

Consensus Statement on the

UTILISATION OF CARDIAC COMPUTED TOMOGRAPHY

2015 2nd Edition



Ministry of Health Malaysia



National Heart Association of Malaysia



Society of Cardiac Imaging Malaysia



COLLEGE OF
RADIOLOGY
Academy of Medicine of Malaysia

Committee

the 1990s, the number of people in the UK who are employed in the public sector has increased from 10.5 million to 12.5 million, and the number of people in the public sector who are employed in health care has increased from 2.5 million to 3.5 million (Department of Health 2000).

There are a number of reasons for the increase in the number of people employed in the public sector. One reason is that the public sector has become a more important part of the economy. Another reason is that the public sector has become a more attractive place to work. A third reason is that the public sector has become a more important part of the welfare state.

The increase in the number of people employed in the public sector has led to a number of changes in the way that the public sector is organized. One change is that the public sector has become more decentralized. Another change is that the public sector has become more market-oriented. A third change is that the public sector has become more customer-oriented.

The increase in the number of people employed in the public sector has also led to a number of changes in the way that the public sector is funded. One change is that the public sector has become more dependent on government funding. Another change is that the public sector has become more dependent on private funding. A third change is that the public sector has become more dependent on user fees.

The increase in the number of people employed in the public sector has also led to a number of changes in the way that the public sector is managed. One change is that the public sector has become more professionalized. Another change is that the public sector has become more bureaucratic. A third change is that the public sector has become more hierarchical.

The increase in the number of people employed in the public sector has also led to a number of changes in the way that the public sector is evaluated. One change is that the public sector has become more subject to external evaluation. Another change is that the public sector has become more subject to internal evaluation. A third change is that the public sector has become more subject to self-evaluation.

The increase in the number of people employed in the public sector has also led to a number of changes in the way that the public sector is perceived. One change is that the public sector has become more respected. Another change is that the public sector has become more valued. A third change is that the public sector has become more trusted.

The increase in the number of people employed in the public sector has also led to a number of changes in the way that the public sector is viewed. One change is that the public sector has become more visible. Another change is that the public sector has become more accessible. A third change is that the public sector has become more transparent.

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Target audience:

This update on the existing Consensus Statement on the Utilisation of Cardiac CT (2008) aims to mainly cater for physicians (cardiologists and radiologists) and radiographers involved in providing cardiovascular computed tomography services.

Format:

This consensus statement consists of the latest evidence-based information on the utilisation of cardiac computed tomography based on best practice recommendations from internationally recognised bodies. Where localisation of best practice was required, the committee's recommendations were based on a reached consensus. It also includes an additional section to aid physicians, radiographers as well as centres offering cardiac computed tomography services to evaluate and monitor this service.

The consensus statement on the use of cardiac computed tomography 2015 may be obtained from the National Heart Association of Malaysia and the Academy of Medicine Malaysia's website at <http://www.malaysianheart.org/> and <http://www.acadmed.org.my/> respectively.

Disclosure:

No conflict of interest declared by any of the committee members.

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This update on the existing consensus statement on the use of cardiac computed tomography was made possible by the National Heart Association of Malaysia (NHAM).



Disclaimer:

The content and recommendations made in this consensus statement are based on currently available scientific data and best clinical practice recommendations from internationally recognised bodies. Its use is for the sole purpose of physicians (cardiologists/radiologists) and radiographers trained to use this modality within Malaysia. Clinical judgement is to prevail in all decisions and should not replace individual responsibility, especially with regards to the safety of users and patients/clients.

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Messages

MESSAGE FROM THE FOUNDING PRESIDENT OF THE SOCIETY OF CARDIOVASCULAR COMPUTED TOMOGRAPHY

Cardiac computed tomography and especially coronary computed tomography angiography has matured into an extremely valuable tool for the cardiologist. However, in order to be beneficial to its full extent, the examination has to be performed with adequate technology and with expertise, results have to be interpreted by a sufficiently experienced physician, and recommendations based on the computed tomography (CT) results must be embedded into a clinical assessment of the patient.

Therefore, guidance is necessary to make sure that cardiac CT is used to the best of its potential and maximally benefits the patients. Malaysia has been among the first countries in the world to adopt cardiac CT, and it was also among the first countries in which a professional society issued a consensus document to guide proper use of the technique. Now, a second edition of this document has become available and the authors deserve congratulations for having created a comprehensive, clear, and superbly useful statement. It clearly shows the amount of care and true expertise that has gone into the creation of the document, and it reflects the current state-of-the-art in an admirable fashion.

This document will certainly contribute to assuring that patients in Malaysia are able to receive cardiac care at the highest level. I am sure it will receive wide recognition both in your country and internationally.

I would like to thank the authors and the involved professional societies for their effort, expertise, and support of this exciting new technique.

Sincerely,

Stephan Achenbach, MD, FESC, FACC, FSCCT
Chairman, Department of Cardiology
University of Erlangen
Germany

MESSAGE FROM THE PRESIDENT AND FOUNDING MEMBER OF THE ASIAN SOCIETY OF CARDIOVASCULAR IMAGING

I am most honored to witness the publication of the updated Malaysian Consensus Statement on the Utilisation of Cardiac Computed Tomography (CT) 2015, 2nd Edition.

The Asian Society of Cardiovascular Imaging (ASCI) was founded to bring together and provide a forum for cardiologists, radiologists, and other individuals in related fields to improve the level of clinical practice, research and education of cardiovascular imaging in Asia. In order to achieve this goal, we hold annual scientific meetings and have research activities that include a congenital heart disease study group, CT and MRI guideline committees, and a multi-center research committee. In 2010, ASCI published the Appropriateness Criteria of Cardiac Computed Tomography, tailored for Asian patients. Currently, several multi-disciplinary, multi-center and multi-national research projects related to cardiac imaging are under way.

Continued advancements in science and technology propel the development in cardiovascular imaging and it is important that medical professionals are constantly updated with the necessary information to have a clear understanding of the procedures, safety and guidelines in using these tools for diagnosing and treating patients with cardiovascular diseases. Since The Malaysian Consensus Statement on the Utilisation of Cardiac CT was published in 2008, there have been major technical and clinical advances in cardiac CT. This makes the need for and the timing of this updated second edition to be most appropriate and welcome.

I would like to applaud the joint effort of the National Heart Association of Malaysia, the Society of Cardiac Imaging Malaysia, and the College of Radiology, Academy of Medicine Malaysia, in the completion of this important work.

Dr. John Hoe, MD

*President and Founding Member,
Asian Society of Cardiovascular Imaging*

MESSAGE FROM THE DIRECTOR GENERAL OF HEALTH, MALAYSIA

Cardiovascular disease remains the world's biggest killer with coronary artery disease (CAD) being the largest contributor. In Malaysia, it has surpassed infective diseases as the leading cause of death, making it the most important non-communicable disease that the nation has to combat against.

Cardiac computed tomography (CCT) has been utilised in the last 20 years as one of the imaging modality used to diagnose CAD. Its tremendous growth in technology has seen its application grow from coronary calcium imaging and non-invasive coronary angiography to more functional cardiac and non-coronary work. With these advancements, Malaysia has to keep abreast with the contemporary use and application of this modality to be in parallel with the rest of the world.

This consensus statement is one of the ways that Malaysians especially the medical professionals involved in the care of patients with cardiovascular diseases will be able to understand and apply the use of this imaging modality in our setting. I would like to thank the National Heart Association of Malaysia, its sister society the Society of Cardiac Imaging Malaysia and the College of Radiology for their efforts to make this second edition come to fruition. Together, we can now utilise it in our fight against cardiovascular disease.

Datuk Dr. Noor Hisham Bin Abdullah
MD, MS, AM, FAMM

*Director General of Health,
Ministry of Health Malaysia*

MESSAGE FROM THE PRESIDENT OF THE NATIONAL HEART ASSOCIATION OF MALAYSIA

The first consensus document on the utilisation of cardiac computed tomography (CCT) for Malaysia was launched in 2008. Seven years has lapsed and more centres are now offering CCT as a tool for screening and diagnosing coronary artery disease. However we must understand the full application and drawbacks of this imaging tool to protect the best interest of our patients.

Research in the field of CCT has progressed tremendously. From looking for evidence of stenosis in the coronary vessels, plaque characterisation and vulnerability, we can now look at the haemodynamics across a stenosis to evaluate its significance non-invasively. Views of the cardiac valves, especially the aortic valve has made it a pivotal imaging tool in percutaneous aortic valve therapeutics. I appreciate that some of these new applications are not ready for prime time as yet, but the wait for it to mature and its routine use will not be long. This field of cardiology is definitely exciting, and I look forward to its advancements and its anticipated future milestones.

The team from the National Heart Association of Malaysia (NHAM), the Society of Cardiac Imaging Malaysia (SCIM) and College of Radiology (COR) has been working hard for the last six to nine months to make this document relevant to contemporary practice of CCT in Malaysia. Centres and individuals can use this document to ensure appropriate indication of use and as a guide for CCT reporting, training requirements of personnel and, importantly patient safety and audit.

This document is bigger than its predecessor; however it remains easy and pleasurable to read. Thank you to all involved in making this document a success.

Regards,

Dato' Dr. Rosli Mohd Ali
MD, MRCP, AM, FNHAM, FAPSIC, FASCC
President,
National Heart Association of Malaysia (NHAM)

MESSAGE FROM THE PRESIDENT OF THE COLLEGE OF RADIOLOGY

It gives me great pleasure to write an opening remark for this excellently prepared update to the existing Consensus Statement on the Utilisation of Cardiac CT.

The committee of dedicated members from the National Heart Association of Malaysia, the Society of Cardiac Imaging Malaysia as well as Dr. Yusri Mohammed and team from the College of Radiology, led by Dr. Mohd Rahal Yusoff, has done a tremendous job in completing this difficult task.

This document is definitely larger than its predecessor. Recent advances in cardiac imaging technology have led us to a deeper insight into the progression of cardiovascular diseases and sparked some fundamental changes in our approach to cardiac care. Thus, we are able to identify a cardiac condition at an earlier stage with greater accuracy and better safety. Definitely, our non-invasive imaging tools have helped us discover cardiac problems that several years ago were undetectable using conventional methods of diagnosis.

It is a prime example of how multi-disciplinary approach and commendable communication between various stakeholders have helped us to improve patient care. The consensus reached will definitely lead to the optimisation and cost-effective use of computed tomographic imaging. The benefit will therefore be to the patient with accurate diagnosis and best treatment options.

A big “thank you” from the College of Radiology Council and myself to the members of the Writing Committee on a job well done.

Regards,

Dr. Abdul Rahman Mohamad
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*President,
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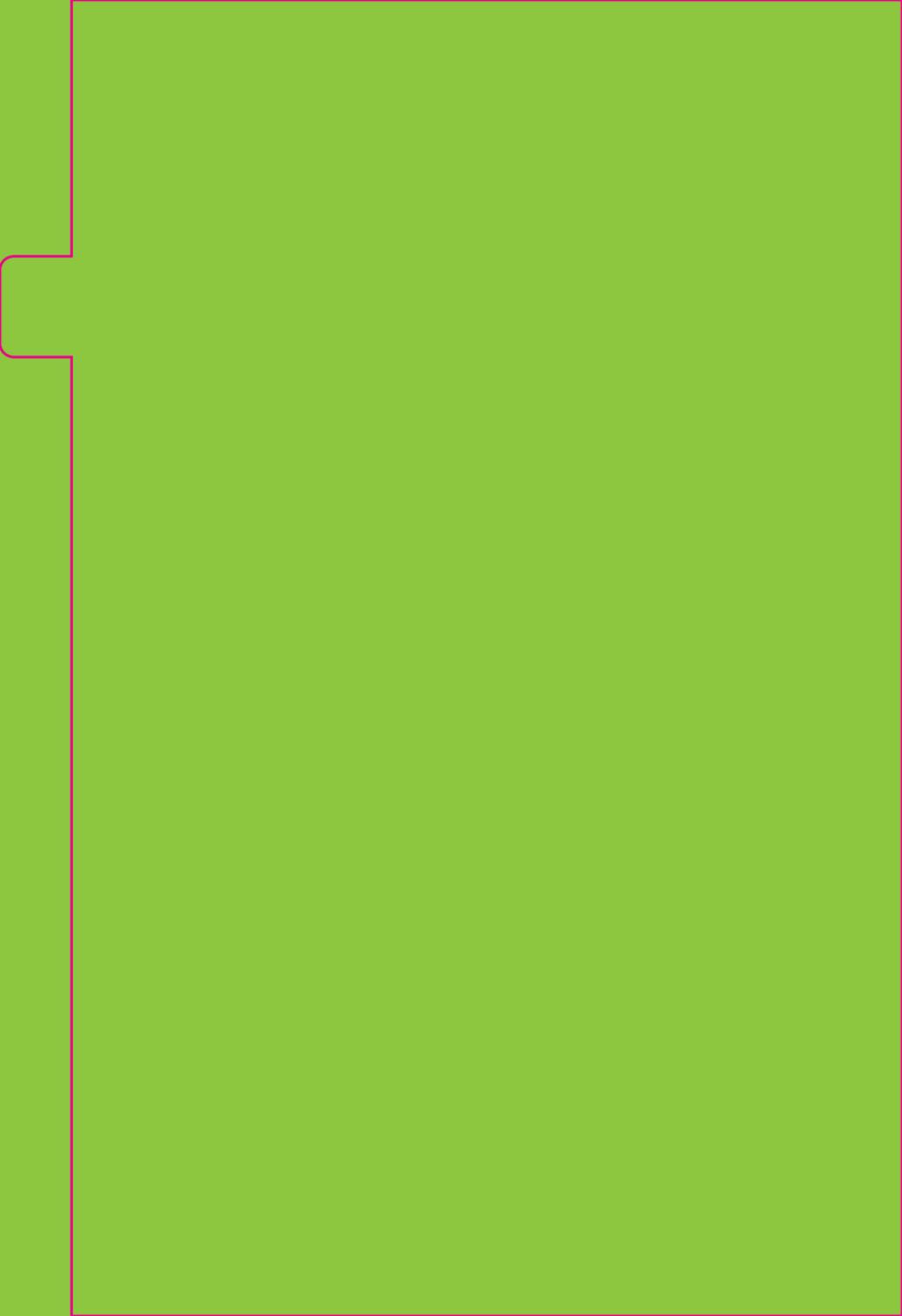
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Introduction



1.0 INTRODUCTION

In 2008, the National Heart Association of Malaysia (NHAM) and the College of Radiology (COR) of the Academy of Medicine Malaysia (AMM) published the first Malaysian consensus statement on utilisation of cardiac computed tomography (CCT).¹ Since then, the rapid technological advancements in this field have led to a review of the use of CCT by radiologists and cardiologists. This follow-up statement updates the 2008 statement to reflect current advances and the appropriate use criteria.

Cardiovascular disease is reported to be a cause of significant morbidity and mortality among adults in Malaysia. The National Health and Morbidity Survey 2011² found that 15.2% (2.6 million) of adults above 18 years of age have diabetes whilst 32.8% (5.8 million) have hypertension and 35.1% (6.2 million) have hypercholesterolemia. The Ministry of Health (MOH) publication, Health Facts 2013, reported that deaths from diseases of the circulatory system were the leading cause of in-house mortality in government hospitals (24.6%), contributing up to 25.1% of total deaths in both private and government hospitals.³

Coronary artery disease (CAD) is characterised by the presence of atherosclerotic plaque(s) in the coronary arteries. These plaques may be calcified, non-calcified or mixed. The plaques progressively narrow the arterial lumen and hence impair blood flow. The reduction in coronary artery flow may be asymptomatic. If symptomatic, it can occur with or without exertion, and may culminate in a myocardial infarction, depending on the severity of the obstruction and rapidity of development.⁴

A comprehensive cardiac assessment requires information on the coronary vascular anatomy, cardiac morphology, function, perfusion pressure, metabolism and tissue characterisation. At the moment, no single imaging modality is able to successfully achieve accurate global assessment of the heart on its own. Furthermore, the heart is a difficult organ to image because of its rapid, complex, cyclical, variable rate-dependent motion and the small vessels of coronary vasculature.

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Anatomical and functional imaging of the heart and its vessels often requires a combination of imaging tools. These include echocardiography (ECHO), single-photon emission computed tomography (SPECT), positron emission tomography (PET), cardiac magnetic resonance imaging (CMR) and CCT. Although the gold standard for diagnosing obstructive coronary disease is still invasive coronary angiography (ICA), in certain clinical settings CCT is an acceptable alternative.⁵⁻⁸ CCT is now used for the quantification of coronary calcium and the evaluation of the coronary arteries. It also can play a role in plaque characterisation and assessment of myocardial viability.⁹ Recent exciting developments in CCT include the assessment of myocardial perfusion and computed tomography (CT)-based fractional flow reserve (FFR) measurement.^{9, 10}

Cross-sectional CT imaging of the coronary arteries was first performed with the electron beam CT in 1984. Since 1998, with the introduction of the 4-slice and subsequently 16- and 64-slice CT scanners with higher spatial and temporal resolutions, accurate visualisation of the coronary arteries, cardiac anatomy as well as its functional imaging have become possible.

In recent years, the availability of CCT services in Malaysia has experienced tremendous growth. Based on the National Medical Device Statistics 2009¹¹, there were a total of 126 CT scanners, with or without CCT capability, being used in both government and private sectors. Therefore, it is important for physicians to understand the need to obtain adequate and accurate datasets for use in the interpretation of a cardiac study. It is also important to adhere to guidelines that recommend proper patient selection and preparation, patient and staff safety, usage of radiation dose reduction protocols, and to provide high quality reporting. In order to gain maximum benefit from the use of this powerful imaging tool in daily clinical practice and to increase its diagnostic yield, its strengths and limitations must be understood. Specifically, this statement aims to provide updated information on the requirements for CCT services in Malaysia. It encompasses the following topics: current indications; safety issues; reporting; training of physicians and

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radiographers; and, quality assurance measures. The Writing Committee understands that CT technology and its applications are evolving rapidly. Therefore, it is pertinent that the earlier consensus statement be updated and revised in tandem with these recent developments.

Similarly, many radiology and cardiology societies in other countries have updated their guidelines and standards. It is timely then for the NHAM and the COR of the AMM to revise the Malaysian Consensus Statement on Utilisation of Cardiac CT issued in 2008. The updated consensus statement includes criteria that were formulated based on growing evidence and conditions in Malaysia, with reference to accepted standard clinical practices worldwide.

Requirements

2.0 REQUIREMENTS OF CARDIAC COMPUTED TOMOGRAPHY

Imaging of the heart using CT demands very precise execution of appropriate scanning modes and protocols. These requirements include:

2.1 Minimisation of Cardiac Motion Artifacts

This is the most critical aspect of cardiac imaging. The coronary artery goes through a series of complex movements during the cardiac cycle. In order to image the coronary artery successfully, a scanner with a high temporal resolution is necessary.¹² One method of achieving this image is by reducing the gantry rotation time (the time required to complete a 360° rotation) as it contains both the x-ray source and the detector array.¹³ We recommend that the scanner should have a gantry rotation time of not more than 250 milliseconds (ms).

Electrocardiography (ECG) gating is required for CCT imaging. Two ECG gating techniques are employed, namely, prospective ECG triggering and retrospective ECG triggering. Currently, prospective ECG triggering is preferred because of lower radiation dose.¹⁴

2.2 Minimisation of Respiratory Artifacts

CCT scanning is usually performed during a single breath-hold in order to minimise motion from respiration. The 64-slice CT scanner has an acquisition time of < 10 seconds(s). The newer scanners (128-slice or higher) have even shorter acquisition time thereby further minimising respiratory artifacts.¹⁵

2.3 High Spatial Resolution

The epicardial coronary arteries are small, with diameters ranging from 5 millimeters (mm) proximally to < 1 mm distally. Imaging of these small structures requires high spatial resolution. The current 64-slice CT scanners have detector widths ranging between 0.5 and 0.625 mm.¹³

2.4 Adequate and Uniform Contrast Enhancement

Vessel opacification is one of the factors that affect the image quality of the CT examination. Distal vessels in particular, may be difficult to evaluate. Therefore, the contrast injection protocol must be tailored to optimise contrast-to-noise ratio and to obtain uniform contrast enhancement. This is achieved by using non-ionic intravenous contrast media (CM) with high iodine concentration and contrast delivery techniques, such as the automatic bolus tracking or test bolus technique. Contrast needs to be administered via a powered injector followed by normal saline solution using a dual auto-injector system.¹⁶⁻¹⁸

2.5 Employment of Radiation Dose Reduction Techniques

Minimising radiation dose to the patient during a CCT scan is a primary concern. Most radiation experts feel that there is no safe dose of radiation and any exposure may increase the long-term risk of cancer induction. Therefore, it is reasonable to request a cardiac computed tomography angiogram (CCTA): only when indicated; to perform the CCTA with the minimum radiation dose required for adequate quality; and, to avoid unnecessary repeat scans.¹⁵ Various methods for dose reduction are available. During the scan, the tube current (mA) and tube voltage (kV) can be adjusted to be optimum at the time of the targeted phase acquisition (usually diastolic). At other times, the tube current is kept at a nominal level. Using this technique, a dose saving of about 45% can be achieved, depending on the heart rate during the acquisition.¹³ Thicker slices and greater table advance per gantry rotation (expressed as pitch) also lowers radiation dose, especially when the heart rate is slow and well controlled.¹⁹ As the radiation dose absorbed by patients cannot be measured easily, the effective radiation dose (expressed in units of millisieverts, mSv) is the most frequently used unit of measurement.¹⁹

2.6 Management of Large Volume of Image Data

CCT using submillimeter detector thickness results in a large amount of image data that needs to be reconstructed and interpreted. This poses a challenge to the physician in the management of these data. CT scanners currently need to be equipped with software which enable these data to be analysed in the native axial, multi-planar reconstruction (MPR), maximum intensity projection (MIP) as well as three-dimensional (3D) volume rendering images. Software for measurement having quantitative manual and semiautomatic tools is useful for further analysis of coronary artery stenosis.¹³ A complete series of digital axial images, reconstructed in at least one phase for gated studies, must be permanently stored in a format that will allow future multi-planar reformatting. A system for recording and archiving CT data (images, measurements and final reports) obtained for diagnostic purposes must be in place as well.²⁰

In view of the above requirements, it is the recommendation of this committee that the acceptable imaging systems that can be utilised for cardiac imaging should be at least a 64-slice multi-detector CT scanner.²⁰ A summary of the requirements is listed in Table 1.

REQUIREMENTS OF CARDIAC COMPUTED TOMOGRAPHY

Table 1. Summary of minimum CT requirements

Scanner	<p>CT scanners used for coronary arteries and coronary bypass grafts must meet the following minimum specifications:</p> <ul style="list-style-type: none">▶ 64-slice system or higher▶ ≤ 0.5 s rotation speed▶ ECG-gating: prospective (preferred) or retrospective▶ Dual auto-injector system
CCTA Reconstruction software system	<p>The software must be:</p> <ul style="list-style-type: none">▶ able to display data as multi-planar reformat (MPR)▶ able to display data in a curve plane reformat▶ able to display 3D volumetric data via volume-rendering technique (VRT)▶ capable of MIP, thick or thin slices▶ able to extract relevant measurements▶ able to perform quantification of coronary calcium
Radiation dose reduction and exposure	<ul style="list-style-type: none">▶ Ensure indication for CCTA is justified▶ Avoid unnecessary repeat scans▶ Based on patient characteristics, use the lowest setting of tube current possible▶ Based on patient characteristics, use the lowest setting of tube voltage possible▶ Optimal slice thickness▶ Greater table advance (or pitch) with less overlap of radiation between successive gantry rotations▶ Use of ECG-controlled tube current modulation to reduce tube current further during the period of the cardiac cycle that is unlikely to be used for image reconstruction (usually in the systole phase)▶ Use of prospective triggering (also known as sequential scanning or "step and shoot" method) with radiation output only during predetermined portions of the cardiac cycle (usually in the diastole phase) whenever possible

Adapted from IAC Standards and Guidelines for CT Accreditation. 2014.

Indications

3.0 INDICATIONS FOR CARDIAC COMPUTED TOMOGRAPHY

CCT is a well-established, non-invasive cardiac imaging modality. However, not all the applications of CCT have been fully defined. Its use in many clinical scenarios remains as areas of research. The committee has adapted the American College of Cardiology Foundation (ACCF)^{21, 22} guidelines to suit local practice. The ACCF guidelines combine scientific evidence and practical experience by engaging a diverse technical panel to rate each indication as appropriate, inappropriate or uncertain. In formulating a consensus, the ACCF guidelines authors were aided by the report of the American College of Cardiology Foundation Quality Strategic Directions Committee Appropriateness Criteria Working Group. The working group included the American College of Radiology (ACR), Society of Cardiovascular Computed Tomography (SCCT), Society for Cardiovascular Magnetic Resonance (SCMR), American Society of Nuclear Cardiology (ASNC), North American Society for Cardiac Imaging (NASCI), Society for Cardiovascular Angiography and Interventions (SCAI), and Society of Interventional Radiology (SIR).

- An **appropriate** imaging study is one in which the expected additional information, combined with clinical judgment, exceeds the expected negative consequences by a sufficiently wide margin to allow performance of the test to be generally considered acceptable care and a reasonable approach for that indication (negative consequences include the risks of radiation or contrast exposure and test inaccuracies).
- An **inappropriate** test means that CCT is not generally acceptable and is not a reasonable approach for that indication.
- Some indications remain **uncertain**. In other words, CCT may be regarded as generally acceptable or a reasonable approach for that indication but would require more research and/or patient information to classify that indication definitively.

INDICATIONS FOR CARDIAC COMPUTED TOMOGRAPHY

In deliberating the appropriateness of CCT, the committee evaluated only clinical evidence from CCT imaging using slice collimations of < 1.0 mm for the detection of haemodynamically significant coronary artery stenosis – usually defined as $\geq 50\%$ luminal stenosis.²³ Local data that might be more relevant to the Malaysian population were also included.^{24, 25} Assuming that image quality is adequate, evaluation should be performed by CCT level 2 or level 3 trained doctors (see under Section: Training) and patients should be properly selected and prepared for the study. CCT has been investigated and reported for the following indications:^{21, 22}

- Detection of haemodynamically significant coronary artery stenosis
- Coronary stent and bypass graft patency
- Non-coronary cardiac and extracardiac imaging

3.1 Contrast Cardiac Computed Tomography

3.1.1 Appropriate Indications

3.1.1.1 Exclusion of coronary artery disease (CAD) in the following **symptomatic** patients:

- Atypical chest pain with low to intermediate pre-test probability of CAD²⁶
 - » not suitable for exercise treadmill test (ETT)
 - » uninterpretable or equivocal functional tests (ETT, nuclear perfusion scan, stress echocardiogram or CMR)
 - » non-diagnostic ECG changes or equivocal cardiac biomarkers
- Unexplained systolic heart failure with low or intermediate pre-test probability of CAD
- Confirmation of graft patency post-coronary artery bypass grafting (CABG) (but not for the assessment of the native vessels)

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3.1.1.2 Exclusion of CAD in the following **asymptomatic** patients

- Intermediate global cardiovascular disease (CVD) risk with strong family history of premature CAD
- Pre-operative coronary assessment for non-coronary cardiac surgery, for example, valve surgery or correction of congenital heart defects in males > 50 years old and females > 55 years old.
- Follow up angiogram of left main coronary stent with diameter ≥ 3 mm

3.1.1.3 Structure and Function Evaluation

- Suspected coronary anomalies
- Assessment of complex congenital heart disease
- Evaluation of intracardiac masses and pericardial diseases in patients with technically limited echocardiogram (including transoesophageal echocardiogram) or CMR
- Evaluation of pulmonary vein anatomy prior to radio frequency ablation
- Coronary vein mapping prior to placement of biventricular pacemaker
- Localisation of coronary bypass grafts prior to re-operation for other chest or heart conditions (to avoid accidental injury to grafts)
- As part of the planning for transcatheter aortic valve implantation (TAVI)/transcatheter aortic valve replacement (TAVR)²⁷

3.1.2 Inappropriate Indications

3.1.2.1 Detection of CAD in the following **symptomatic** patients

- Typical cardiac chest pain and high pre-test probability of CAD
- Acute chest pain with high pre-test probability of CAD and definite ischaemic ECG changes and/or positive cardiac biomarkers
- Evidence of moderate-to-severe ischaemia on functional tests (ETT, nuclear perfusion scan, stress echocardiogram or CMR)

3.1.2.2 Screening for CAD in the following **asymptomatic** patients

- Low global CVD risk with no family history of premature CAD
- High global CVD risk but CCT or conventional angiography was normal up to 2 years previously
- Pre-operative coronary assessment for low risk noncardiac surgery
- Pre-operative coronary assessment for intermediate risk noncardiac surgery and low global CVD risk

3.1.2.3 Structure and function evaluation

- Evaluation of left ventricular function without prior echocardiogram
- Evaluation of cardiac tumour or thrombus without prior echocardiogram

3.1.3 Uncertain Indications

- Detection of CAD in patients with atypical chest pain but high pre-test probability of CAD
- Detection of CAD in asymptomatic patients with high global CVD risk
- Unexplained systolic heart failure with high pre-test probability of CAD
- Mild ischaemia on functional tests (ETT, nuclear perfusion scan, stress echocardiogram or CMR)
- Assessment of coronary stents especially those with diameter < 3 mm
- Assessment of bypass graft patency after CABG \geq 5 years in the absence of symptoms
- Rest and stress myocardial perfusion imaging
- Pre-operative coronary assessment for intermediate risk noncardiac surgery with intermediate global CVD risk but good functional status
- Evaluation of prosthetic valve function

3.2 Coronary Calcium Score

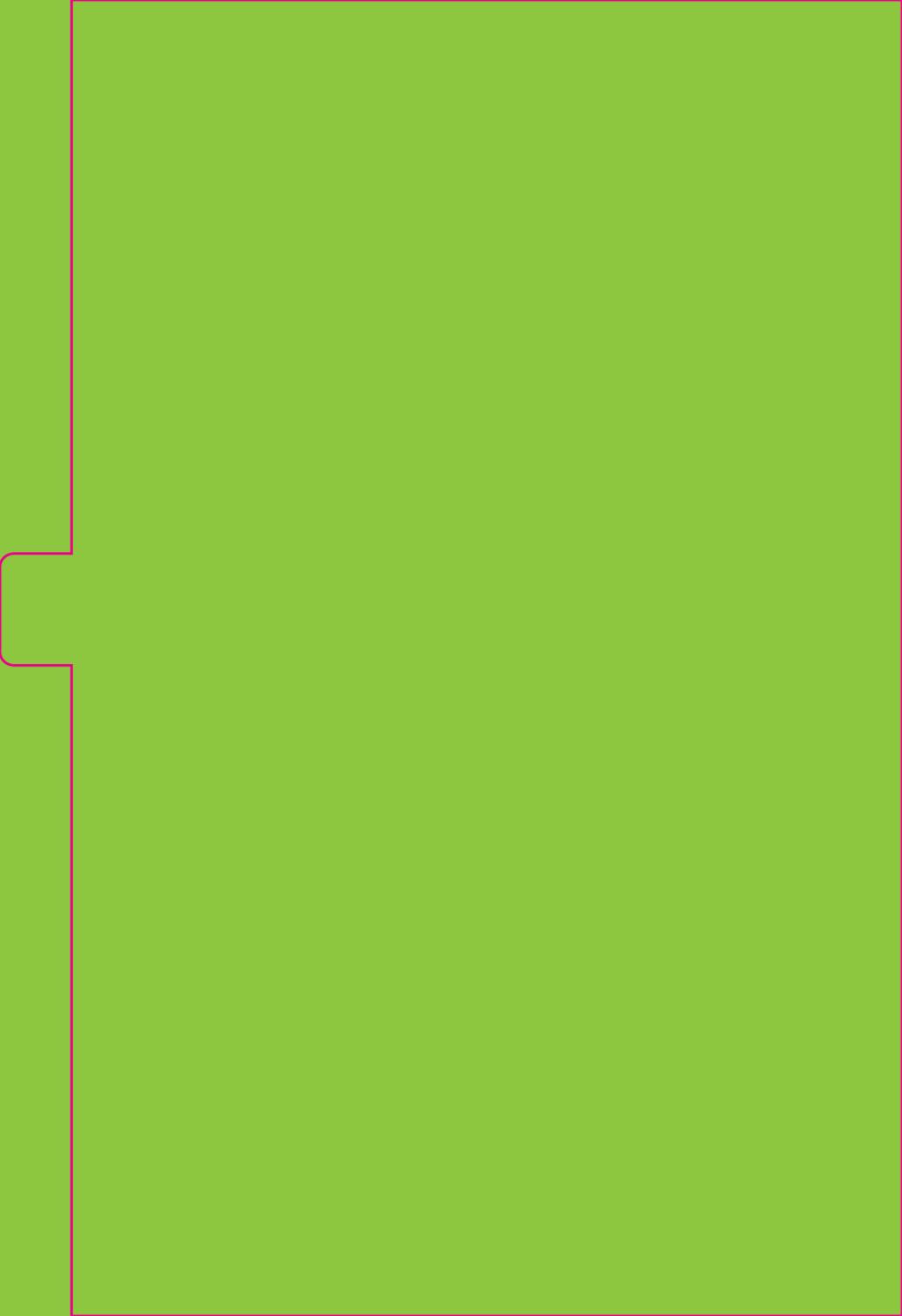
Numerous publications suggest calcium scoring provides additional prognostic information to traditional risk scores. The presence of calcium and incremental levels of coronary artery calcium score denote higher levels of risk and, hence guide the aggressiveness of preventive therapies and target goals. There are no well-defined boundaries of risk levels or cut-off values. Instead, the calcium score and CAD risk relationship is a continuum, similar to hypertension. Calcium scoring has been shown to be independently predictive of cardiovascular risk and adds incremental prognostic information to conventional risk factor scoring methods.²⁸⁻³⁷

Appropriate use of coronary calcium score for screening includes:

- Low global CVD risk with family history of premature CAD
- Intermediate global CVD risk with no family history of premature CAD

Despite very low radiation exposure, coronary calcium scoring should not be done (inappropriate) for asymptomatic individuals with low global CVD risk and no family history of premature CAD.

Interpretation & Reporting



4.0 INTERPRETATION AND REPORTING OF CARDIAC COMPUTED TOMOGRAPHY ANGIOGRAPHY

Components of the report can be divided into:

- Coronary arteries, bypass grafts and stents
- Non-coronary cardiac:
 - » Myocardium, in particular myocardial enhancement
 - » Others
- Extracardiac findings (ECF)

A format for reporting of CCT is shown in the table below.

Table 2. CCT reporting format

CCT Report Format	<p>The documentation of a CCT report should include the following headings:</p> <ol style="list-style-type: none">1. Patient demographics2. Reporting physician(s)3. Type of examination4. Indication for CCT5. CT hardware and acquisition protocols (scanning and contrast)6. Need for beta-blocker or any adjunctive medications and dosage used7. Adequacy of image quality8. Contrast used and amount9. Findings10. Extracardiac findings11. Complication(s) if any12. Conclusion(s)13. Recommendations
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4.1 Coronary Arteries, Bypass Grafts and Stents

The CCTA volume dataset must be examined in multiple reconstruction protocols including axial, multi-planar and MIP.³⁸ Axial images are the most valuable for the evaluation of the coronary arteries.^{39,40} Advanced post-processing tools e.g. 3D-volume-rendered techniques and MIP are most accurate when viewed together with the axial data. Proper window width and level or appropriate kernel should be used to visualise the structure of interest or excessive calcification, if present.

4.1.1 Coronary Arteries

Every segment of the coronary tree needs to be examined and documented using established nomenclature. The most commonly used coronary tree segmentation model is based on the American Heart Association (AHA) 17-segment model (Figure 1).⁴¹ This would allow cross-referencing with findings during catheter angiography. It also provides standardisation in the reporting which is crucial for clinical trials and communication.

Specific segments with less than optimal image quality may be better assessed with reconstructions at different phases of the cardiac cycle where available. Presence of non-assessable segments should be described. In reporting the coronary arteries, dominance, presence of variants and anomalies should be noted. Description of plaques should include segmental location, extent of disease, attenuation characteristics, degree of stenosis and presence of vessel remodelling.

4.1.1.1 Stenosis estimation

Stenosis estimation may be made qualitatively or quantitatively. Qualitative grading correlates fairly well with invasive angiography if image quality is optimal and devoid of artifacts. Table 3 shows the SCCT suggested qualitative method of grading stenosis severity.⁴²

INTERPRETATION AND REPORTING OF CARDIAC COMPUTED TOMOGRAPHY ANGIOGRAPHY

Table 3. Recommended qualitative stenosis grading

0	Normal	Absence of plaque and no luminal stenosis
1	Minimal	Plaque with negligible impact on lumen
2	Mild	Plaque with no flow-limiting stenosis
3	Moderate	Plaque with possible flow-limiting disease
4	Severe	Plaque with probable flow-limiting disease
5	Occluded	-

Adapted from Raff G, et al. J Cardiovasc Comput Tomogr. 2009;3:122-36.

Quantitative estimation of stenosis severity may be made using digital tools which measure luminal area stenosis and plaque area estimation but these metrics are not adequately reproducible and are not in line with decision making information which is derived from invasive catheter angiography's luminology studies. Hence, the most useful CCT stenosis quantification is based on maximal luminal diameter stenosis.

Similar to catheter angiography, one of the drawbacks is of course the fact that most plaques are eccentric in distribution. Diameter estimation therefore, may not truly reflect the maximal diameter stenosis. Vessel axial and longitudinal (MIP & MPR) views should be used for estimation.³⁸ Visual estimate and/or electronic callipers can perform stenosis quantification. The commonly used quantitative grading scale described in the SCCT guidelines is shown in Table 4.⁴²

Table 4. Recommended quantitative stenosis grading

0	Normal	Absence of plaque and no luminal stenosis
1	Minimal	Plaque with 25% stenosis
2	Mild	Plaque with 25%-49% stenosis
3	Moderate	Plaque with 50%-69% stenosis
4	Severe	Plaque with 70%-99% stenosis
5	Occluded	100% stenosis

Adapted from Raff G, et al. J Cardiovasc Comput Tomogr. 2009;3:122-36.

INTERPRETATION AND REPORTING OF CARDIAC COMPUTED TOMOGRAPHY ANGIOGRAPHY

In addition to lumen stenosis, other lesion-related characteristics should be described if relevant. This information may be useful for the conduct and success of an interventional procedure. These include lesion length, reference vessel diameters (proximal and distal), ostial location, bifurcation involvement, aneurysmal segment and presence of myocardial bridge. Complete total occlusions (CTO) and subtotal occlusions may be difficult to differentiate but should be described if suspected. Volume-rendered techniques may be useful to define collateral reconstitution of distal vessel and this information may be useful during complex CTO percutaneous interventions.

The characteristics of the CTO lesion e.g. tapered stump also helps to predict likelihood of a successful percutaneous coronary intervention (PCI). Long CTO of > 15 mm and presence of calcification predicts CTO PCI failure and may help sway towards a surgical bypass revascularisation option.^{43, 44}

4.1.1.2 Plaque imaging

Plaque attenuation characteristics may be described as calcified, non-calcified or mixed. The use of the terms “lipid” or “fibrous-rich” plaques is not recommended as the Hounsfield units correlate poorly with pathological tissue. Plaque distribution, whether concentric or eccentric, may be described. It is now recognised that many acute coronary syndrome culprit lesions are non-obstructive. These vulnerable plaques may be identified on CCT by the presence of large amount of low attenuation plaque, positive vessel remodelling and spotty calcification. The ‘napkin-ring’ sign is described for a lipid-rich vulnerable plaque.⁴⁵ This “plaque” is a lesion with a hypodense centre surrounded by a hyperdense rim. The napkin-ring sign is reported to have high specificity and positive-predictive value for such advanced lipid-rich plaque with thin fibrous cap but has poor sensitivity (25-45%). It has been linked with prediction of lesion-specific acute coronary syndrome.⁴⁶ Other features (e.g. plaque ulceration, vessel dissection, and thrombus) may sometimes be seen.

INTERPRETATION AND REPORTING OF CARDIAC COMPUTED TOMOGRAPHY ANGIOGRAPHY

Experts may report additional information if optimal images are available such as; cardiac chambers (e.g. size and morphology), myocardium (e.g. thinning, contour change or attenuation difference), pericardium (e.g. masses, thickness, calcification or effusion) and extracardiac structures. Information on cardiac function and valve structures, and function may be obtained with other post-processing methods if needed.

4.1.2 Bypass Graft Assessment

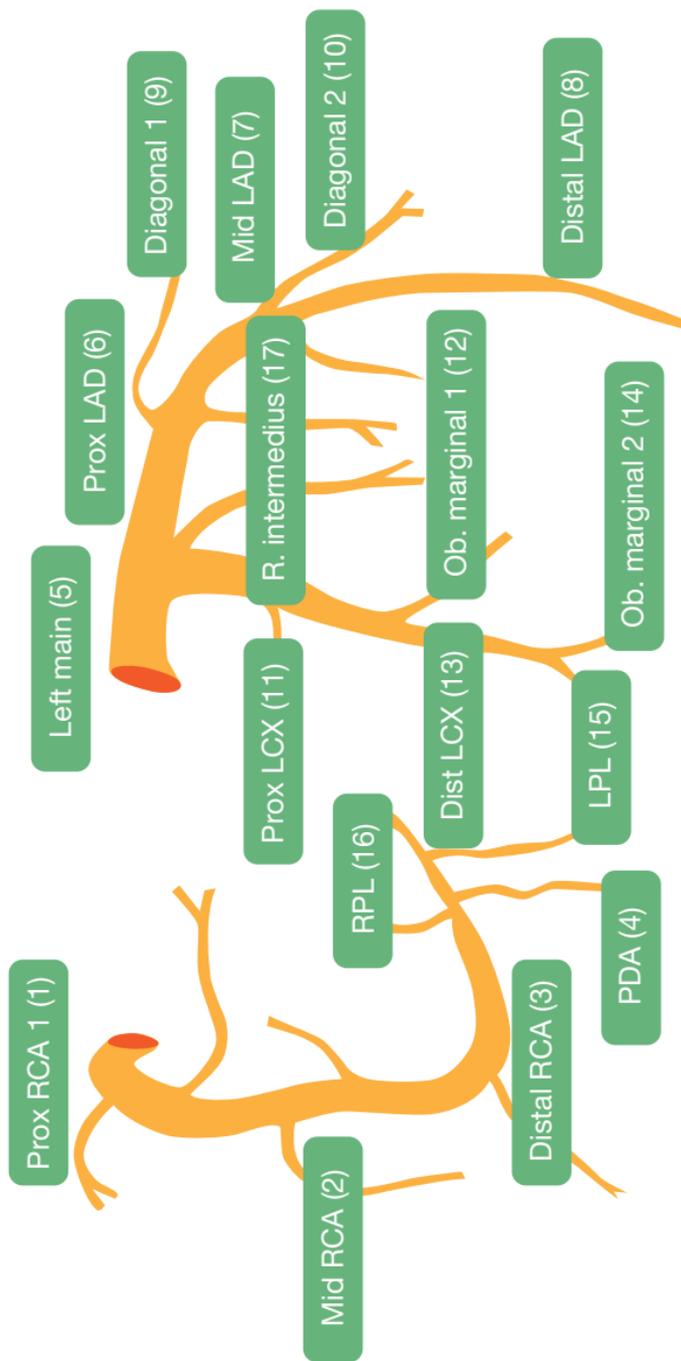
There is evidence that evaluation of bypass grafts with CCT is highly accurate when compared with invasive coronary angiogram (ICA).⁴⁷ Graft description in the report should include: interpretability, number of grafts, any identified graft stumps, type of graft (arterial or venous), location of origin and insertion of each graft, patency of proximal and distal anastomosis as well as distal vessels; and location and severity of each stenosis (if present).⁴⁷ In planned re-do cardiac surgery, detailed description of the position of patent grafts relative to the chest wall is necessary.⁴⁷

Volume-rendering technique (VRT) displays good 3D-orientation of the grafts and the target anastomotic sites.^{5,48} Venous grafts are well visualised by CCT owing to its larger size and lack of mobility. Graft disease and stenosis are reported in a manner similar to native coronary arteries.

4.1.3 Stent Assessment

Patency of stents may be evaluated in most cases.⁴⁸ The accuracy of assessment, however, is influenced by the metal and size of stents. Owing to the high attenuation from stent material, appropriate window width and level or kernels should be chosen. Intra-stent filling defects or reduction of intra-stent contrast filling are used to give an impression of the severity of in-stent restenosis (ISR)/occlusion. Inadequate stent expansion may explain the reason for restenosis.

Figure 1. Modified 17-segment of the AHA reporting system⁴¹



Adapted from Austen W, et al *Circulation*. 1975;51:5-40.

4.2 Non-coronary Cardiac: Myocardium and Others

CCT is primarily designed for the anatomical assessment of the coronary arteries. Additional information, in particular of the myocardium to determine absence or presence of significant ischaemia/infarction is particularly useful. Hence, comprehensive evaluation of not only coronary anatomy, but also myocardial enhancement and function (if and when multiphase dataset is available) should be performed whenever possible. With this approach, increased diagnostic confidence may be achieved. A perfusion defect may be localised to a same location of regional wall motion abnormality.⁴⁷ Differentiation of beam hardening artifacts from actual pathology may be possible. In addition, true regional perfusion defect will be unlikely in the absence of obstructive coronary artery disease or prior revascularisation.⁴⁷

Apart from assessment of the coronary arteries and myocardial enhancement/function, the CCT scan also contains dataset of the adjacent non-coronary and noncardiac structures within the scan range which include the cardiac chambers, myocardium, pericardium, cardiac valves, thoracic and peripheral arteries and veins, as well as lung parenchyma and upper abdominal structures.

4.3 Extracardiac Findings

CT scans performed for cardiac evaluation includes visualisation of extracardiac structures within its scan range. The importance of this is two-fold. Firstly, some of the risk factors for CAD such as smoking, male sex and age overlap with the risk factors for other chest diseases such as bronchial carcinoma.^{49,50} Secondly, chest pain is not unique to cardiac disease and may be a result of other chest pathology.^{51,52}

INTERPRETATION AND REPORTING OF CARDIAC COMPUTED TOMOGRAPHY ANGIOGRAPHY

With the same raw data at no additional radiation exposure to the patient, reconstructions of the images into a larger field of view allow visualisation of the lung and chest wall at the level of scan. Dedicated CCTA focused on the heart displays 35.5% of total chest volume, while images reconstructed at maximal field of view visualises 70.3%.⁴⁹

Studies have shown that CCT demonstrated a significant number of previously unknown extracardiac findings, some of which had an immediate impact on workup, follow-up or both. The incidence of extracardiac findings is up to 41%, of which up to 16% of patients were reported to have significant findings.⁵³ These included pulmonary embolism, bronchogenic carcinoma, liver tumours and congenital anomalies. A radiologist should therefore perform an evaluation of extracardiac structures.

As cardiac scans have a small field of view restricted to the heart, which precludes a complete evaluation of the thorax, both patients and referring physicians have to understand that the focus of the CCT is specifically for the detection of cardiac diseases.

Radiation Protection

5.0 RADIATION PROTECTION IN CARDIAC COMPUTED TOMOGRAPHY

Whilst CCT is not the only cardiac imaging modality using ionising radiation, it has contributed significantly to the increase in medical imaging radiation exposure (refer to Appendix 2). With the earlier generation 16- and 64-slice scanners, effective radiation dose varies widely between sites from 5 mSv to 30 mSv with a median dose for CCTA of 12 mSv, the equivalent of approximately 600 chest radiographs.¹⁴ Quite often this is due to suboptimal application and variable adoption of dose-saving strategies. Factors affecting patient radiation dose include factors intrinsic to the scanner (e.g. model and scanner generation), operator selected parameters and size of the patient.

The principles of radiation protection namely justification and optimisation should be upheld at all times.⁵⁴ In justification no practice shall be carried out unless its introduction produces a positive net benefit (in diagnosis, prognosis and management) whilst in optimisation, all exposures shall be kept as low as reasonably achievable (ALARA) with economic and social factors being taken into account.

Therefore, the following precautions are recommended:

- Perform CCT/CCTA only where justified. CCT is not a screening procedure (see under Section: Indication)
- Use dose reduction techniques where possible and scanner generations which have more up to date radiation dose control design where possible, such as⁵⁵⁻⁵⁸
 - » minimise scan length
 - » use electrographically controlled tube current modulation
 - » use prospective ECG-triggering techniques
 - » select lower tube voltage
 - » use sequential scanning

5.1 Estimation of Radiation Dose

The absorbed dose, the overall energy delivered by a given CT scan protocol, is reflected by the Dose-Length Product (DLP) and is expressed in milligray-centimeter (mGy-cm). The DLP denotes the total radiation energy absorbed and reflects the potential biological effect of the examination. However, the biological effect of the absorbed dose is dependent on the tissue that was exposed. For example, a 100 mGy-cm dose to the bones of the hands would not have the same potential biological effect as a 100 mGy-cm dose to the abdomen. This difference in the biological effect of the absorbed dose in the different CT protocols is measured by multiplying the DLP with a conversion factor for the area exposed. This is known as the effective dose and is measured in mSv. The conversion factor recommended for thoracic CT imaging for an adult is 0.014.⁵⁹ As a general rule 1 mSv is equivalent to 50 chest radiographs.

Safety Issues

6.0 SAFETY ISSUES IN CARDIAC COMPUTED TOMOGRAPHY

6.1 Radiation Exposure

Of paramount importance in CCT scanning is the risk of radiation exposure and its link to cancer. Therefore, all attempts to minimise radiation as recommended in the previous sections should be standard practice (see under Section: Requirements of cardiac computed tomography and Section: Radiation protection in cardiac computed tomography). This would include the training of all personnel involved in cardiac imaging to increase awareness and knowledge about strategies to minimise radiation dose. As these strategies may differ between CT scanners, the training of personnel and accreditation of centres will be the way forward. Documented policies and procedures for monitoring doses and evaluating risks, equipment performance and routine quality testing should be in place.

6.2 Contrast Media

Safety issues related to contrast media include allergic-like and physiological reactions to intravascular iodinated contrast media (CM), contrast-induced nephropathy (CIN) and extravasation around infusion sites.

Contrast allergy can happen although uncommon. Special consideration should be given to those with seafood allergy, previous contrast allergy and history of atopy (e.g. eczema and asthma). CIN has been of concern leading to greater precautions⁶⁰⁻⁶² when administering CM. Recent papers suggest it may not be as significant as previously thought.⁶³⁻⁶⁵ Even so, it is recommended that CM be used judiciously in those with renal impairment/failure, diabetics on metformin and patients with multiple co-morbidities. The supervising physician should be able to identify patients at higher risk of complications, including those with contraindications, and be well versed in the management of these potential complications. Adequate vascular access with the appropriate sized cannula (IV cannula of 22 gauge/pink branula and above), preferably in the ante-cubital fossa, must be secured prior to CM injection, especially as automatic power injectors are used in CCT. Care must be taken to prevent air embolism and infection/cross infection.^{60, 63}

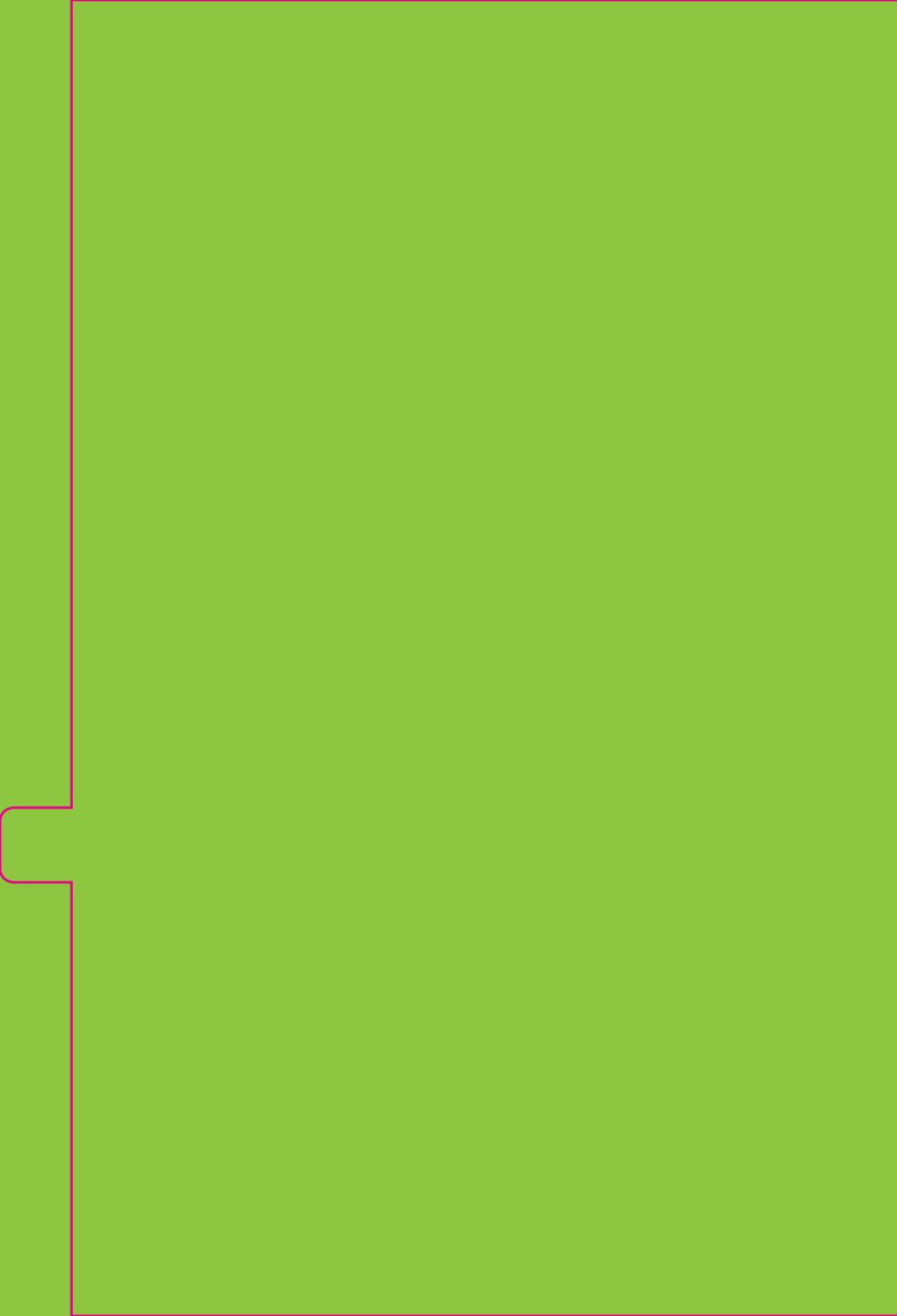
6.3 Drugs Used for Cardiac Computed Tomography

These are primarily β -blockers and nitrates. These drugs are used to ensure good quality CCTs are obtained and β -blockers are still the preferred choice to reduce heart rate. The best rate control protocol has to be decided by the personnel overseeing the examination.⁶⁴ In addition, supervising physicians should be aware of the dosage, action and contraindications of β -blockers. However, for patients in whom the use of β -blockers are contraindicated, alternative heart rate lowering drugs such as calcium channel blockers or ivabradine can be used.⁶⁶⁻⁶⁸ The optimal heart rate also plays a role in ensuring lower radiation doses (through enabling dose reduction techniques such as prospective-triggering) and not just better image quality.

6.4 Infection Control

Policies and procedures should be clearly put in place for all involved to prevent the spread of infection among patients and personnel. Universal precautions should be routine. This will involve the venous insertion of the cannula for contrast injection as well as the proper disposal of the syringes and catheters.⁶⁵

Training



7.0 TRAINING IN CARDIAC COMPUTED TOMOGRAPHY

7.1 Training Requirements for Physicians

CT is an important imaging modality for the detection and characterisation of cardiac diseases; therefore it is crucial that physicians who supervise and interpret CCT should have appropriate competency, experience and expertise.⁶⁹

Competencies are divided into:

- Criteria for interpreting calcium scoring only
- Criteria for interpreting CCT
 - » Level 1 competency
 - » Level 2 competency
 - » Level 3 competency

7.1.1 Criteria for Interpreting Calcium Scoring Only

7.1.1.1 Any registered physician who has undergone training that includes cardiac anatomy, cross-sectional imaging and interpretation of calcium scoring may interpret calcium scoring only.⁶⁹

7.1.2 Criteria for Interpreting Cardiac Computed Tomography

Physicians should have adequate knowledge and understanding of the anatomy, physiology and pathophysiology of the cardiac systems.

TRAINING IN CARDIAC COMPUTED TOMOGRAPHY

7.1.2.1 Level 1 competency

This is defined as the minimal introductory training for familiarity with CCT but is not sufficient for independent interpretation of the CCT studies.^{70,71} Training requirements include:

- Active involvement in CCT interpretation under the direction and supervision of a qualified level 2 or 3 mentor.
- Mentored interpretation of at least 25 cases of CCT with contrast (of which a minimum of 10 cases should be in correlation with conventional coronary angiography). Studies may be taken from an established teaching file or previous CCT cases.
- Proof of training (e.g. verified log book and letter of certification by a qualified level 2 or 3 mentor).

7.1.2.2 Level 2 competency

This is defined as the minimum level of training for a physician to independently perform and interpret CCT accurately.⁷¹ This person can be responsible for quality control and training of radiographers upon completion of training. Training requirements include:

- Mentored interpretation of at least 100 cases of CCT, of which the trainee must perform at least 25 cases under supervision of a qualified level 2 or 3 mentor. A minimum of 25 cases should be correlated with coronary angiography. Studies may be taken from an established teaching file or previous CCT cases.
- Training in advanced anatomy, contrast administration and radiation protection principles, CCT hardware and software requirements, and appropriate patient monitoring (pre-, during and post-procedure).
- 20 Category 1 (refer to Appendix 3) continued medical education (CME) hours in general or CCT.⁷²
- Proof of training (e.g. verified log book, certificate of attendance and letter of certification by a qualified level 2 or 3 mentor).

TRAINING IN CARDIAC COMPUTED TOMOGRAPHY

7.1.2.3 Level 3 competency

This represents the highest level of expertise that would enable an individual to serve as a director of a CCT centre.⁷¹ This person would also be directly responsible for quality assurance and quality control, safety programs, training of radiographers as well as involvement in research activities. Training requirements include:

- A further minimum cumulative training period of 6 months after completion of level 2 training.
- Interpretation of at least an additional 200 cases of CCT, 75 of which have active data sets. Studies may be taken from an established teaching file or previous CCT cases. These cases should reflect a broad range of pathology expected in cardiac imaging.
- Training in quality assurance and quality control, safety programs, training of radiographers as well as involvement in research activities.
- Conduct of ≥ 2 CME courses on the topic of CCT and obtain 20 Category 1 CME hours in CCT.⁷²
- Proof of training (e.g. verified logbook, certificate of attendance and letter of certification) by a qualified level 3 mentor.

7.2 Training Requirements for Radiographers

CT radiographers should possess a minimum of a diploma in radiography, or any equivalent radiography qualification recognised by the MOH or the Society of Radiographers Malaysia. It is encouraged that the radiographers performing the CCT examination have advanced certification in at least post-basic CT and/or an advanced diploma in cardiovascular imaging. The radiographers must also be able to; prepare, position, ensure patient safety (especially ALARA), monitor the patient, and apply the contrast injection and scanning protocols as prescribed by the supervising doctors. They should also perform regular quality control testing.⁶⁹

If the radiographer does not have an advanced certification in CT, a minimum of 3 months full-time CCT training is required under the supervision of a suitably trained CT radiographer and radiologist before being allowed to operate a CT scanner independently. Radiographers are encouraged to keep a logbook of the number of CT cases performed.

The radiographer should also have adequate Continuous Professional Development (CPD) on CCT related topics. Minimal CPD requirement is 10 points per year on general and CCT related topics. As a rule, any person (e.g. medical physicists, technicians, research staff, post-doctoral fellows and nurses) without the above stated qualifications and any other non-qualified staff should not operate CT scanners. Radiographers and nurses under the direction of supervising physicians can administer intravenous contrast materials, if such practice is in compliance with institutional regulations.

Evaluation & Monitoring

8.0 EVALUATION AND MONITORING OF A CARDIAC COMPUTED TOMOGRAPHY SERVICE

Currently in Malaysia, a 64-slice CT is considered the standard of care for an anatomic based non-invasive ischaemic heart disease assessment. While there are laws regarding radiation exposure and protection, regulations to enforce appropriate use of this modality or to safeguard patient/client welfare and safety are lacking. These are areas of concern to the Writing Committee. We recommend that centres providing CCT services to self-regulate as a safeguard to ensure that the best care is provided to their patients/clients. The Committee's recommendations for practice-vigilance are as follows:

8.1 Justification

As one of the basic tenets of radiation protection,⁵⁴ regular evaluation and monitoring should be carried out to ensure that each examination is justified. The benefit of the examination should outweigh the risk of radiation exposure to the patient.⁵⁴

To achieve this, it is important that the centres providing CCT services understand the indications and appropriateness of the use of CCT for cardiovascular health screening, diagnosis, intervention, surveillance and risk stratification (see under Section: Indication). Care should also be taken to ensure that the appropriately trained specialists and technicians/radiographers are responsible in their delivery of this service to the patients/clients^{73,74} (see under Section: Training).

8.2 Risk and Safety of Patients/Clients: Optimisation of Radiation Exposure and Protection

A huge variability exists regarding reported radiation doses between users of 64-slice CT where some centres report doses 6 times higher than those with the lowest.⁵⁸ CCT users and centres are encouraged to strictly abide by the ALARA protocol guidelines to enhance the acquisition of diagnostically useful information with minimal radiation exposure. These protocols differ between scans obtained via prospective and retrospective ECG-gating methods.

EVALUATION AND MONITORING OF A CARDIAC COMPUTED TOMOGRAPHY SERVICE

It is recommended by the Committee that regular monitoring and evaluation be carried out as follows:

- Ensure that dose reducing protocols are in place. The acceptable total radiation dose for current scanners are 3-5 mSv for prospective gating and 9-12 mSv for retrospective gating.⁷
- The total radiation (including calcium score) dose administered is to be included into the report of all examinations (see under Section: Radiation protection in CCT). Both actual dose and corrected dose have to be included.

8.3 Risk and Safety of Patients/Clients: Contrast Administration

It is the recommendation of the Committee that regular monitoring and evaluation of patients/clients be carried out as follows:

- Serum creatinine should be checked within 4 weeks prior to the procedure.⁶⁰
- Repeat the test if clinically indicated.
- The total contrast volume used should not exceed 120 milliliters (mls).⁷⁵
- Serum creatinine should be re-checked within 24-96 hours after the procedure in selected high risk patients (refer to Appendix 4) and appropriate measures instituted accordingly if found abnormal.¹⁶

These recommendations should undergo regular internal and external audit exercises to ensure new standards are established and to promote further use of CCT. A checklist of items to be evaluated and monitored is shown in Appendix 5.

Appendices

APPENDIX 1: CVD Risk Assessment (Section: Indications)

CVD risk assessments can be done using various different standardised and approved international risk calculators like the example below of the Framingham Risk Score.²¹

Table 5. 10-Year CAD risk for men according to Framingham Risk Score

Age	30-34	35-39	Age progress in 5 year increments	70-74	Absolute Risk	Absolute risk
Low-risk* level	(2%)	(3%)		(13%)	Total CHD [‡]	Hard CHD [§]
Points [†]						
0	1.0				2%	2%
1	1.5	1.0			3%	2%
2	2.0	1.3			4%	3%
3	2.5	1.7			5%	4%
4	3.5	2.3			7%	5%
5	4.0	2.6			8%	6%
6	5.0	3.3			10%	7%
7	6.5	4.3		1.0	13%	9%
8	8.0	5.3		1.2	16%	13%
9	10.0	6.7		1.5	20%	16%
10	12.5	8.3		1.9	25%	20%
11	15.5	10.3		2.3	31%	25%
12	18.5	12.3		2.8	37%	30%
13	22.5	15.0		3.5	45%	35%
> 14	26.5	> 17.7		> 4.1	> 53%	> 45%

Adapted from Hendel RC, et al. *J Am Coll Cardiol.* 2006.

*Low-risk level is defined in the Framingham Report as the risk of coronary heart disease (CHD) at any age for a non-smoker, non-diabetic, with blood pressure < 120/80 mmHg, total cholesterol of 160–199 mg/dL, LDL-C 100–129 mg/dL, and HDL-C ≥ 45 mg/dL in men and ≥ 55 mg/dL in women. †Points = number of points estimated from ACC/AHA Scientific Statement: Assessment of Cardiovascular Risk by Use of Multiple-Risk-Factor Assessment Equations, ‡Total Coronary Heart Disease (Total CHD) includes angina pectoris, recognised and unrecognised myocardial infarction, unstable angina, and CHD deaths. §Hard CHD includes all of the total CHD events except for angina pectoris.

APPENDIX 1: CVD Risk Assessment

(Section: Indications)

Table 6. 10-Year CAD risk for women according to Framingham Risk Score

Age	40-44	45-49	Age progress in 5 year increments	70-74	Absolute Risk	Absolute risk
Low-risk* level	(2%)	(3%)		(13%)	Total CHD [‡]	Hard CHD [§]
Points [†]						
0	1.0				2%	1%
1	1.0				2%	1%
2	1.5	1.0			3%	2%
3	1.5	1.0			3%	2%
4	2.0	1.3			4%	2%
5	2.0	1.3			4%	2%
6	2.5	1.7			5%	2%
7	3.0	2.0			6%	3%
8	3.5	2.3			7%	3%
9	4.0	2.7		1.0	8%	3%
10	5.0	3.3		1.3	10%	4%
11	5.5	3.7		1.4	11%	7%
12	6.5	4.3		1.6	13%	8%
13	7.5	5.0		1.9	15%	11%
14	9.0	6.0		2.3	18%	13%
15	10.0	6.7		2.5	20%	15%
16	12.0	8.0		3.0	24%	18%
≥ 17	> 13.5	> 9.0		5.4	> 27%	> 20%

Adapted from Hendel RC, et al. *J Am Coll Cardiol.* 2006.

*Low-risk level is defined in the Framingham Report as the risk of coronary heart disease (CHD) at any age for a non-smoker, non-diabetic, with blood pressure < 120/80 mmHg, total cholesterol of 160–199 mg/dL, LDL-C 100-129 mg/dL, and HDL-C ≥ 45 mg/dL in men and ≥ 55 mg/dL in women. [†]Points = number of points estimated from ACC/AHA Scientific Statement: Assessment of Cardiovascular Risk by Use of Multiple-Risk-Factor Assessment Equations, [‡]Total Coronary Heart Disease (Total CHD) includes angina pectoris, recognised and unrecognised myocardial infarction, unstable angina, and CHD deaths. [§]Hard CHD includes all of the total CHD events except for angina pectoris.

APPENDIX 2: Radiation Exposure (Section: Safety Issues)

Radiation exposure in medical imaging^{76,77}

Table 7. Radiation exposure scenario comparing different situations and approximate effective dose in an individual

Radiation exposure scenario	Approximate effective dose (mSv)
X-rays	
Intraoral x-ray	0.005
Chest x-ray	0.02
Lumbar spine x-ray	1.3
Single-screening mammogram (breast dose)	3.0
CT scans	
Low-dose CT colonography	0.5-2.5
Head CT	2.0
Spine CT	6.0
Chest CT	7.0
Heart	
CCTA (lower reported range)	0.5-2.5
CCTA (higher reported range)	2.0
CCT for calcium scoring	6.0

Adapted from RadiologyInfo.org.2015 and Ollendorf D, Kuba M. ICER.2008.

APPENDIX 3: MMC-CPD Grading System Scoring Schedule

(Section: Training)

Table 8. Malaysian Medical Council-Continuing Professional Development (MMC-CPD) grading system scoring schedule

Category	CPD activity description	Credit points	Additional criteria required
IA	Medical congress (Local/international)	20 points per congress	A congress should: <ul style="list-style-type: none"> • be conducted not < 3 full days, a full day being 5-8 hours. • involve speakers of international standing. • contain plenary lectures/symposia. • allow presentation of free communication/posters etc.
IB	Scientific meetings of chapters of academy/universities/colleges/associations/public and private medical institutions <ul style="list-style-type: none"> • < 2 hours • 2-4 hours (1/2 day) • 5-8 hours (full day) • ≥ 4 full days 	1 point 2 points 3 points 10 points	Between 1,2 or 3 days, points are awarded according to hours.
IC	Workshops/Courses <ul style="list-style-type: none"> • full day • more than full day but less than 2 full days • 2 full days • ≥ 3 full days 	3 points 5 points 6 points 10 points	A full day is 5-8 hours.

APPENDIX 4: Risk Factors to Consider for Contrast Medium Induced Nephropathy (Section: Evaluation and Monitoring of a CCT Service)

Table 9. Risk factors to consider for contrast medium induced nephropathy

Related to patient	Co-morbidities: <ul style="list-style-type: none">• Pre-existing renal impairment (serum creatinine level \geq 1.5 mg/dl; eGFR < 30 ml/min)• Diabetes mellitus• Cardiovascular disease Others: <ul style="list-style-type: none">• Age > 70 years• Use of diuretics• Dehydration
CM related	High osmolarity agents Large doses of contrast medium

Adapted from Jinzaki M, et al. Int J Cardiovasc Imaging.2010.

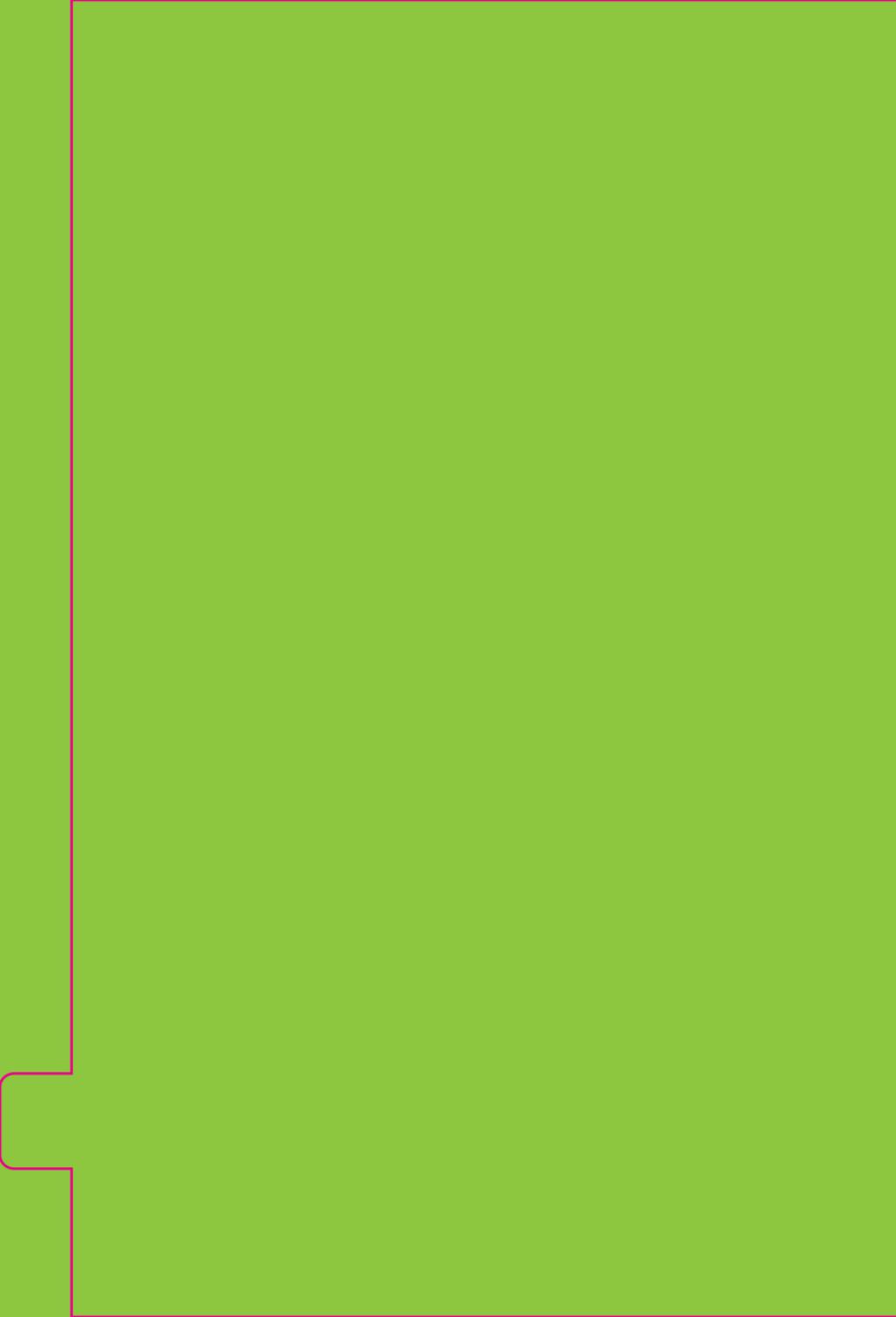
APPENDIX 5: Monitoring and Evaluation of a CCT Service Checklist

(Section: Evaluation and Monitoring of a CCT Service)

Table 10. Monitoring and evaluation of a CCT service

Items	Monitoring and evaluation of a CCT service	Compliance	
		Yes	No
Justification of examination:			
a.	Indications and appropriateness of use of CCT.	<input type="checkbox"/>	<input type="checkbox"/>
b.	Trained specialist in-charge.	<input type="checkbox"/>	<input type="checkbox"/>
c.	Trained radiographers/technicians performing the examination.	<input type="checkbox"/>	<input type="checkbox"/>
Risk and safety of patients/clients: Optimisation of radiation exposure and protection			
a.	Ensure that dose reducing protocols are in place.	<input type="checkbox"/>	<input type="checkbox"/>
b.	The total radiation (including calcium score) dose administered, to be included into all examinations that will then be kept as records.	<input type="checkbox"/>	<input type="checkbox"/>
Risk and safety of patients/clients: Contrast administration			
a.	Serum creatinine should be checked within 4 weeks prior to the procedure. Repeat the test if clinically indicated.	<input type="checkbox"/>	<input type="checkbox"/>
b.	Serum creatinine should be re-checked within 72-96 hours after the procedure in selected high risk patients and appropriate measures instituted accordingly if found abnormal.	<input type="checkbox"/>	<input type="checkbox"/>
c.	The total contrast volume used should not exceed 150 mls.	<input type="checkbox"/>	<input type="checkbox"/>

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