greater the likelihood of occlusive coronary artery disease, but there is not a one to one relationship, and the findings may not be site specific.
- The total calcium score correlates best with the total amount of atherosclerotic plaque, although the true "plaque burden" is underestimated.
- A high calcium score may be consistent with moderate to high risk of a cardiovascular event within the next 2 to 5 years.

It is pertinent to emphasise that the above statements are derived on the basis of epidemiological data from large populations. The physician is advised to tailor this information in the management of the individual patient.

As MDCT evolves and becomes more widely utilised, there will be more data related to MDCT available in the future. The recommendations of the committee are based on EBCT data. We feel that the principles pertaining to the results obtained by the two modalities are similar.

Recommendations: As calcium scoring is still under intense study, it is difficult to formulate specific clinical indications for calcium scoring that can be widely accepted. Nevertheless, some general principles can be agreed upon:

- First, as with any other non-invasive test, the test result should not be considered in isolation, but rather as part of the overall assessment that includes symptoms, risk factors and the pretest likelihood of disease. Thus, it is advisable for all patients being considered for calcium scoring to first undergo risk assessment by a physician, based on symptoms and risk factors.
- Second (as with any other non-invasive test), a calcium score should be performed only when the test result can improve the assessment of risk of coronary artery disease and possibly alter the patient's management.

Examples of situations such as these include:

1. Asymptomatic patients with intermediate risk profiles for coronary artery disease when the results obtained may refine the assessment risk and in doing so possibly alter the clinical management.
2. Symptomatic patients with atypical chest pain and risk factors for coronary artery disease especially when established tests such as stress testing or stress imaging have equivocal results; or where there is a need to have additional confidence about the likelihood of coronary artery disease.

Coronary artery calcium scoring is of uncertain value in the following clinical scenarios:

- In asymptomatic patients when additional assessment of the coronary artery calcium will generally not modify the clinical management of the subject. For example, patients in whom the risk has already been established to be either very high or very low.
- In clearly symptomatic patients as a result of occlusive disease or who have an established diagnosis of coronary artery disease. The test result is unlikely to alter the clinical management of the subject.

The committee, in accordance with the American College of Cardiologists and American Heart Association Expert consensus 2000, does not recommend the use of coronary artery calcium scoring in asymptomatic subjects with no or minimum risk of ischaemic heart disease.

CTA of Coronary Arteries

The ability to assess the coronary arteries non-invasively was made possible with the advent of multi-detector CT scanners. There is an increasing amount of data to support the accuracy of the modality. To date, the majority of the published literature utilises the 4 or 16 detector scanners. There is emerging data assessing the accuracy and utility of the 32, 40 and 64 detector CT scanners. The acquisition of a data set (of images), which is essentially three-dimensional, has allowed multi-planar reconstruction of images of the heart. This, in addition to the high temporal resolution and spatial resolution of the data, allows the assessment of the heart, the great vessels associated with the heart and also the coronary arteries.

In view of the radiation dose and the need for intravenous contrast medium, which in itself carries a risk of causing renal impairment or anaphylaxis, the test should be used with prudence.

Accepted knowledge of coronary artery CTA can be summarised as follows:

1. Good diagnostic accuracy for detection and quantification of haemodynamically significant stenosis in

assessment of major segments of right and left coronary arteries.

2. Most studies (16-slice) report a sensitivity of 85% to 95% and a specificity of 95% to 98%.

3. A high negative predictive value of 97%.

4. Coronary artery CTA can non-invasively detect "soft plaque," or non-calcified plaque in coronary arteries. The plaque may engender future cardiac events in the absence of lifestyle changes or medical treatment.

5. The conventional catheter coronary angiogram is still considered the "gold standard" for the assessment of coronary artery lumen patency. Interventional procedures may be coupled with the diagnostic conventional angiogram at the same sitting. The conventional coronary angiogram has higher resolution and is required prior to revascularisation with angioplasty or bypass surgery.

6. CTA is useful in the assessment of anomalous coronary artery origins. The ability to visualise the data in an infinite number of imaging planes and the ability to visualise the data in a three-dimensional format allows for easy orientation and assessment of coronary artery bypass graft anatomy and patency.

Based on the available evidence, it appears that CTA is capable of detecting coronary artery disease with a reported sensitivity of 85% to 95% and a specificity of 95% to 98%. However, as with calcium scoring, knowledge of test accuracy and limitations does not immediately translate into a consensus on clinical indications, since any new technique needs to be compared to previously established methods and ideally shown to add value to established clinical practice. Nevertheless, in view of the increasing use of this procedure, there is a need for a position statement on this technique.

Recommendations: As CTA is still under intense study, it is difficult to formulate specific clinical indications for its use that can be widely accepted. Nevertheless, some general principles can be agreed upon:

- First, as with any other non-invasive test, the test result should not be considered in isolation, but rather as part of the overall assessment that includes symptoms, risk factors and the pretest likelihood of disease. Thus, it is advisable for all patients being considered for CTA to first undergo risk assessment by a physician, based on symptoms and risk factors. The risks (radiation and contrast) and benefits (diagnostic information) of the procedure should be carefully weighed and compared to the alternatives. In view of the radiation and contrast exposure, CTA might not be a preferred test if the patient has a high likelihood of requiring a conventional angiogram,

based on symptoms, risk factors and the results of other tests.

- Second, a CT angiogram should be performed only when the test result is likely to alter the patient's management or where there is a critical need to have additional confidence of the presence or absence of coronary artery disease e.g. in airline pilots. Examples of situations such as these include:

  1. Assessment of graft and stent patency in patients with previous coronary artery by-pass grafting or stenting and have subsequently developed symptoms especially when other techniques (e.g., stress testing or stress imaging) yield equivocal results, and knowledge of the graft and stent patency is likely to alter management. In this situation, it is important to consider the risks versus benefits of conventional angiography compared to CTA.

  2. Diagnosis of coronary artery disease when other modalities (e.g., stress testing or stress imaging) provide equivocal results.

  3. Diagnosis of coronary artery disease when other modalities (e.g., stress testing or stress imaging) yield negative results but the patient has persistent symptoms or other clinical findings that result in a continued suspicion of coronary artery disease. Before ordering the test, the physician should consider whether the results are likely to alter clinical management.

  4. Patients with unusual symptoms for coronary artery disease (e.g., chest pain unrelated to physical exertion), but low-to-intermediate risk profiles for coronary artery disease.

  5. Patients with a low-risk profiles for coronary artery disease but have positive stress-test results.

  6. Patient in whom there is a suspicion of congenital anomalies of the coronary arteries.

CTA is currently of uncertain value in the evaluation of asymptomatic patients with risk factors for coronary artery disease.

CTA is of limited value, of no use, in the following clinical scenarios where technical factors may render the images non-interpretable:

- Patients with very high heart rates where the use of beta blockers is contraindicated. The heart rate can be lowered with other medications e.g., calcium channel blockers administered by a clinician with the use of adequate monitoring.

- Patients with severe coronary artery calcification where blooming artifacts interfere with accurate lumen assessment.

- Patients with arrhythmias, in particular ventricular ectopic beats, resulting in image discontinuity.
- Patients who are unable to hold their breath for the time needed to acquire the images.
- Situations where the patient cannot fit through the gantry or lie comfortably on the examination couch.

Performance of Cardiac CT Examinations

Requests for cardiac CT examinations should be made by qualified physicians and the clinical indications should accompany the request.

Patients scheduled for cardiac CT examinations must be screened for contraindications by the supervising physician and the attending radiographer before being allowed to proceed with the study. The supervising physician must be consulted in the event of doubt with regard to patient safety.

The attending radiographer must document the following data:

a. Patient identification data
b. Name of referring clinician
c. Date and type of cardiac CT examination
d. Concentration and volume of contrast material as well as beta blockers if administered
e. Attending radiographer and physician

The data should be recorded and retained for a minimum period commensurate with institutional and national guidelines.

All cardiac CT examinations must be supervised, interpreted and reported by a suitably trained physician and a formal report with images will be issued.

Cardiac CT Scanner

A cardiac CT examination should be performed with a CT scan machine designed for cardiovascular imaging. The equipment should have the following characteristics:

- High temporal resolution to minimise motion artifacts
- High spatial resolution to depict small coronary vessels and complex cardiac anatomy
- Fast continuous coverage with a complete scan of the whole heart in a single breath hold
- Synchronisation of the cardiac cycle with ECG

This working group suggests that the minimum system required for performing cardiac CT angiogram is a 16-slice CT scanner. The technical specifications associated with 16 and 64-slice scanners lend themselves to suitable delineation of coronary anatomy for clinical decision-making. Importantly, the breath-hold times associated with these systems are reasonably achieved by most patients. Performance parameters for both systems are summarised in Table 1.

Table 1. Scan Parameters for 16 & 64-slice Row CT

	16-slice CT	64-slice CT
Gantry rotation	420-500 ms	330-500 ms
Breath hold time	16-20 s	5-12 s
Temporal resolution	200 ms	83-165 ms
Spatial resolution	0.75-1.0 mm	0.35-0.5 mm

Patient Preparation

- Fast 4 to 6 hours prior to the CT angiogram examination. No fasting required if no intravenous contrast is to be administered (as in calcium scoring)
- Obtain medical history e.g., contrast allergy, previous surgery, current medications and contraindications to beta-blockers
- Obtain informed consent with precise and clear explanation of the procedure and the risks related to contrast allergy, contrast extravasation and beta-blocker administration

Beta-blocker Administration

In patients with relatively high heart rates, beta-blocker administration should be considered with a view to lowering the heart rate to an optimal rate before the start of the scan. This ensures minimal motion artifact due to cardiac pulsation. The recommended target heart rate differs between various CT scanners, but should ideally be less than 60 bpm. Patient's blood pressure and heart rate should be monitored and recorded. Several commonly used beta-blockers are listed below:

Oral metoprolol (Betaloc): 50-100 mg (depending on the patient's weight) at 30-90 minutes prior to the scan

Oral atenolol: 50-100 mg (depending on the patient's weight) at 30-90 minutes prior to the scan

Intravenous metoprolol (Betaloc): 5-20 mg immediately before the scan. Bolus administration of 5 mg aliquots up to a maximum dose of 20 mg

Intravenous esmolol: bolus 500 µg/kg body weight over 1 min. 50-100 µg/kg body weight per minute (maintenance dose)

Contrast Administration

The introduction of ever-faster CT acquisition techniques require careful delivery of the contrast bolus to achieve adequate, consistent, and homogeneous opacification of the coronary arteries. This facilitates attenuation-threshold dependent two and three dimensional rendering. The contrast attenuation within the vessels should be high enough to allow lesion detection, but not so high that it

obscures calcified coronary artery wall lesions (at attenuation higher than 350 HU).

For coronary CTA, intravenous contrast medium injection can be performed by using either a test bolus or an automatic bolus-triggering technique. Contrast medium needs to be injected at a rate of 3 to 5 mL/sec to maintain homogeneous vascular contrast throughout the scan. The volume of injected contrast material is dependant on the CT scanner being used and ranges from 60 to 120 mL. Saline bolus (e.g., bolus of 50 mL of saline injected immediately after the iodinated contrast medium bolus) ensures consistent vascular enhancement and prevents streak artifacts (from dense contrast material in the superior vena cava and right atrium) that may interfere with the evaluation of the right coronary artery.

ECG Synchronised CT Scan Acquisition

An ECG synchronised CT scan acquisition is mandatory for a successful cardiac CT study. This minimises motion artifacts caused by cardiac pulsation. Two types of ECG synchronisation techniques are most commonly employed for cardiac CT scanning: prospective ECG triggering and retrospective ECG gating.

Prospective ECG triggering directs the CT scanner to scan the heart only during a certain part of the cardiac cycle. This is usually in diastole when the heart has least motion. Prospective ECG triggering has the advantage of a lower radiation dose and is commonly used in coronary artery calcium assessment.

With retrospective ECG gating, the heart is scanned continuously for several cycles, but only data from a particular phase of the ECG cycle is used for image reconstruction. This improves visualisation of the heart but exposes the patient to a higher radiation dose. Retrospective ECG-gated acquisition is the preferred method for coronary artery CTA.

Image Reconstruction

The images are reconstructed by using a medium soft-tissue kernel with ECG gating. One or multiple image sets are reconstructed in various parts of the cardiac cycle such as 40% to 70% of the R-R interval or 300 to 550 msec absolute reverse ECG gating.

In general, reconstruction is avoided at 10% to 30% or greater than 80% of the R-R interval as these phases are particularly susceptible to motion artifact.

Typically on a 4-slice CT, 1.25 mm thick sections are reconstructed at 0.6 mm intervals; on a 16-slice CT, 1 mm thick sections are reconstructed at 0.5 mm intervals; and on a 64-slide CT, 0.625 mm thick sections are reconstructed at 0.35 mm intervals.

Reporting of Cardiac CT Examinations

Coronary Calcium Scoring

Most vendors manufacturing workstations for this purpose provide coronary calcium reporting systems. These systems are fairly standardised and are usually semi-automated. Reports of calcium score are usually made using the Agatston scoring method for individual major coronary arteries, as well as total calcium burden. Alternative methods of scoring include estimating calcium volume.

Coronary CTA

The evaluation of coronary arteries involves post-processing data at a 3D workstation. Maximum intensity projection (MIP), multi-planar reformation (MPR), and 3D rendering of the coronary arteries and the heart are usually performed. The ability to evaluate coronary arteries in the true axial plane, as well as orthogonal longitudinal planes, is needed for complete evaluation. This usually requires the assessment of studies at workstations.

Evaluation of results purely on the basis of film images is not encouraged, as this limits the ability of the reader to evaluate lesions in different phases of the cardiac cycle and in different projections.

CT evaluation of cardiac function and wall motion are currently not in routine use. However, various vendors are introducing new software for this purpose and we predict that this application will be of growing importance in the years to come. However, widespread use of these techniques awaits rigorous clinical validation against established modalities.

Image storage may be in the form of "hard copy" films or saved in electronic "soft copy" forms. Due to the large volume data set obtained in a cardiac CT study, electronic "soft copy" storage and dissemination methods are preferred. This facilitates ease of use and subsequent post-processing.

Assessment and reporting of coronary arterial anatomy is preferably based on the modified 17-segment American Heart Association classification.

Right coronary artery (RCA)
1) proximal
2) mid
3) distal
4a) posterior descending artery
4b) posterolateral

Left main coronary artery (5)

Left anterior descending artery
6) proximal
7) mid

8) distal
9) 1st diagonal
10) 2nd diagonal

Circumflex coronary artery

11) proximal
12) 1st obtuse marginal artery
13) mid
14) 2nd obtuse marginal artery
15) distal
16) intermediate branch

Non-assessable (unreportable) segments should be indicated.

Reporting of contrast enhanced scans for coronary CTA should encompass the following areas:

- Origins of the left and right coronary arteries are to be assessed for the presence of anomalies. Important patterns include anomalous origins of right or left coronary artery arising from the opposite sinus of Valsalva. The vessel then courses between the aorta and pulmonary trunk. This can be associated with sudden death. Anomalous coronary arteries may also arise from the pulmonary artery.

- Assessable arteries should be examined for the presence of plaque (with or without calcification) and severity of luminal narrowing.

- Abnormal findings of the heart should be reported. The size, location and configuration of the heart and its chambers may be described. Information regarding ventricular wall thickness and integrity of inter-atrial and inter-ventricular septa may also be mentioned.

- The pericardium should also be assessed for thickness and the presence of masses, calcification and effusion.

- Extra-cardiac findings must be reported. When sufficiently included, the course, caliber and patency of the pulmonary vessels should be evaluated and reported. Lung, mediastinum, soft tissue and bone abnormalities within the field of view (FOV) should be included in the report.

Safety Issues

(Adapted from *Advice on the Management of Reactions to Intravenous Contrast Media*, RCR 1996)

All facilities operating CT scanners for the purpose of cardiac imaging must have clear and unambiguous safety guidelines documented in writing. Safety guidelines, practices and policies shall be periodically written, enforced, reviewed and documented by the supervising physician.

The safety guidelines and policies should address the following aspects:

1. Use of Intravenous Contrast Media, Potential Hazards and Management of Associated Complications

The reported reaction rate and rate of severe reactions are 3.1% and 0.04% respectively for non-ionic contrast agents.

Subcutaneous extravasation is a well-recognised complication of IV contrast administration. The overall extravasation rate for contrast media injections ranges from 0.1% to 0.6%. Although the number of reported extravasation injuries has increased with the use of automated power injectors, the relationship between extravasation frequency and injection rate remains controversial. Large bore IV cannulas that are able to handle the higher injection rates used in CT angiograms are advisable. Contrast reactions and extravasation must be treated quickly and appropriately.

Physicians supervising contrast-enhanced cardiac CT should be familiar with the various contrast media available and the indications for each. The physician should also be familiar with patient preparation for the examination, including any necessary hydration. She/he should have an understanding about the volume and concentration of the appropriate contrast material required for a given examination.

Personnel familiar with the various risk factors, preparation and any necessary premedication strategies should perform appropriate history and preprocedural screening. It is necessary for the supervising physician or designee to acquire familiarity with the patient history (this should include indications and risk factors that might increase the likelihood of adverse effects from contrast media). The supervising physician must be specifically aware of relative contraindications and pertinent risk factors. The physician has the responsibility for reviewing all indications for the examination and for specifying the type, use, dosage and rate of administration of contrast agents.

The person responsible for the injection, who may be a radiographer or registered nurse, must be aware of the signs and symptoms of adverse effects and must monitor the patient for the development of these signs and symptoms during the examination. The supervising physician must be on-site and immediately available to respond promptly to an adverse effect. Appropriate medications and resuscitation equipment must be available on-site to treat serious adverse effects.

The supervising physician must be knowledgeable in the recognition and treatment of adverse effects (e.g., idiosyncratic reactions, extravasations) of contrast materials used for these supervised studies.

2. Use of Beta Blockers, Potential Hazards and Management of Complications

Beta-adrenergic receptor blocking agents are sometimes

used to reduce heart rate and improve image acquisition.

The supervising physician should be responsible for the administration of beta-blockers, should they be required. She/he should be familiar with the various beta-blockers available, dosage, contraindications and risk factors. The supervising physician should be knowledgeable in the recognition and treatment of adverse effects and must be immediately available to respond to an adverse effect.

Training and proficiency in cardio-pulmonary resuscitation are recommended for those who attend to patients undergoing contrast-enhanced examinations with or without beta-blocker premedication.

3. Radiation exposure in cardiac CT

There is considerable variation in the literature as to the actual radiation dose applied during cardiac CT as different CT scanner types are used in the interrogation of the heart. For a retrospectively ECG-gated acquisition and routine scanner settings with four-detector row CT, the radiation exposure is comparable to the radiation exposure received during a typical routine diagnostic conventional coronary angiographic examination. With the use of ECG-gated dose modulation in retrospectively ECG-gated acquisition, the radiation exposure for CT coronary angiography may be further reduced to a level of 5 to 7 mSv. The estimated radiation exposure for a prospective ECG-gated acquisition, commonly used for calcium scoring, is about 1 mSv. A potential application of cardiac CT is myocardial perfusion study, which will further contribute to increase in radiation dose.

In principle, the lowest possible exposure factors that would produce images of diagnostic quality should be chosen (Table 2).

All imaging facilities should have policies and procedures to reasonably attempt to identify pregnant patients prior to the performance of any diagnostic examination involving ionizing radiation. If the patient is known to be pregnant, alternative modalities that do not involve ionizing radiation should be considered.

Training

Physicians Supervising, Performing and Interpreting Cardiac CT

Computed tomography involves the use of ionizing radiation and contributes significant radiation exposure to individual patients. To ensure safety of patients and to maximise benefits and reduce risks from radiation exposure, it is important that physicians supervising, performing and interpreting CT scans receive the appropriate level of training.

The areas of training should include radiation safety,

Table 2. Estimated Radiation Doses for Diagnostic Procedures

Radiologic procedure	Radiation dose
Chest radiograph (frontal)	0.03-0.05 mSv
Selective/diagnostic coronary angiography (dependent on operator and nature of diagnostic procedure)	3-10 mSv
MSCT coronary calcium score	0.7-1.0 mSv
CT angiography of coronary arteries (16-slice)	4-7 mSV
Cardiac nuclear stress test (maximum dose of technetium99m 1489 MBq/day)	10 mSv
Regulatory dose limits	
Radiation worker	20 mSv/year
Natural background	
The world	2.5-3.0 mSv/year

understanding of CT technology and usage of IV contrast, the anatomy, physiology and pathophysiology of anatomical region being imaged and familiarity with alternative and complimentary imaging techniques.

Such training can be formal, leading to a recognised certification; or informal but documented, such as attendance of courses, lectures, CME and self-study. The training should be sufficient to equip the physicians supervising, performing and interpreting cardiac CT scans with the necessary core knowledge to safely conduct such examinations.

1. Radiation Safety

The physician should have documented evidence of formal training in the principles of radiation protection and should be familiar with the hazards of radiation exposure, as low as reasonably achievable (ALARA) principle, expected radiation dosage of CT scans, factors that affect such radiation dosage and how these can be modified to reduce radiation exposure while preserving image quality.

Such training should also provide sufficient knowledge on radiation protection to ensure safety of patients and staff working with ionizing radiation. The physician should be able to discuss and explain the risks and benefits of radiation exposure to patients. Finally, the physician should also be conversant with local legislation on radiation protection.

2. Understanding CT and Workstation Technology

The physician should possess documented formal training or informal training in the form of courses, lectures, CME and self-study in the physics of diagnostic radiology, CT technology and use of workstation. This would include the physics involved in the production of X-rays, interactions of X-rays with matter, data acquisition and image

reconstruction in CT scanners. The physician should be conversant with common scan parameters such as collimation, slice thickness, pitch, table movements and exposure factors, and understand how these factors affect scan quality and radiation dose. The physician should have sufficient experience to be able to recognise artefacts as well as to make changes to minimise them. There should be sufficient knowledge of and experience with the use of diagnostic workstations to perform maximum intensity projections, multiplanar reformations and 3D-reconstructions. Physicians first embarking on coronary CTA should have their results validated by a suitably trained physician or by correlation with a gold standard such as conventional catheter coronary angiogram.

3. Usage of contrast

The physician should be familiar with the use of iodinated contrast, the indications, contraindications and side effects. An understanding of injection protocol is also needed for optimal use in cardiac imaging and to avoid risk of contrast extravasation. Please also refer to the report of the subcommittee on the use of contrast agents in diagnostic imaging May 1990.

4. Anatomy, Physiology and Pathophysiology of Anatomical Region Being Imaged

The physician should have adequate understanding of the anatomy, physiology and pathophysiology of the anatomical region being imaged. This would primarily involve the heart but should also include adequate knowledge on the adjacent structures such as the mediastinum, lungs, chest wall, upper abdomen and thoracic spine. Important reasons for this are (1) chest pain may be non-cardiogenic and such causes may be demonstrated on cardiac CT, and (2) incidental lesions may be found. These may or may not need further evaluation.

If the primary physician is trained only in the evaluation of the heart, another suitably trained physician should review the scans for evaluation of extra-cardiac abnormalities.

All physicians performing CT examinations should demonstrate evidence of continued competence in interpretation and reporting of cardiac CT. Competence could be assured through monitoring and evaluation that indicates acceptable technical success and accuracy of interpretation.

5. Training Recommendations

Regarding the training required for interpreting cardiac CT (CCT) studies (not including examinations performed exclusively for calcium scoring), the joint committee has drawn up guidelines for Levels 1, 2 and 3 competencies.

Level 1 Training

This is defined as the minimal introductory training for familiarity with CCT, but is not sufficient for independent interpretation of CCT images. The individual should have been actively involved in CCT interpretation under the direction of a qualified (Level 2 or Level 3-trained) physician-mentor.

There should be mentored interpretation of at least 25 cases of CTA with contrast, of which a minimum of 10 should be correlated with conventional coronary angiography. Studies may be taken from an established teaching file or previous CCT cases.

Level 2 Training

This is defined as the minimum level of training for a physician to independently perform and interpret CCT. It is intended for individuals who wish to practice or are actively involved with CCT performance and interpretation.

There should be mentored interpretation of at least 75 cases of CTA with contrast, of which a minimum of 25 should be correlated with conventional coronary angiography. Studies may be taken from an established teaching file or previous CCT cases.

Level 3 Training

This represents the level of expertise that would enable an individual to serve as a director of an academic CCT section or a director of an independent CCT facility or clinic.

The minimum cumulative training period will be 6 months. This will include all requirements of Level 2 training, extra-cardiac interpretation, as well as participation in CCT study interpretation under the direction of a qualified Level 3 trained physician mentor. Upon completion of Level 3 training, candidates will be able to independently interpret all aspects of CCT studies.

Level 3 training should include active and ongoing participation in clinical research.

Training Requirements for Technologist

The CT technologist should possess a diploma in Diagnostic Radiology, Ministry of Health, Singapore, DCR (UK) or an equivalent diagnostic radiography qualification recognised by the relevant licensing bodies namely the Singapore Society of Radiographers and Ministry of Health, Singapore.

Before being allowed to operate a CT scanner independent of supervision, the diagnostic radiographer must undergo a minimum of 3 months of full time CT training under supervision of both a suitably trained radiographer and radiologist. The trainee must maintain a logbook and performed a minimal number of CT examinations under

supervision as required by the relevant accreditation body.

Under no circumstances are CT scanners to be operated by a person without the above stated qualifications. On no account are medical physicists, technicians, research staff, post-doctorate fellows, nurses and any other non-radiological qualified staff to operate a CT scanner for clinical practice.

The technologist must be able to prepare, position, ensure safety and monitor the patient, as well as apply the injection and scanning protocol as prescribed by the supervising physician.

The technologist should also perform regular quality control testing of the CT system on top of the less frequent but more elaborate testing done by the CT vendors. There should be enough familiarity to ensure early fault detection and correction.

Quality Control and Safety

The supervising physician has overall responsibility for quality control and safety in the use of the CT scanner. The following policies and programmes should be in place and reviewed annually:

- Comprehensive CT quality-control programme
- Radiation protection measures in accordance with regulations.
- Procedure and policy to identify pregnant patients prior to CT scanning.
- Scanning protocol should be optimised such that diagnostic requirements can be met with lowest possible radiation dose.
- Adequate monitoring of scan outcomes to ensure acceptable levels of technical success and interpretation accuracy.

Acknowledgements

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